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APPLIED SCIENCES TO CULTURAL HERITAGE MATERIALS AND SITES

Urushi lacquer in four Asian artefacts from MAO: historical-iconography study and analysis of materials

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Abstract

This study investigates four Urushi lacquer artifacts housed at the Museum of Oriental Art in Venice (Museo d'Arte Orientale di Venezia, MAO). These include a brush holder (inv. 10736/10410), a fan-shaped covered box (inv. 10721/10368), a box with drawers (inv. 10781/10355), and a polychrome plate (inv. 10766).

The study aims to: 1) characterize the pigments and the chemical composition of the four lacquerwares; 2) assess their provenance based on historical-iconographic and scientific analysis. To achieve this, a two-step approach was used. In the first step, wide historical research on Urushi lacquer production in China and Japan was combined with iconographic analysis, supported by Digital Microscopy for surface examination. In the second step, an overview of the materials present in the four artifacts was carried out in situ using non-invasive techniques such as Fiber Optic Reflectance Spectroscopy (FORS), External Reflectance Infrared spectroscopy (ER-FTIR), and Digital Optical Microscopy to analyze the materials. On fragments naturally detached from the artifacts, non-destructive methods (micro-Raman, micro-FTIR, SEM-EDS, EPR) were applied to characterize, also stratigraphically, the materials, having further insights in the component materials, in the production technique and in the degradation processes. For more detailed organic analysis, Gas Chromatography-Mass Spectrometry (GC-MS) was used on two small fragments from the brush holder and the box with drawers. This analysis helped identify the main components and additives in the lacquerware.

By cross-referencing historical, iconographic, non-invasive and invasive scientific data, the materials and techniques used to create these artifacts were understood. The study also identified the likely origin (China or Japan) and examined the causes of deterioration.

The significance of this research lies in its interdisciplinary approach, combining historical research with materials science to improve understanding of the craftsmanship, provenance, and conservation needs of Asian lacquerware. This study showcases the value and limitations of both invasive and non-invasive scientific techniques for lacquerware analysis.

Questo studio indaga quattro manufatti in lacca Urushi conservati presso il Museo d'Arte Orientale di Venezia (MAO). Questi includono un portapennelli (inv. 10736/10410), una scatola coperta a forma di ventaglio (inv. 10721/10368), una scatola con cassetti (inv. 10781/10355) e un piatto in lacca policroma (inv. 10766).

L'obiettivo dello studio è duplice: 1) caratterizzare i pigmenti e la composizione chimica delle lacche Urushi; 2) valutare la provenienza dei manufatti basandosi su un'analisi storico-iconografica e scientifica. Per raggiungere questi obiettivi, è stato adottato un approccio in due fasi. Nella prima fase, si è combinata un'ampia ricerca storica sulla produzione della lacca Urushi in Cina e Giappone con un'analisi iconografica, supportata dalla microscopia digitale per l'esame delle superfici. Nella seconda fase, è stata effettuata un'indagine analitica dei materiali presenti nei quattro manufatti, utilizzando tecniche non invasive in situ come la spettroscopia di riflettanza a fibra ottica (FORS), la spettroscopia infrarossa a riflessione esterna (ER-FTIR) e la microscopia ottica digitale. Su frammenti naturalmente distaccati dai manufatti, sono stati applicati metodi non distruttivi (micro-Raman, micro-FTIR, SEM-EDS, EPR) per caratterizzare, anche stratigraficamente, i materiali, ottenendo informazioni sulla tecnica di produzione e sui processi di degrado. Per un'analisi organica più dettagliata, è stata utilizzata la spettrometria di massa associata alla gas cromatografia- (GC-MS) su due piccoli frammenti prelevati dal portapennelli e dalla scatola con cassetti. Questa analisi ha permesso di identificare i principali componenti e gli additivi utilizzati nella lacca.

Incrociando i dati storici e iconografici con metodi scientifici invasivi e non invasivi, si sono compresi i materiali e le tecniche utilizzate per creare questi manufatti. Lo studio ha, inoltre, identificato le probabili origini (Cina o Giappone) ed esaminato le cause del deterioramento.

L'importanza di questa ricerca risiede nel suo approccio interdisciplinare che combina ricerca storica e scienza dei materiali con lo scopo di migliorare la comprensione della tecnica artigianale, della provenienza e delle esigenze di conservazione dei manufatti in lacca asiatica. Lo studio mette in luce il valore e i limiti delle tecniche scientifiche, sia invasive che non invasive, nell'analisi della lacca.

Introduction

The study of lacquered objects often defined as "Asian" encompasses a vast and diverse geographical area, involving multiple countries with their unique geographical, cultural, and historical contexts. The identification of lacquer materials not only aids in distinguishing the specific regional and technical origins of these artifacts but also helps in understanding the complex relationships between natural resources, cultural traditions, and craftsmanship. The term "Asian" often oversimplifies the rich diversity of techniques and materials employed by different countries and periods. Therefore, conducting in-depth research on these lacquer materials is of significant importance.

Accurate definition and analysis of the materials used in lacquerware are crucial for developing effective restoration and preservation strategies. Understanding the composition and properties of these materials assists restorers in selecting the most suitable intervention methods. Precise material identification ensures the preservation of these artifacts and reduces the risks of improper restoration practices that may compromise their historical and artistic value.

Furthermore, in-depth research on lacquerware can enhance the understanding of its form, technique, and iconographical influences, particularly the interactions between Chinese and Japanese traditions. By studying these influences, scholars can achieve a more comprehensive understanding of the development of lacquer art in Asia, as well as the artistic exchanges and cultural interactions within this context. This understanding not only enriches the historical narrative of lacquerware but also provides a more detailed perspective on its aesthetic and cultural significance.

The application of scientific methods in the study of lacquerware is a vital tool for advancing this field. Various analytical techniques offer information ranging from the identification of chemical compositions to the uncovering of manufacturing techniques and degradation processes. These scientific insights are essential for restorers, as they provide a scientific basis for restoration strategies, ensuring that intervention methods align with both scientific principles and cultural values. This thesis aims to integrate scientific analysis with art historical and cultural research, fostering a comprehensive understanding of Asian lacquerware, supporting restoration practices, and bridging the gap between science and art.

Chapter 1: Historical context

1.1 Introduction to oriental lacquer

Asian lacquer is a natural resin coating commonly used in Asia since ancient times. Natural lacquer is a milky white viscous emulsion that flows from the inner bark when the lacquer tree is cut and hardens upon exposure to air. It has many excellent properties, including moisture resistance, acid and alkali resistance, heat resistance, wear resistance, and insulation. As a precious natural coating, it is widely applied in various fields. Lacquer primarily serves decorative, protective, and waterproof functions and can be applied to different substrates such as wood, bamboo, earthenware, pottery, metal, paper, leather, and cloth. It has a long history and rich cultural traditions in East Asia, Southeast Asia, and South Asia.

Different countries have various names for "lacquer." In China, it is called "漆" (qī); in Japan, it is referred to as "漆, うるし" (urushi); in Korea, lacquer is known as "漆, 옻칠" (ott-chil or ochil). In Thailand, it is called "รัก" (rak). In Vietnam, lacquer is termed "sơn mài" (son mai), while in Myanmar, it is known as "ချ" (cha), and the lacquerware craft is referred to as "thitsi." These names demonstrate the different ways lacquer is termed in various countries, reflecting its significance and diversity in Asian cultures.

1.1.1 Lacquer Tree

The lacquer tree is a deciduous tree that can grow up to 50 cm in diameter and 10 meters tall. The lacquer tree thrives in warm and humid subtropical regions, particularly favoring fertile, gravelly mixed soil, and requires abundant sunlight and carbon dioxide. The lacquer sap is collected at the moment of oozing out from the cut phloem after removal of the outer bark of lacquer trees.

Lacquer can be harvested from trees that have been growing for 5 to 8 years. Trees around 10 to 15 years old yield about 100 - 150 grams annually, although carefully cultivated superior varieties can produce more than 250 grams. The low yield is a primary reason for the high price of lacquer, further driven up by the labor-intensive process from cutting the tree bark, collecting, to refining the lacquer.

The harvesting season is from summer to early autumn, with the exact timing varying based on the region and annual climate conditions. During this period, the warmer temperatures promote vigorous growth of the trees, resulting in higher yield and quality of the sap, and better flow of the tree sap.

Harvesting lacquer is a highly skilled task that requires experienced lacquer farmers to ensure the health of the trees and the quality of the lacquer. These farmers use specially designed tools to make small incisions in the tree trunks to allow the sap to flow out. The sap is then collected and undergoes a series of processing and refining steps to become usable raw lacquer (natural lacquer) (NATIONAL MUSEUM OF JAPANESE HISTORY 2004, URUSHI) (LIU L., FU J. 2023).

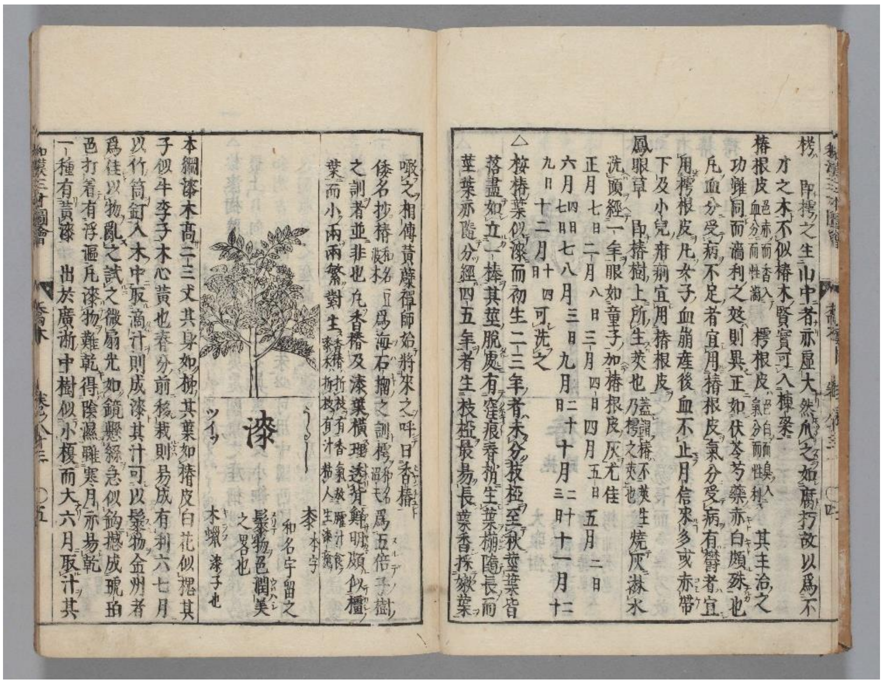


Figure 01. – Terajima Ryōan. 1712, *Illustrated Sino-Japanese Encyclopedia of the Three Realms《和漢三才図会》(Wakan Sansai Zue) - Lacquer Tree* (National Book Database 国書データベース)

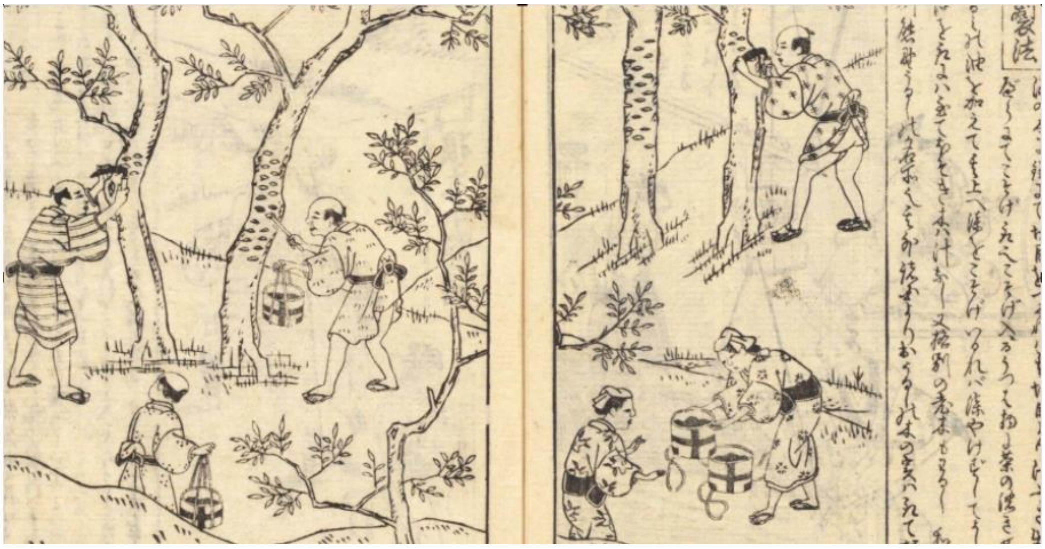


Figure 02 – Urushi lacquer harvesting , mid-Edo period, 1754, *"Illustrated Collection of Famous Japanese Products"《日本名物図絵》* - 漆製法(うるしのせいほう)

Figure 03 – Lacquer harvesting, 18th–19th century, *"Illustrated Collection of Chinese Natural History Paintings" 《中国自然历史绘画》* - *"Illustrations of Chinese Lacquer Making" 《中国制漆图谱》*

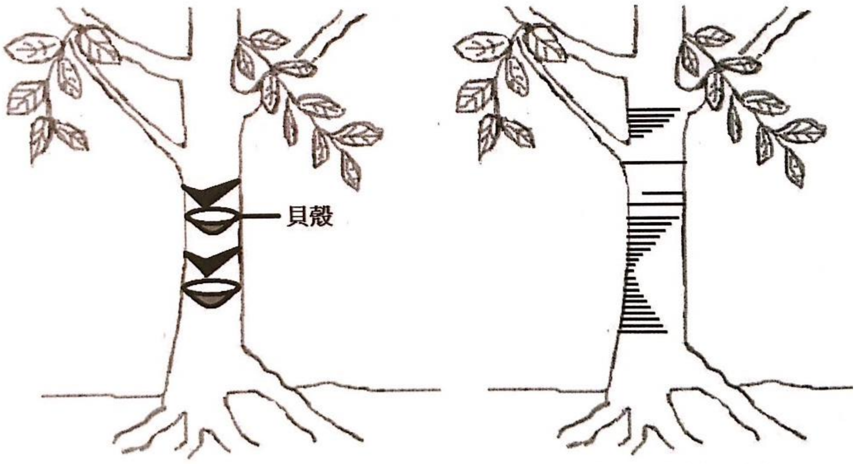


Figure 04 – Different way of harvesting the lacquer from lacquer tree. Left: Chinese way of lacquer harvesting. (use shell to collect the lacquer sap) Right: Japanese way of lacquer harvesting. (NAGASE K.. 1986)

1.1.2 Lacquer Production

Lacquer production is a meticulous process that ensures the creation of high-quality lacquerware, with each step being crucial to achieving the desired durability and finish. Depending on local weather conditions and the state of the raw lacquer, some steps may be adjusted accordingly (HSU Y.-F., HSU T.-C. 2022).

1. Raw Lacquer Selection: This is the initial step where raw lacquer, also known as urushi, is chosen based on its quality. The character of urushi varied according to the time it is harvested. Raw sap is known as "荒味漆 arami urushi" in Japanese.
2. Filtering Impurities (Chinese: 滤漆 lǜ qī ; Japanese: 漆濾 urushi koshi): The raw lacquer is first coarsely filtered using a grinding cloth like hessian fabric to remove large impurities, followed by fine filtration with finer cloth like white cotton fabric and absorbent cotton, repeat few times to achieve a purer lacquer. This filtration process is crucial for maintaining the quality and consistency of the lacquer. Once filtered, it is called "生正味漆 kijōmi urushi", generally refers to "生漆 ki urushi" in Japanese. It is called "生漆 shēng qī" in Chinese.
3. Homogenization (Chinese: 晾制 liàng zhì ; Japanese: ねやし nayashi): This step involves constant stirring of the lacquer (with some adding more water) to homogenize the substance and break the water down into small, uniform particles, enhancing the lacquer's hardness and brightness. This process helps to refine the lacquer's texture and improve its overall properties.
4. Dehydration (Chinese: 曬制 shài zhì ; Japanese: くろめ kurome): The lacquer is then heated under the sun at temperatures between 40°C-50°C, stirring to evaporate the water content to less than 5%. This step is critical for increasing the lacquer's transparency and strength by reducing its water content. The resulting refined urushi after homogenization and dehydration is called "素ぐろめ漆 sugurome urushi". It is called "精製漆 jīng zhì qī" in Chinese.
5. Low-Temperature Baking (Chinese: 煎漆 jiān qī): The lacquer undergoes around 30°C-40°C, baking to remove any remaining moisture marks (reduce till 3% - 5% water content). This process typically takes about 2-3 hours and is essential to prevent any water traces that could affect the final product's quality.
6. Fine Filtration (Chinese: 細濾 xì lǜ ; Japanese: 漆濾 urushi koshi): The lacquer is subjected to a final fine filtration to ensure it is free from any remaining impurities, resulting in a smooth and refined product. In Japan, before lacquering procedure, usually the artisan will filter the urushi again with filter paper "濾紙 koshigami".
7. Ripe Lacquer (Chinese: 熟漆 shú qī ; Japanese: 透漆 suki urushi / 木地呂漆 kijiro urushi): Finally, the lacquer changes from a milky white to a semi-transparent brownish

color, becoming a ready-to-use ripe lacquer, a refined lacquer. This transformation indicates that the lacquer is fully processed and suitable for many applications.

Figure 05 – Lacquer Craftsman (Urushishi) squeezing lacquer from a bag, mid-Edo period, late 17th century and early 18th century," *《職人尽歌合》(Shokunin-zukushi Uta-awase)* (National Diet Library of Japan)

Figure 06 – Dehydration and low-Temperature Baking, " 18th–19th century, *"Illustrated Collection of Chinese Natural History Paintings" 《中国自然历史绘画》- "Illustrations of Chinese Lacquer Making" 《中国制漆图谱》*

1.1.3 Types and Distribution of Asian Lacquer Trees

The lacquer trees in Asia can be roughly divided into three categories, and their distribution areas are shown below (NATIONAL MUSEUM OF JAPANESE HISTORY 2004, *URUSHI*):

1. *Toxicodendron vernicifluum*: Mainly distributed in China, Japan, and South Korea, contains the characteristic "urushiol".
2. *Toxicodendron succedaneum*: Distributed in the South of China (Guangdong, Guangxi, Fujian, and Yunnan, etc.) Vietnam and Taiwan, contains the characteristic "laccol", which is similar in structure to urushiol, but its alkyl side chain is slightly different. In China, it is called "wild lacquer"; in Japan, it is called "Annan lacquer" or "Indian lacquer".
3. *Gluta usitata*: Mostly distributed in Southeast Asian countries such as Myanmar, Laos, and Cambodia, contains the characteristic "thitsiol", which is a phenolic acid compound with carboxyl and phenolic hydroxyl groups. It is called "Burmese lacquer" in both China and Japan.

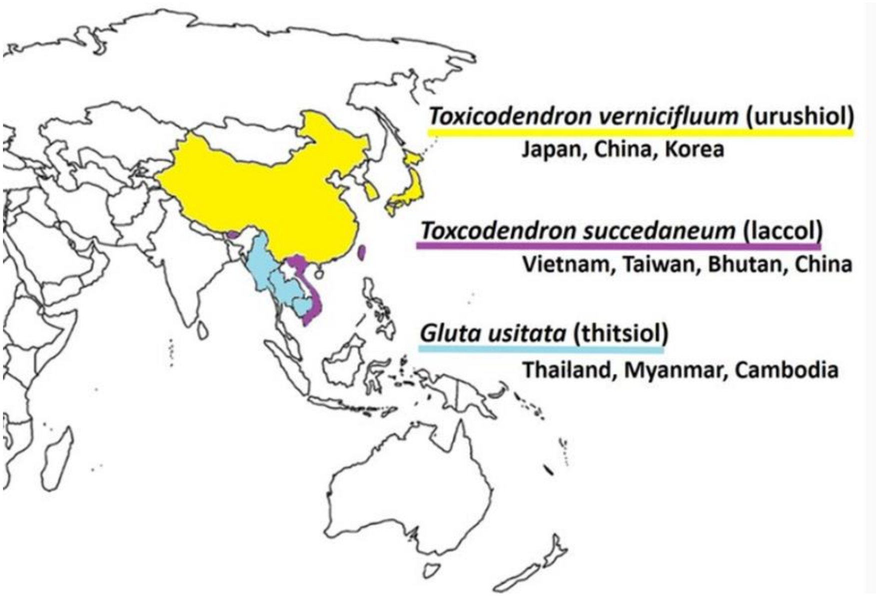


Figure 07 – Asian Lacquer Tree Species Distribution Map (by Suzanne Ross)

1.1.4 Composition of Lacquer

Lacquer is a complex mixture composed of various natural compounds, with its main components including urushiol or laccol or thitsiol, and some volatile substances. These components together give lacquer its unique physical and chemical properties. Urushiol is the most important component in lacquer, determining the quality and durability of the lacquer film. Other components such as laccase, gum, and water affect the curing process of the lacquer and the performance of the final lacquer film. If the skin has direct contact with uncured raw lacquer, it is likely to cause an allergic reaction within 2-7 days, leading to symptoms such as redness, swelling, blisters, and itching. Most of these symptoms will be resolved within a week to a month without leaving scars. The reason urushiol causes allergies is that it reacts with proteins in the skin, causing inflammation. However, fully dried lacquerware does not cause allergic reactions.

Main Components of Lacquer Liquid (McSHARRY C., etalt.2000,):

- Urushiol: Urushiol is a natural organic compound, primarily composed of catechol derivatives, and constitutes about 50-80% of the lacquer liquid. The content and structure of urushiol determine the quality and performance of raw lacquer. A high content of urushiol helps in forming a strong and durable lacquer film.
- Laccase enzyme: Laccase enzyme is a polyphenol oxidase enzyme that catalyzes the oxidation and curing of urushiol at room temperature to form a lacquer film. The presence of laccase allows the lacquer liquid to cure at room temperature, forming a tough lacquer film with a high molecular structure. The activity of laccase affects the curing speed of the raw lacquer and the final quality of the lacquer film.
- Gum: Gum is a colloidal substance secreted by the lacquer tree when injured. This gum makes the lacquer liquid insoluble in organic solvents but soluble in water. Although gum is not essential in the polymerization process of lacquer, it acts as a natural emulsifier and stabilizer, playing an important role in the drying speed and the performance of the lacquer film.
- Water: Water constitutes about 15-35% of the lacquer liquid. Typically, raw lacquer with a high-water content is of poorer quality because excessive water affects the viscosity and slows down the polymerization process, thereby impacting the final quality of the lacquer film.

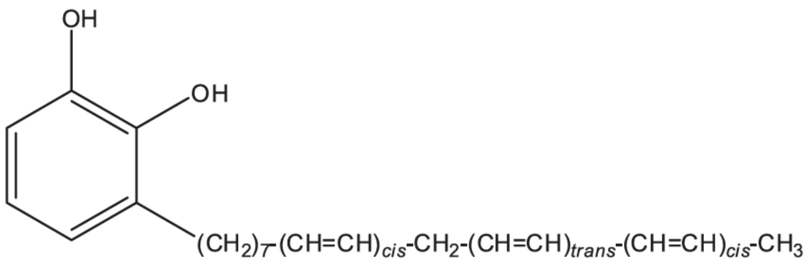


Figure 08 – Structure of the most abundant catechol isomer found in urushiol (McSHARRY C., et al.2000,)

1.1.5 Curing Mechanism of Lacquer

The curing process of raw lacquer involves a series of complex chemical reactions, primarily through the oxidation and polymerization of urushiol catalysed by laccase enzyme. This process can be divided into three stages: initial oxidation, polymerization reaction, and film formation. (SCHILLING M. R., HEGINBOTHAM A., 2016) (KUMANOTANI J. 1998)

1. Initial Oxidation: In the early stage of oxidation, urushiol and laccase begin to oxidize under the action of oxygen (O_2) in the air, forming phenoxy radicals. Laccase catalyses the oxidation of urushiol at the interface layer, and these radicals further react to form peroxides.
2. Polymerization Reaction: Subsequently, the oxidation products further react to form high molecular weight polymers, which cross-link to form a network structure. These phenoxy radicals rearrange to form semiquinone radicals, which react with neighbouring urushiol molecules to form biphenyl dimers. These reactions ultimately involve electron transfer and the inhibition of urushiol polymerization at the interface layer, allowing O_2 to continuously permeate into the aqueous phase, further oxidizing and reducing laccase, thereby sustaining the polymerization of urushiol.
3. Film Formation: As these reactions proceed, the lacquer gradually hardens, forming a tough and wear-resistant lacquer film. These films exhibit excellent abrasion resistance and corrosion resistance, providing long-term protection for the substrate. The cured lacquer film has a high gloss and smooth surface and possesses a certain degree of elasticity, allowing it to accommodate minor deformations of the substrate without cracking.

Additionally, the presence of stellacyanin (~ 0.02%), which is a single-copper glycoprotein in the water can inhibit certain free radicals and control their concentration, which helps regulate the rate of polymerization reactions and the quality of the final lacquer film. (YANG J. et al. 2020)

The curing of raw lacquer requires a high humidity environment, typically with a relative humidity between 70-90%, which promotes the oxidation reaction of urushiol to form a strong lacquer film. The temperature should be controlled between 20-30°C to enhance laccase enzyme activity, ensuring full curing of urushiol. Low humidity and inappropriate temperatures can significantly affect the curing process of lacquer. If the environmental humidity is below 70% or the temperature is below 20°C or above 30°C, the activity of laccase enzyme decreases, causing the curing reaction to slow down or halt. In low-temperature environments, the curing time will be greatly extended, while temperatures above 40°C may stop the curing process altogether.

Proper ventilation maintains the oxygen content in the air and prevents dust and impurities from affecting the quality of the lacquer film. The thickness of each lacquer application should be controlled between 0.1-0.2 millimeters, with multiple thin coats resulting in a high-quality lacquer film. Each layer of lacquer typically requires about 24 hours to cure under the right humidity and temperature conditions. After applying a layer of lacquer, the lacquered items are placed in a room specifically designed to control temperature and humidity. This room(or box) is known in Japanese called "風呂 muro" (TSUTOKI K., KUDO S., NISHIKAWA H. 2018) or "", in Chinese called" 陰房 yīn fang" or" 陰室 yīn shì" (HUANG C., YANG M. 2021). This controlled environment is crucial for ensuring that the lacquer hardens properly. Also, during the curing process, direct sunlight should be avoided, and the environment should be kept clean. Subsequent layers should be fully cured to ensure the stability and durability of each lacquer layer.

Figure 09 – Lacquer artist ("風呂 muro" at right upper side of the picture), early Edo period (1600s), 海北友雪 Kaihoku Yusetsu,《職人絵尽》(Shokunin E-zukushi)

Figure 10 – Lacquerware manufacturing ("陰房 yīn fang" or"陰室 yīn shì" at left upper side of the picture), 18th–19th century, *"Illustrated Collection of Chinese Natural History Paintings" 《中国自然历史绘画》- "Illustrations of Chinese Lacquer Making" 《中国制漆图谱》*

1.2 LACQUERWARE MANUFACTURING

1.2.1 ARCHAEOLOGY OF LACQUERWARE

The history of lacquer is extensive, with ancient peoples using it as a coating and adhesive for thousands of years. From religious artifacts and offerings to buildings and everyday items, lacquer has been integral to Asian life. Studying lacquer reveals ancient craftsmanship, tax systems, daily life, social hierarchies, religious practices, and aesthetic standards. Many lacquered items found in archaeological sites have preserved their lacquer layers even when the materials of the body have decayed.

The oldest known lacquer artifacts come from China and Japan. In China, lacquerware dates back to the Neolithic era, with a lacquered wood bowl from the Hemudu Site in Zhejiang Province dating back about 7,000 years. The Liangzhu Culture, around 5,000 years ago, also produced early lacquerware. In Japan, the earliest example is from the Kakinoshima B Site in Aomori Prefecture, about 9,000 years ago, from the early Jomon period, red lacquer thread products. The oldest urushi wood is even older, with branches dating back approximately 12,600 years being found at the Torihama shell mound in Fukui Prefecture. Other significant early lacquer artifacts have been found in Korea's Sinan Shipwreck, Vietnam's Dong Nai Site, and Thailand's Ban Chiang Site.

Figure 11 –Neolithic Hemudu Culture Wooden Bowl with red Lacquer (from from the Zhejiang Provincial Museum official website)

Figure 12 – Burial lacquer-coated thread artifacts, Hakodate City, Hokkaido, Kakinokishima Site of the Jomon Era, B site 垣ノ島遺跡 B 遺跡 (from Hokkaido’s official website) (UZUKI M., NOSHIRO S., etalt. 2020)

Southeast Asia, due to their rich natural resources, such as lacquer trees, developed similar cultural practices. The climatic conditions in these areas were ideal for the growth of lacquer trees, which contributed to the development of lacquerware craftsmanship. Examples of this can be seen in the lacquerware craftsmanship from China's Neolithic period and Japan's Jomon period, both of which demonstrate the profound impact of natural resources on cultural development. Lacquerware not only played a significant role within these cultural spheres but was also spread to wider regions through ancient trade routes. Archaeological findings from Korea's Sinan Shipwreck and Vietnam's Dong Nai Site reveal that the lacquerware techniques and cultural practices of East and Southeast Asia were exchanged and transmitted through these trade networks.

The "Nanhai One" shipwreck was a merchant ship from the Southern Song Dynasty of China (1127-1279), discovered in the South China Sea in the late 1980s. This ship carried a large number of trade goods, particularly porcelain, metal utensils, and lacquerware, confirming the prosperity of the maritime Silk Road during the Southern Song period. Since 1987, archaeologists have been excavating the ship, and in 2007, they successfully raised the entire vessel. More than 180,000 artifacts have been unearthed, providing abundant physical evidence of maritime trade during the Southern Song Dynasty and showcasing the vastness of the trade networks at that time (Wei, J. 2023).

In Japan, the significant increase in the number of lacquerware artifacts unearthed from the mid to late Jōmon period suggests that lacquerware was largely distributed along the coastal areas of the Sea of Japan. The remarkable characteristics of the entire era indicate that culture was transmitted through the Tsushima current, which also facilitated prosperous trade, leading this tidal route to be called the "Lacquer Sea Route"*(漆海道)* (YANAGI Y., 2021).

When exploring the origins of lacquer culture, the lacquerware history of China and Japan is inextricably linked. China, as one of the birthplaces of lacquerware, had a profound influence on Japan through its early lacquer production techniques and artistic styles. Early Jōmon sites on the Sea of Japan's side show similarities to the Hemudu sites in China, where characteristic C-shaped earrings (jué-shaped earrings) from the Jiangnan (lower Yangtze River) region have also been discovered. Over time, the two cultures continuously influenced and interacted with each other, and lacquerware techniques further developed and evolved through trade and cultural exchange.

1.2.2 Ancient Literature on carved Lacquerware Techniques

Detailed records of the Chinese carved red lacquer technique can be found in several ancient texts. "Exploitation of the Works of Nature" *《天工開物》(Tiāngōng Kāiwù)*, an important technological book by Ming Dynasty author *宋應星(Sòng Yìngxīng)*, describes various craft techniques, including lacquerware production. "Essential Criteria of Antiquities" *《格古要論》 (Gé*

Gŭ Yào Lùn), written by Ming Dynasty's *曹昭 (Cáo Zhāo)*, also mentions lacquerware techniques, including *剔紅 (Tīhóng)*. Ming Dynasty, *黃成 (Huáng Chéng)*'s "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* is a specialized book on lacquerware crafts, detailing steps and techniques, categorizing lacquerware into 14 types: *colored lacquer 色漆, transparent lacquer 罩漆, painted lacquer 彩繪, gold-painted 描金, build-up lacquer 堆漆, inlaid lacquer(even surface)填漆, carved and inlaid lacquer 雕填, mother-of-pearl inlay 螺鈿, rhinoceros skin pattern 犀皮, carved redlacquer 剔紅, Carved with alternating red and black pattern 剔犀, incised base coat and refilled with colors(relief effect)款彩, Gilded 戗金,* and *inlaid with precious stones or jewels 百寶嵌* (HUANG C., YANG M. 2021).

The carving technique *剔紅,* is particularly complex, involving applying dozens or even hundreds of layers of lacquer, repeatedly coating and drying until thick enough for intricate carving, resulting in a deep relief effect. Chinese lacquerware is known for its rich colors, commonly using red, black, gold, yellow, and green these five colors, with striking contrasts and exquisite craftsmanship.

Excerpt from "Records of Lacquering" *《髹飾錄·坤集》(Xiūshì Lù·kūn jí.),* "Carving and Engraving, Chapter 10" *雕鏤第十 (Diāo Lòu Dì Shí)*[1]:

"剔紅，一名珠雕，即雕紅漆也。髹層之厚薄，朱色之明暗，雕鏤之精粗，大甚有巧拙。唐制多印板刻，平錦朱色，雕法古拙可賞，復有陷地黃錦者。宋元之制，藏鋒清楚，隱起圓滑，纖細精緻。又有無錦紋者，共有象旁刀跡見黑線者，極精巧。又有黃錦者，黃地者次之。又矞胎者不堪用。

（楊明注）唐制如上說，而刀法快利非後人所能及。陷地黃錦者，其錦多似細鉤雲，與宋元以來之剔法大異也。藏鋒清楚，運刀之通法。隱起圓滑，壓花之刀法。纖細精緻，錦紋之刻法。自宋元至國朝皆用此法。古人精造之器，剔跡之紅間露黑線一二帶。一線者，或左上或在下，重線者，其間相去或狹或闊，無定法，所以家家為記也。黃錦，黃地亦可賞。矞胎者，矞朱重漆，以銀朱為面，故剔跡殷暗也。又近琉球國產精巧而鮮紅，然而工趣去古甚遠矣。"

Translation:

剔紅 (Tīhóng), also known as *珠雕 (Zhūdiāo)*, refers to carving on red lacquer. The thickness of the lacquer layers, the brightness or darkness of the red color, and the fineness or coarseness of the carving can vary greatly. During the Tang dynasty, the technique often involved using engraved printing plates, resulting in flat surfaces with a red color. The carving style was simple but admirable, with some pieces featuring sunken areas filled with yellow brocade patterns. By the Song and Yuan dynasties, the carving style became more refined, with clear lines and smooth, rounded cuts, resulting

[1] HUANG C., YANG M.. 2021

in intricate and delicate work. There is also a type of *Tīhóng* without brocade patterns, where black lines from the carving knife are visible, displaying great craftsmanship. Another type involves yellow brocade patterns, with yellow backgrounds being slightly inferior. Additionally, there are pieces made with alum-based lacquer, which are less durable. (alum-based lacquer refers to lacquerware with a foundational layer of alum red, which is the red lacquer containing iron oxide).

(Yang Ming's annotation) The Tang dynasty's technique, as described above, featured sharp and precise knife work, unmatched by later generations. The sunken yellow brocade patterns often used hooking cloud technique, significantly different from the carving methods used since the Song and Yuan periods. 'Concealed blade with clear edges' refers to the precise carving technique, 'rounded and smooth raised surfaces' to the technique used for pressing patterns, and 'fine and delicate' to the method of engraving brocade patterns. These techniques have been employed from the Song and Yuan dynasties through to the Qing dynasty. The finely crafted ancient pieces sometimes feature one or two thin black lines within the red carving. The lines could be at the upper part or lower part, and when there are multiple lines, their spacing varies, which serves as a unique characteristic for each workshop. Yellow brocade pattern and yellow base lacquer are also worth admiring. Pieces made with alum-based lacquer are created by applying multiple layers of alum red lacquer, with a top layer of vermillion, resulting in darker carved lines. Recently, finely crafted and vividly red *Tīhóng* items have been produced in Ryūkyū, but their artistic style is far from the ancient works."

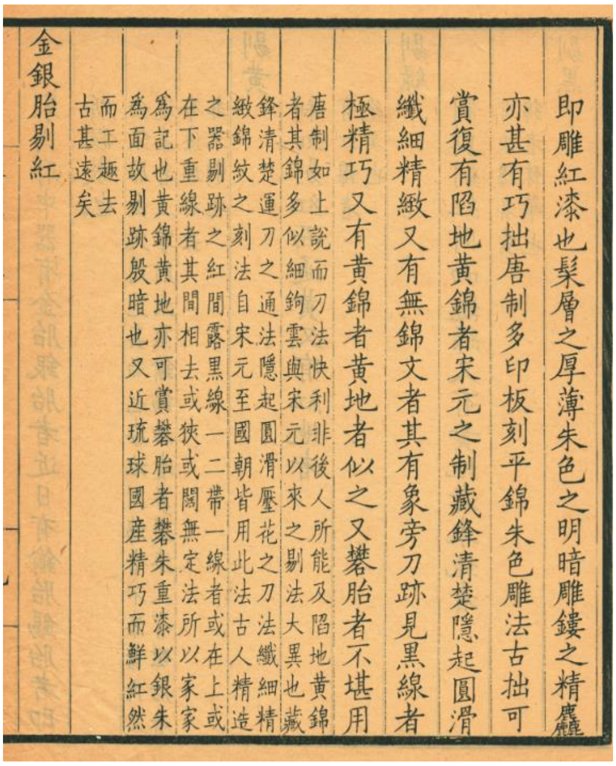

即雕紅漆也髹層之厚薄朱色之明暗雕鏤之精麤
亦甚有巧拙唐制多印板刻平錦朱色雕法古拙可
賞復有陷地黃錦者宋元之制藏鋒清楚隱起圓滑
纖細精緻又有無錦文者其有象旁刀跡見黑線者
極精巧又有黃錦者黃地者似之又髹胎者不堪用
唐制如上說而刀法快利非後人所能及陷地黃錦
者其錦多似細鉤雲與宋元以來之剔法大異也藏
鋒清楚運刀之通法隱起圓滑壓花之刀法纖細精
緻錦紋之刻法自宋元至國朝皆用此法古人精造
之器剔跡之紅間露黑線一二帶一線者或在上或
在下重線者其間相去或狹或闊無定法所以家家
爲記也黃錦黃地亦可賞髹胎者髹朱重漆以銀朱
爲面故剔跡殷暗也又近琉球國產精巧而鮮紅然
而工趣去
古甚遠矣
金銀胎剔紅

Figure 13 – *剔紅 (Tīhóng)* (from "Records of Lacquering" *《髹飾錄·坤集》(Xiūshì Lù·kūn jí.),* "Carving and Engraving, Chapter 10" *雕鏤第十 (Diāo Lòu Dì Shí)*)

According to the process recorded in "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* for making *剔紅 (Tīhóng),* carved lacquerware, the steps are as follows: First, mix polished lacquer(The main components of polished lacquer include raw lacquer, hardeners, natural pigments, and vegetable oils.) and primer oil(The primary components of primer oil include raw lacquer, drying oils such as linseed oil or tung oil, and fine carbon powder or other fillers) in equal parts to make thick lacquer. Add finely ground cinnabar or vermilion pigment, and stir to form a thick red lacquer, with color ratios varying by artisan. Apply the lacquer layer by layer, letting each dry fully before applying the next, until the desired thickness is achieved. When the surface is uniformly dry and soft to the touch, carve the desired pattern using carving tools. After carving, let the lacquerware rest for a long time to fully harden. Next, use knives, horsetail grass or ash strips to smooth the surface, then brush with straw or brushes dipped in tile ash, followed by fine polishing with bamboo grass, and finally use paraffin powder to achieve a shine. The lacquerware is then left to rest for several years for the lacquer to fully develop its luster. During the Ming and Qing periods, instead of modern sandpaper, a plant called "horsetail grass" *(銼草, cuòcǎo)* was used for polishing. It is smooth and resilient, used with repeated tapping and longitudinal friction. This method is still used by some ivory carving master today. Nowadays the carved lacquer process involves, after the foundation is completed, applying a mixture of pigment, raw lacquer, and refined tung oil. The ratio of raw lacquer to refined tung oil is typically 1:1, but the exact proportions are determined by the artisan based on their experience and requirements. The lacquer is applied in thin layers, repeatedly stacking to achieve the desired thickness and texture. After each layer is applied, it needs to dry and be polished before the next layer is added.

During the mid-Edo period in Japan, which coincided with the Qianlong and Jiaqing eras of the Qing dynasty in China, the "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* had already been lost in China. *木村 蒹葭堂（Kimura Kenkadō,1736–1802）*possessed a manuscript of the "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)*, which came to be known as the "Kenkadō Manuscript"《蒹葭堂抄本》. This manuscript, along with another known copy, the "Tokugawa Manuscript"《德川抄本》, provided significant insights into lacquer techniques of the time. In the Meiji period, this manuscript was housed in the Imperial Museum (today's Tokyo National Museum). Since then, various copies of the "Kenkadō Manuscript" 《蒹葭堂抄本》 have been made by libraries, schools, and private collectors across Japan. The book later became a classic reference for many lacquer art experts and masters. It was not until the early 20th century that it was reintroduced to China.

Figure 14 – Left: "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* "Kenkadō Manuscript " *《蒹葭堂抄本》*
Right: "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* "Tokugawa Manuscript" *《德川抄本》*
(from 黃成. 2021, 髹飾錄圖說, 山東書報出版社.)

There are many detailed records of Japanese lacquerware production. "Procedures of the Engi Era" *《延喜式》(Engishiki)* is a set of legal codes compiled by order of Emperor Daigo in 905AD and completed in 927AD, consisting of 50 volumes. Volume 17 details the materials needed for lacquerware in court ceremonies (YANAGI Y.. 2021).

An excerpt from "Procedures of the Engi Era"*《延喜式》(Engishiki)* regarding the materials and process for making a red lacquer rice bowl (ENGISHIKI*《延喜式》*, Volume 17, Heian Period:
“飯椀一口／径八／寸。‖料。漆一合二勺。朱沙一分。貲布五寸。〓。布各一寸。綿三分。掃墨二勺。油一勺。炭一升。長功一人大半。中功二人。短功二人小半。”
"A rice bowl with a diameter of eight inches. Materials needed: 1.2 units of lacquer, 1 part cinnabar, 5 inches of fine cloth, 1 inch of each type of cloth, 3 parts cotton, 2 units of sumi ink, 1 unit of oil, and 1 shō (about 1.8 liters) of charcoal. Required craftsmen: 1 master craftsman (for about half a day), 2 journeymen, and 2 apprentices (for about half a day each)."

Another excerpt for making a red lacquer pedestal tray:
“朱漆台盤三面／各三尺。／加台。‖料。漆九升。朱砂〓両。掃墨三升。油五合。焼土五升。綿三屯。絹七尺。細布一丈二尺。信濃布一丈二尺。調布一丈五尺。伊予砥一顆。青砥二枚。阿膠十両。炭一斛。単功廿五人。”
"Three red lacquer trays, each three feet in diameter, with added stands. Materials needed: 9 shō (about 16.2 liters) of lacquer, an unspecified amount of cinnabar, 3 shō (about 5.4 liters) of sumi ink, 5 gō (about 0.9 liters) of oil, 5 shō (about 9 liters) of burnt earth, 3 tun of cotton, 7 feet of silk, 12 feet of fine cloth, 12 feet of Shinano cloth, 15 feet of adjusted cloth, 1 Iyo whetstone, 2 Aoto whetstones, 10 ryō (about 375 grams) of gelatin, and 1 koku (about 180 liters) of charcoal. Required craftsmen: 25 individual workers."

In "Procedures of the Engi Era"*《延喜式》(Engishiki)*, the " ‖ " symbol is used to separate different sections, similar to modern paragraph separators. The " 〓 " symbol usually indicates missing or unrecognizable text in the original manuscript, due to damage, copying errors, or later editorial difficulties. These symbols alert readers to gaps that need to be inferred from context or other sources.

The compilation of “Wakan Sansai Zue"*《和漢三才図会》(Wakan Sansai Zue)* dates back to early Edo period Japan and was completed by *寺島良安(Terajima Ryōan)* in 1712AD. This encyclopedia covers various Japanese and Chinese techniques and crafts, including lacquerware techniques. Key highlights include: using natural lacquer (tree sap) as the primary material, filtered and processed to remove impurities; base materials like wood and bamboo are finely sanded for smooth surfaces. Lacquerware must be left to dry and harden fully, then polished using fine stones, charcoal, horsetail grass(similar with Chinse one, in Japanese called *砥草(とぐさ, togusa)*, or deer hide to make surface smooth and shine .

Though it mentions multiple traditional techniques, the book does not detail the carved lacquerware process. Instead, it broadly describes basic procedures and common methods like using natural lacquer, creating bases, painting techniques*(蒔繪, maki-e)*, burnishing and polishing.

Common red and black color lacquer[2]:

Red lacquer:

1. *朱漆(Zhūqī) (しゅうるし, Shūrushi)*: Mercuric sulfide (HgS), know as cinnabar or vermilion. Vermilion and cinnabar were both red pigments in ancient times, but their main difference is about their origin: cinnabar is a natural mineral of mercury sulfide, ground into a pigment; vermilion, while chemically identical to natural cinnabar, is produced by synthetically combining mercury and sulfur through heating, resulting in a brighter and more uniform color. As both contain mercury, they are toxic and require careful handling.
2. *弁柄漆(Biàn bǐng qī) (べんがらうるし, Bengaraurushi)*: Bengara is a red pigment primarily composed of ferric oxide (Fe_2O_3), commonly known as red iron oxide or hematite. *Bengara lacquer, alum red 礬紅(fán hóng)* and red ochre, all share the same primary component, ferric oxide (Fe_2O_3), so their chemical formula is identical. However, their sources and preparation processes differ. Alum red is produced by calcining green vitriol (ferrous sulfate, $FeSO_4$) to create ferric oxide, which has a vibrant red color. Red ochre is a naturally occurring ferric oxide mineral. The pigment is obtained through simple crushing and processing and can be used directly. Bengara is a red pigment produced through calcination and may involve different mineral sources, such as hematite or limonite. Bengara lacquer is mainly used in traditional Japanese lacquerware.

Black lacquer:

1. Natural carbon element from soot of completely burned pine and oil, mixed with refined lacquer. (Ancient time: Used in intermediate and base coats, not topcoat)
2. Iron powder, ferric hydroxide, and other iron agents react with lacquer phenols to produce a black coating. (Modern time: Used in topcoat, but turns brown over time) Lacquer without adding black pigment but itself oxidized to black-brown color are called "black series lacquer," not black lacquer.

[2] (YANAGI Y., 2021) (NATIONAL MUSEUM OF JAPANESE HISTORY 2004) (TSUTOKI K., KUDO S., NISHIKAWA H. 2018)

1.2.3 MANUFACTURING PROCESS AND MATERIALS OF LACQUERWARE

The process, materials, and tools used in lacquerware production vary due to regional traditional techniques, individual craftsmen's choices, design requirements, and local material availability. The lacquering process is generally divided into three parts: “base coat” for building up foundation and “top coat” or the lacquering.

Base coat in Chinese is called “底漆(dǐqī)”, in Japanese called 下地(shitaji). Top coat in Chinese is called ”面漆(miànqī)”, in Japanese called ”漆塗り(urushi nuri)”. Regardless of the type of substrate is used, it must be treated and smoothed first to enhance the lacquerware's heat and impact resistance. The purpose of the base coat is to reinforce the construction and the surface of the substrate, and prepare it for the lacquering.

For a wooden body, it is usually first sanded and then coated with a base coat to fill the wood pores. For a metal body, it needs to be derusted first, then coated with multiple layers of natural lacquer to prevent oxidation and corrosion. For a woven body, natural lacquer or other adhesives (such as animal glue or plant glue) are used to fix the fibers, followed by a base coat to fill in the uneven surfaces, making them smoother.

The general term for lacquer application in China is “髹漆 xiū qī”, in Japanese is “塗漆 kyushitsu”, of which there are two main methods: one in which lacquer is applied directly to a substrate without applying a foundation layer, and another in which the body is covered with a foundation layer that provides the base to which subsequent layers of lacquer are applied.

I will use a wooden body covered with a foundation layer lacquerware as an example, since it is the standard across all materials. The focus will be on the manufacturing process, material and relevant terminology in China and Japan. The relative material and tool will aim on the one related with the four lacquerwares of this thesis.

Basic process and materials of wooden substrate lacquerware in China and Japan:

English translation	Chinese	Material used in Chinese process	Japanese	Material used in Japanese process
Wood substrate seam joining	合縫 hé fèng	glue+filtered raw lacquer		
Fiber-Reinforced wood substrate	批地 pī dì	Cotton wadding / hemp fibers + glue +filtered lacquer	刻苧 Kokuso	Raw urushi + Flour paste+ Wood powder /

				Fiber dust from hemp
Wood substrate surface priming	打底 dǎ dǐ	Raw lacquer (raw lacquer + fine powder)	木地固め kiji gatame	Raw urushi
Cloth attachment	布漆 bù qī	Cloth + filtered lacquer+ glutinous rice paste	布着せ Nunokise	Urushi + flour paste/rice glue + hemp cloth/silk cloth
Coarse lacquer plaster	粗灰漆 cū huī qī	coarse powder (sieved through 80-mesh screen) + refined lacquer +water	堅地 Kataji (本地 Honji・蒔地 Makiji・本堅地 Honkataji)	Raw urushi + powder "地の粉 Jinoko" / "砥の粉 Tonoko" (+ water /glue)
Medium lacquer plaster	中灰漆 zhōng huī qī	medium coarse powder (sieved through a 160-mesh screen) +refined lacquer + water	切粉地 Kirikoji	Raw urushi + "地の粉 Jinoko" + "砥の粉 Tonoko"
Fine lacquer plaster	細灰漆 xì huī qī	fine powder (sieved through a 240-mesh screen) + refined lacquer +water	錆地 Sabiji	Raw urushi + "砥の粉 Tonoko"
Line Edging	線緣 xiàn yuán	Oil + clam powder + raw lacquer		
Priming lacquering	糙漆 (灰糙) cāo qī (huī cāo)	Lacquer+ dilute with water or oil	下塗 Shitanuri	Raw urushi + clay powder
Intermediate lacquering	糙漆 (生漆糙) cāo qī (shēng qī cāo)	Filtered lacquer	中塗 Nakanuri	Refined urushi
Top lacquering	糙漆 (煎糙) cāo qī (jiān cāo)	"推光漆" (tuī guāng qī) (Egg white may be added)	上塗 Uwanuri	Highly refined urushi
Lacquering polishing	麭漆(拋光) bào qī (pāo guāng)		蝋色仕上げ Roiro shiage (胴	Charcoal powder ("砥の

			擦 Dōzuri – 摺漆 suri urushi – 艶上げ Tsuyaage)	粉 Tonoko" + Rapeseed oil – raw urushi – rapeseed oil + Deer antler powder)

Table 01 – Basic process and materials of wooden substrate lacquerware in China and Japan

Names of pigments in Chinese and Japanese:

Pigment	**Chinese Name**	**Japanese Name**	**Component**	**Color**
Cinnabar	丹砂 (dān shā), 朱砂, 辰砂	朱 (しゅ, shu)	Mercury sulfide	Deep red, slightly orange
Artificial Vermillion	銀朱 (yín zhū)	朱合漆 (しゅあい shuai.urushi)	Synthetic mercury sulfide	Bright orange-red
Ferric Oxide Red	絳礬 (jiàng fán), 礬紅	弁柄 (べんがら, bengara)	Ferric oxide (Fe_2O_3)	Subdued red
Ochre	赭石 (zhě shí)	黄土 (おうど, oudo)	Hematite (Fe_2O_3)	Red, yellow, brown tones
Realgar	雄黃 (xióng huáng)	雄黄 (おうおう, ōō)	Arsenic sulfide	Bright orange-red
Orpiment	雌黃 (cí huáng)	雌黄 (しおう, shio)	Arsenic trisulfide	Lemon-yellow
Azurite	石青 (shí qīng)	石青 (せきせい, sekisei)	Copper carbonate hydroxide	Vibrant blue
Malachite Green	石綠 (shí lǜ)	緑青 (りょくしょう, ryokusho)	Basic copper carbonate	Bright green
Lead White	鉛白 (qiān bái), 詔粉	鉛白 (えんぱく, enpaku)	Lead carbonate	White
Soot	煙煤 (yān méi)	松煙 (しょうえん, shōen)	Carbon (from pine or oil)	Black

Table 02 – Names of pigments in Chinese and Japanese

The Production Process of Chinese Wood Substrate Lacquerware[3].:

The structure of lacquerware can be compared to a human body: the wood substrate is like the "bones," the fiber attachment layer is the "tendons, the lacquer plaster layer is the "flesh," and the lacquering layers are the "skin"。

Base coat in Chinese is called "底漆 dǐqī", which includes the series of processes start from wood substrate seam joining till fine lacquer plaster. Later start the lacquering, means the top coat, which in Chinese is called "面漆 miànqī", included priming lacquering, intermediate lacquering, and top lacquering.

1. "合縫 hé fèng" (Wood substrate seam joining): For joined wood substrate, use "法漆 fǎ qī" to fill the gaps between the joined wooden pieces. The excess adhesive is scraped off, and once dried and hardened, the surface is sanded smooth. ("法漆 fǎ qī": also known as" 點漆 diǎn qī"， is made by mixing fish bladder glue or gelatin with water in a 2:10 ratio, steaming until fully melted, then cooling and blending it with raw lacquer until it forms long, non-sticky strands when stirred.)
2. "批地 pī dì"(Fiber-Reinforced wood substrate): After the seams are sanded smooth, any imperfections or looseness are filled with broken cotton or hemp fibers mixed with lacquer adhesive. This process is known as "捉麻 zhuō má"。
3. "打底 dǎ dǐ"(Wood substrate surface priming): A thin layer of raw lacquer is applied over the entire piece to seal the pores of the wooden substrate, preventing moisture from entering and ensuring that the subsequent lacquer layers do not seep into the wood, which could cause sagging or leaking. No other adhesive materials should be used as substitutes.
4. "布漆 bù qī"(Cloth attachment): After priming, the substrate is wrapped with cloth soaked in lacquer paste, ensuring that the wooden pieces are tightly bonded into a single, cohesive structure that will not come apart. Raw lacquer and glutinous rice paste are mixed in a 4:6 ratio. The cloth should be longer than the surface, applied evenly without wrinkles or gaps, and overlapping cloth edges should be offset. The cloth is pressed down to allow the lacquer to penetrate the fibers, and excess lacquer is scraped off. Once dried and hardened, any raised seams from overlapping cloth are shaved off, and the surface is polished with water-soaked bricks or stones, taking care not to break the cloth fibers.
5. 灰漆"huī qī" (Lacquer plaster): Lacquer plaster is a mixture of lacquer and sieved powdered horn, clay, or shell. It comes in coarse, medium, and fine varieties, with the specific type used depending on the region, object size, and decorative requirements. The ash can come from various sources, with the best being fine powders from animal horns

[3] (HUANG C., YANG M. 2021)

or ceramic fragments, and the lower quality being shell powder, bone powder, brick powder, or stone powder. In the late Ming Dynasty, cheaper materials like unburnt brick powder, charcoal powder, thick paste, pig blood, pond mud, and glue began to be used, resulting in less durable products.

In response to the growing popularity of carved and inlaid designs, the blood mix with powder, which is softer to carve became a trend from southern to northern China. As lacquer plaster layers became thicker, the amount of lacquer decreased, and the use of water or other adhesives increased.

5.1 "粗灰漆 cū huī qī" (Coarse lacquer plaster): Typically sieved through an 80-mesh screen, coarse powder mixed with refined lacquer in a 1:1 ratio is applied with a scraper to a thickness of about 0.8-1mm, covering the cloth pattern. After drying, the surface is polished with water-soaked grinding stones.

5.2 "中灰漆 zhōng huī qī" (Medium lacquer plaster): Powder sieved through a 160-mesh screen, the lacquer ratio is reduced, mixed with water, and applied to a thickness of about 0.6-0.8mm. After drying, it is polished with grinding stones or wooden blocks wrapped in wet sandpaper. Gaps, seams, and edges are inspected, filled if necessary, and polished again.

5.3 "細灰漆 xì huī qī" (Fine lacquer plaster): Powder sieved through a 240-mesh screen, further reducing the lacquer ratio. It is mixed with water and applied thinly with a scraper to fill small pores. Multiple thin coats are applied if carving or inlaying is required. In some areas, adhesive or blood paste replaces refined lacquer in fine lacquer plaster.

6. "線緣 xiàn yuán" (Line edging): A mixture of oil, clam powder, and lacquer, known as lacquer jelly "漆凍 qī dòng " is used to mold patterns and edges. This is also called "開光 kāi guāng" resembling opening windows on the lacquer surface with scenic details inside.
7. "糙漆 cāo qī"(Lacquering): "糙漆 cāo qī" includes "灰糙 huī cāo", "生漆糙 shēng qī cāo" and "煎糙 jiān cāo". Sequentially applying raw lacquer and "推光漆 tuī guāng qī"(polishing lacquer) to fill the small pore of previous plaster. Polishing lacquer mixed with color can provide depth and richness, such as black. Once dried, the surface is polished with stones, charcoal, or fine sandpaper.

    7.1 "灰糙 huī cāo"(Priming lacquering): Diluted lacquer, with water, glue, or kerosene depending on usage, penetrates the plaster layer and seals pores. After drying, the surface is polished with wet sandpaper. Any remaining small pits need to be filled within this step.

    7.2 "生漆糙 shēng qī cāo"(Intermediate lacquering): A thin layer of raw lacquer is brushed on. After drying, the lacquer plaster is completely sealed. After natural drying, use water sandpaper wrapped around a wooden block, dipped in water, and carefully sand the surface until smooth.

7.3 "煎糙 jiān cāo"(top lacquering): A thin coat of polishing lacquer, possibly mixed with color, is brushed on 1-3 times. All defects need to be removed at this last step of lacquering. "推光漆 tuī guāng qī"(polishing lacquer) is prepared by frying or sun-drying. Polishing lacquer can also be mixed with color pigments for application. Additionally, egg whites can be added to the polishing lacquer to make the layer thicker and shinier.

8. "麭漆 bào qī" (Lacquering polishing): The final lacquer layer for polishing and adding decorative patterns.

Materials and Tools Used in the Production of Chinese Lacquerware[4].:

1. Powder: Common powders used in lacquerware production include antler powder, bone powder, clam shell powder, stone powder, brick ash, tile ash, kiln ash, and charcoal dust. Clam shell powder contains fine internal pores that facilitate lacquer penetration and is frequently used by shipbuilders in Wenzhou and modern lacquer craftsmen to prepare lacquer materials. Porcelain ash is derived from unglazed porcelain shards that, after kiln firing, become dense and are considered excellent materials for lacquer ash. Old bricks and tiles ground into ash have a balanced dryness and good breathability, making them a commonly used plaster material in lacquerware production since the mid-Ming Dynasty. Additionally, antler ash has excellent acoustic properties, making it suitable for use in lacquering musical instruments, while charcoal dust aids in the breathability of lacquer liquid. The choice of ash material depends on its properties and the specific needs of lacquerware production, with no fixed standards.
2. Plaster Burnishing: Special burnishing stones are used for grinding the plaster. Select burnishing stones according to different coarseness of plaster. Since the late Yuan and early Ming periods, Chinese lacquer craftsmen have also used wooden blocks wrapped in water sandpaper for ash grinding.
3. Lacquer:

   Half ripe lacquer: know as raw lacquer, means only filtered the lacquer.

   Ripe lacquer: a fully refined lacquer after the full process of filtered, homogenization, dehydration and low-temperature baking.

[4] (HUANG C., YANG M. 2021) (LIU L., FU J. 2023) (HEGINBOTHAM A., CHANG J., KHANJIAN H., SCHILLING M. R. 2016)

- 揩光漆(kāi guāng qī): also known as "推光漆" (tuī guāng qī), is referred to as refined lacquer. It undergoes filtering, homogenization, dehydration process and is used for the gloss treatment of lacquer surfaces. In the Qing Dynasty of China, it was called "嚴生漆"(yán shēng qī), and in Japan, it is known as "透漆" (suki urushi) or transparent urushi.
- 濃漆 (nóng qī): A thick and viscous half-ripe lacquer (only filtered, not fully refined), the water content is between 15% to 20%., belonging to the fast-drying lacquer category. It is used to blend with "推光漆(tuī guāng qī)" or base oil to promote drying.
- 淡漆 (dàn qī): Also known as "罩漆"(zhào qī), it has a light and bright color. It is made by mixing fast-drying lacquer and oil, stirred for one hour. In the Qing Dynasty of China, it was called "明光漆 (míng guāng qī)". It is used for gloss coating and single-layer lacquering.
- 明膏漆(míng gāo qī)：Pigment mixed with "Tuiguang lacquer (推光漆, tuī guāng qī)".
- 透明推光漆(tòu míng tuī guāng qī)：Literally means transparent "推光漆(tuī guāng qī)". Refined from the upper oil layer of bucket lacquer, mixed with brightening agents such as "Huanglu seed juice (黃栌子汁)" or "gamboge powder solution (藤黃粉溶液)", used for gloss coating and single-layer lacquering.

4. Lacquering Buffing (remove scratches) and polishing (creates glossy): After each layer of clay or lacquer is applied and dried, it must be sanded with water. In ancient times, lacquer polishing was done using fine and dense stones, or charcoal made from soft, knot-free woods such as Calocedrus, Fagus, Prunus。If the polishing stones or charcoal contained even slight hard knots, they would leave scratches on the lacquer surface. These tools have gradually been phased out.
5. Pigments: In ancient China, most of the pigments mixed into lacquer were mineral pigments, known as "石色 shí sè"(stone colors). These pigments give the lacquer a deep and rich color that never fades. Natural plant dyes mixed into lacquer are called "草色 cǎo sè"(grass colors) which tend to produce more transparent hues.

"石色 shí sè"(Mineral Pigments in Lacquer)[5]:

- Cinnabar "丹砂 dān shā": Mercury sulfide, commonly known as "cinnabar", also called as "朱砂"、"辰砂" is a natural mineral primarily found in regions like "辰水錦江 chén shuǐ jǐn jiāng" (now Mayang, Hunan) and Sichuan, China. High-quality cinnabar, such as "光明砂 guāng míng shā", "箭頭砂 jiàn tóu shā"、"鏡面砂 jìng miàn shā" is known for its rich and glossy color and is often used directly in painting and lacquerware decoration rather than being refined into mercury, which would reduce its value. Cinnabar has a deep red or slightly orange hue, providing

[5] (SONG Y., 1637) (HUANG C., YANG M. 2021) (CHANG J. & SCHILLING M.R. 2016) (LIU C. 2019)

a dense and durable color when mixed into lacquer, with excellent coverage and resistance to fading.

- Artificial Vermillion “銀朱 yín zhū”: Also mercury sulfide, artificial vermillion is made by refining lower-quality cinnabar into mercury and then reprocessing it into a synthetic pigment. This manufacturing process gives artificial vermillion a brighter and more vivid color. It usually appears more orange-red than natural cinnabar and has very strong coverage.

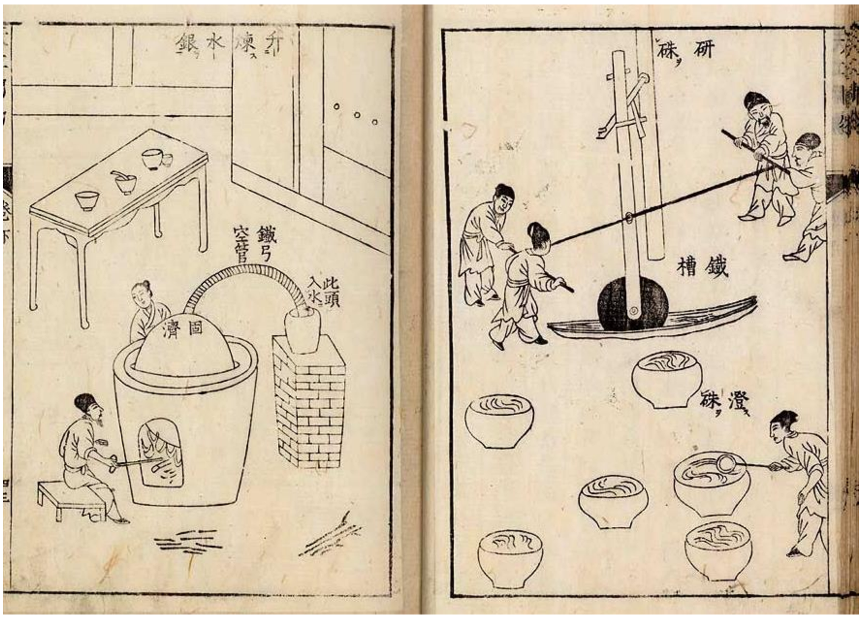
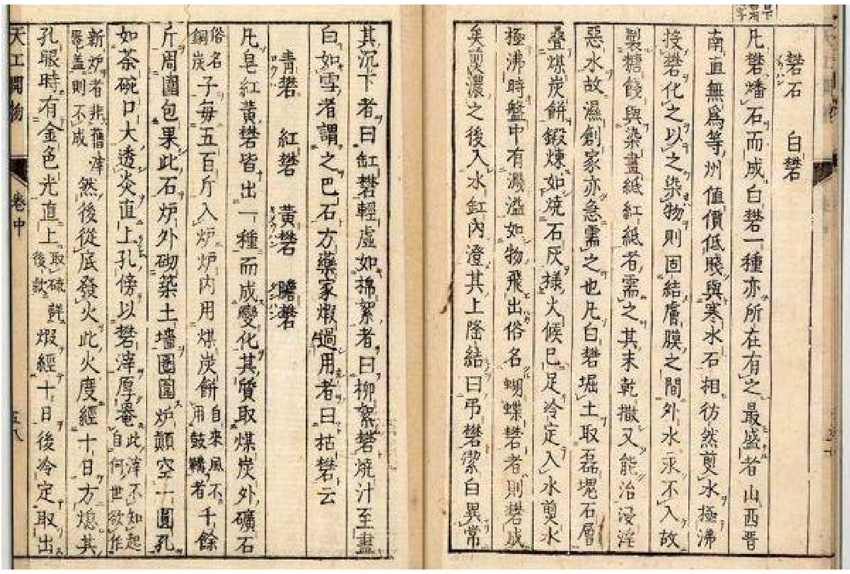


Figure 15 – *Paints and Pigments – Red*. SONG Y.X. 1771, *"The Exploitation of the Works of Nature"* 《天工開物》(Tiangong Kaiwu), Jūsōdō Edition(Meiwa 8), Volume Lower, p. 43. (picture from: http://www.gmzm.org/)



礬石 白礬
凡礬燔石而成白礬一種亦所在有之最盛者山西晉
南直無爲等州值價低賤與寒水石相彷然煎水極沸
投礬化之以之染物則固結膚膜之間外水永不入故
製糖餞與染畫紙紅紙者需之其末乾撒又能治浸淫
惡水故濕創家亦急需之也凡白礬掘土取磊塊石層
疊煤炭餅鍛煉如燒石灰樣火候已足冷定入水煎水
極沸時盤中有濺溢如物飛出俗名蝴蝶礬者則礬成
矣煎濃之後入水缸內澄其上隆結曰吊礬潔白異常
其沉下者曰缸礬輕虛如棉絮者曰柳絮礬燒汁至盡
白如雪者謂之巴石方藥家煅過用者曰枯礬云
青礬 紅礬 黃礬 膽礬
凡皂紅黃礬皆出一種而成變化其質取煤炭外礦石
子(俗名銅炭)每五百斤入爐爐內用煤炭餅(自來風不用鼓鞴者)千餘
斤周圍包裹此石爐外砌築土牆圓圍爐巔空一圓孔
如茶碗口大透炎直上孔傍以礬滓厚罨(此滓不知起自何世欲作
新爐者非舊滓罨蓋則不成)然後從底發火此火度經十日方熄其
孔眼時有金色光直上(取硫後款)其煅經十日後冷定取出
天工開物 卷中 五八

Figure 16 – *Burning Stones* – 紅礬 “hóng fán”. SONG Y.X. 1771, *"The Exploitation of the Works of Nature"* 《天工開物》(Tiangong Kaiwu), Jūsōdō Edition(Meiwa 8), Volume Middle, p. 58,. (picture from: http://www.gmzm.org/)

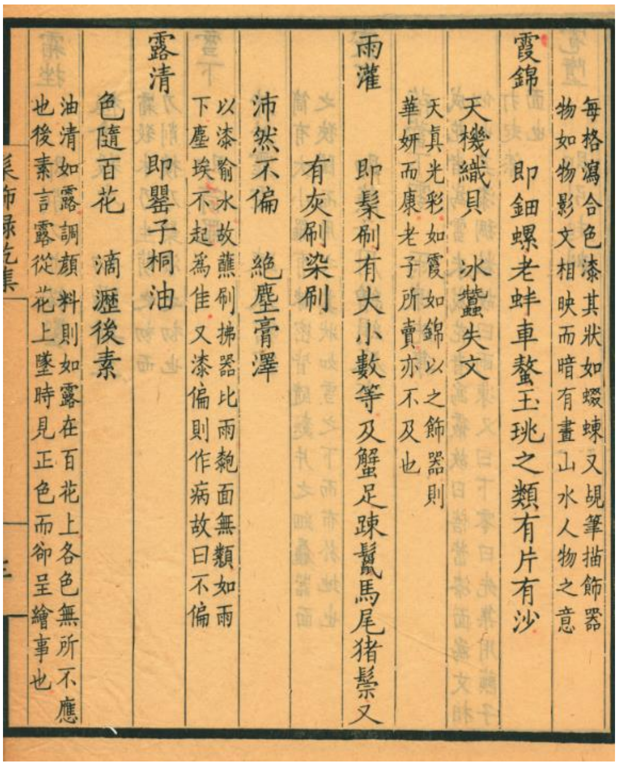
- Ferric Oxide Red “絳礬 jiàng fán”: also known as carved red strip ”剔紅條 tī hóng tiáo” or ferric red “礬紅 fán hóng”. This red pigment consists of ferric oxide (Fe_2O_3) and produces a subdued color when mixed into lacquer. The ferric oxide is extracted from stones commonly found on the outer layers of coal mines, known as “copper charcoal.” The minerals undergo prolonged high-temperature calcination, multiple boiling, and filtering to extract the pure mineral content. The pigment is then soaked, filtered, and reprocessed to produce a stable red hue. When mixed into lacquer, it provides a muted and long-lasting red color.
- Ochre “赭石 zhě shí”: A natural hematite, primarily composed of ferric oxide (Fe_2O_3). The color of ochre depends on its iron content and particle size, commonly appearing in shades of red, yellow, and brown ochre. Red ochre ranges from deep red-brown to reddish-brown due to its high ferric oxide content; yellow ochre is yellow to yellow-brown, containing small amounts of hydrated iron oxide (such as goethite); brown ochre often has a brownish tone due to various mineral impurities. When used in lacquer, ochre typically imparts a subdued earthy red or reddish-brown color, evoking a sense of heaviness and antiquity.
- Realgar”雄黃 xióng huáng” & Orpiment”雌黃 cí huáng”: Realgar and orpiment are closely associated and often found together in mineral deposits. Realgar, composed of arsenic sulfide, is known for its bright orange-red color. The higher quality realgar is called “雞冠石 jī guān shí”(chicken comb stone), characterized by its vibrant orange-red powder. Lower quality realgar, known as "薰黃 xunhuang", has a slightly greenish hue, which is typically caused by impurities such as other metal oxides or sulfides. These impurities can alter the color of realgar, making it lean towards blue-green or yellow-green. Orpiment, composed of arsenic trisulfide, appears as a lemon-yellow powder. Orpiment, composed of arsenic trisulfide, appears as a lemon-yellow powder.
- Ultramarine “石青 shí qīng”: Made by removing yellow particles (impurities like pyrite) from lapis lazuli and finely grinding it. The main component is lazurite, which is the primary blue element of lapis lazuli, giving it a vibrant blue color.
- Malachite Green “石綠 shí lǜ”: Derived from ground malachite, whose primary component is basic copper carbonate ($Cu_2(OH)_2CO_3$), resulting in a bright green pigment.
- Lead White”韶粉 sháo fěn”: known as ”鉛白 qiān bái” it is a white pigment used for painting on lacquer surfaces. Over time, lead white tends to darken due to oxidation. To address this issue, during the Ming Dynasty, pearl powder was mixed with "密陀油 mì tuó yóu” (mastic oil) to maintain the stability of the lacquer’s color.
- Soot”煙煤 yān méi”: Black soot produced from the burning of pine wood or tung oil, used for mixing with black lacquer.

”草色 cǎo sè” (Natural Plant Dyes in Lacquer):

- Indigo (靛藍): Blue. Indigo is a natural blue dye that, when mixed with lacquer, can produce various shades from deep blue to light blue.
- Pagoda Tree Yellow (槐黃): Yellow. Pagoda tree yellow is derived from the buds or fruits of the pagoda tree, resulting in a bright yellow when added to lacquer.
- Gamboge (藤黃): Bright yellow to golden yellow. Gamboge is obtained from the resin of Garcinia plants, producing a bright yellow to golden yellow in lacquer.
- Gardenia Yellow (梔黃): Light yellow to orange-yellow. Gardenia yellow comes from the fruit of the gardenia plant, producing light yellow to orange-yellow hues when mixed into lacquer.
- Madder (茜草): Red. The roots of madder are used to make red dye, which can create shades from bright red to deep red in lacquer.
- Saffron (藏紅花): Orange-yellow to golden yellow. Saffron is derived from the stigmas of the saffron crocus, imparting an orange-yellow to golden yellow sheen in lacquer.

6. Oil: Tung oil is a plant oil extracted from the seeds of the tung tree, with an oil yield ranging from 35% to 60%. Raw tung oil is light yellow and cannot be used directly for coating. After being processed at high temperatures, it becomes refined tung oil, which, although slower to dry and lacking in coverage, possesses greater toughness compared to raw lacquer and varies in hardness and anti-aging properties. Refined drying oils such as tung oil, perilla oil, linseed oil, and walnut oil are used in lacquer after processing. They enhance the lacquer’s adhesion, brightness, and gloss, reduce finishing costs, and are suitable for thick coatings or varnishing. Refined drying oils can also be directly mixed with pigments for decorative painting and were commonly used in lacquerware designs in ancient times. These oils are important companions to lacquer. The ancients believed that "lacquer without oil is not bright" and "lacquer without adherence is not shiny."

   The preparation and use of refined tung oil vary depending on the boiling temperature and additives. During production, tung oil is heated to 200°C and then stirred on low heat to avoid smoking, with the oil’s completion judged by observing oil droplets in cold water. If the temperature exceeds 280°C, the oil becomes charred and unusable. Different types of refined tung oil suit different purposes; for instance, “干油 gān yóu” or “光油 guāng yóu” boiled at around 200°C is suitable for quick application but is not suitable for long-term storage. In contrast, “坤油 kūn yóu” or “明油 míng yóu” boiled at 270°C has high viscosity and good drying performance, making it suitable for making glossy lacquer or mixing with thin lacquer. Ancient lacquer craftsmen would adjust tung oil’s properties according to the needs of lacquerware production, adding drying agents like litharge to achieve the desired lacquer surface effect.



髹飾錄乾集

每格寫合色漆其狀如蠟蝀又硯筆描飾器物如物影文相映而暗有畫山水人物之意

霞錦　即鈿螺老蚌車螯玉珧之類有片有沙

天機織貝　冰蠶失文

天真光彩如霞如錦以之飾器則華妍而康老子所賣亦不及也

雨灌　即髹刷有大小數等及蟹足踈鬣馬尾猪鬃又

有灰刷染刷

沛然不偏　絕塵膏澤

以漆喩水故蘸刷拂器比雨麪面無類如雨下塵埃不起爲佳又漆偏則作病故曰不偏

露清　即罌子桐油

色隨百花　滴瀝後素

油清如露調顏料則如露在百花上各色無所不應也後素言露從花上墜時見正色而卻呈繪事也

Figure 17 – description of specific name and material represent mother-of-pearl, lacquer brush, tung oil (Aleurites cordata Thunb) that used in lacquer production (from "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)*)

7. Glue: Glue is used to bond the wood substrate and decorations of lacquerware. Cowhide glue is inexpensive and suitable for general bonding; fish bladder glue is soft with excellent adhesion, making it ideal for delicate parts; while deer antler glue is expensive and often used in lacquerware. Glue is not only used for bonding but also widely applied in lacquerware due to its flexibility, water solubility, and plasticity. It is used in shaping, adhering metals or shell inlays, making lacquer putty, and various other processes.

The Production Process of Japanese Wood Substrate Lacquerware[6]:

Japanese Wood Substrate Lacquerware: Wood Substrate - "下地(shitaji)"- "漆塗り(urushi nuri)". "下地(shitaji)" refers to the base reinforcement treatment of the surface of the object before applying lacquer. This process fills surface irregularities, enhances the adhesion of the lacquer layers, and provides a uniform foundation, significantly impacting the final quality and durability of the lacquerware. After completing the shitaji treatment, the process moves to the "漆塗り(urushi nuri)" , which involves applying natural lacquer to the object multiple times. The "漆塗り(urushi nuri)"

[6] (TSUTOKI K, KUDO S, NISHIKAWA H., 2018) (SATO K. (https://kiyo-sato.com/search/search.html)) (MEJIRO INSTITUTE OF URUSHI RESEARCH & RESTORATION, ed. 2020) (NATIONAL MUSEUM OF JAPANESE HISTORY 2004, URUSHI)

process includes the application of multiple lacquer layers, each layer needs drying, sanding, and polishing."

“下地(shitaji)” steps in sequence include: “刻苧 Kokuso”, “木地固め kiji gatame”, “布着せ Nunokise”, “堅地 Kataji (本地 Honji・蒔地 Makiji・本堅地 Honkataji)”, “切粉地 Kirikoji”, “錆地 Sabiji”。

1. “刻苧 Kokuso”: To strengthen the joints of a wooden substrate and to make its surface smooth by filling any flaws and imperfections. It is made by mixing raw urushi with a hard paste of flour and water, and then adding wood powder "刻苧粉 kokusoko" or finely chopped hemp fibre "刻苧綿 kokusowata". "刻苧綿 kokusowata" is a material composed of fiber dust collected during the weaving process. It could mixed with wood powder or finely cut hemp paper mixed with glue and lacquer, may also be used as alternatives.
2. “木地固め kiji gatame”: Apply raw urushi to the wooden base forms a waterproof film that seals the wood's pores, preventing moisture penetration and protecting the wood from deformation or damage.
3. “布着せ Nunokise”: pasting pieces of cloth onto a wooden substrate with "麦漆 mugi urushi" (urushi mixed with flour paste) or "糊漆 nori urushi" (urushi mixed with rice glue) is done to reinforce joints and minimize deformation of the wood substrate. Cloth pasting can cover the entire surface of the substrate or be applied as strips only on vulnerable areas such as corners or edges. Hemp cloth is the primary material used; silk cloth is also sometimes used, but cotton cloth is generally avoided because it does not interact well with urushi.
4. “下地 shitaji” (foundation) is categorized into two types:

    4.1 ”漆下地 urushi shitaji”: Uses raw urushi mixed with one or both of two types of powdered clays: "地の粉 jinoko" and "砥の粉 tonoko”. "地の粉 jinoko", also referred to as “地粉 Chiko”, is made from natural minerals such as clay, gypsum, tile ash, or other similar materials, which are crushed and sieved to form a uniform fine powder. "砥の粉 tonoko”, also known as “砥粉 Toiko”, is primarily composed of natural minerals like quartz, shale, and diatomaceous earth. Depending on regional practices and recipes, additional ingredients such as glutinous rice paste or pig's blood might be mixed into the raw lacquer. A foundation made solely of layers containing "地の粉 jinoko" is called "地 ji" (primary foundation coating), and the process of applying this mixture is known as "地付け jitsuke." The constitution of the mixture and the application method further categorize this foundation, known as “堅地 kataji,” into three types: “本地 Honji,” “蒔地 Makiji,” and “本堅地 Honkataji.”

4.1.1 “本地 Honji”: The hardest kind of kataji (堅地 kataji) foundation. It is made by mixing raw urushi with "地の粉 jinoko" clay powder in to the paste and apply to the substrate by spatula. Due to its high content of raw lacquer, hardening needs to put in specialized lacquer curing cabinet, “漆風呂 urushi muro" for few days, and it creates a strong and durable base coating. However, the disadvantage is that it is challenging to handle due to its difficult workability.

4.1.2 ”蒔地 Makiji”: Apply a thin layer of raw urushi with a brush, and immediately sprinkle "地の粉 jinoko" clay powder on it, allowing the clay powder to fully saturate into the raw urushi. Similar to "本地 honji," it has a high content of raw lacquer, so hardening requires placing it in a specialized lacquer curing cabinet, "漆風呂 urushi muro," for a few days. This process creates a strong and durable base coating. Since the layer is thinner than "本地 honji," it needs to be applied more times.

4.1.3 “本堅地 Honkataji”: Made with a paste of mix of water(or glue) and "地の粉 jinoko" clay powder, then mix with raw urushi, apply to the substrate by spatula. In Wajima, is made with it's special"地の粉 jinoko", diatomaceous earth 珪藻土, and then mixed with raw urushi. The relatively high water or glue content helps the workability, also means hardening will take place without “漆風呂 urushi muro". "本堅地 honkataji" is the most commonly used methods in Japan today.

4.2 Other foundations: The foundations that do not use urushi include, instead use persimmon tannin, called “柿渋下地 Kakishibu Shitaji”; use pig’s blood, called “豚血下地 Butachino Shitaji”; use animal glue mixed with ash, called “膠灰下地 Nikawa Hai Shitaji”.

5. “切粉地 Kirikoji” : The foundation made using "切粉 kiriko," a paste of "砥の粉 tonoko" powder and water mixed with raw urushi, further blended with "地の粉 jinoko" clay powder. The process of applying kiriko is called “切粉付け kirikotsuke”. Compared to “堅地 kataji”, which only uses "地の粉 jinoko," "切粉地 Kirikoji" incorporates "砥の粉 tonoko," resulting in a finer texture.
6. “錆地 Sabiji”: The foundation made from "錆漆 sabi urushi", which is a paste of "砥の粉 tonoko" powder and water mixed with raw urushi. It's extremely fine as it's the last foundation coating in order to provide a smooth final surface for the lacquering later. The process of applying sabi urushi is called "錆付け sabitsuke”.

“漆塗り(urushi nuri)” 工序依序包括: “下塗 Shitanuri”, “中塗 Nakanuri”, “上塗 Uwanuri”, “蝋色仕上げ Roiro shiage” (“胴擦 Dōzuri” – “摺漆 suri urushi” – “艶上げ Tsuyaage”)。

1. “下塗 Shitanuri”: raw urushi mixed with powdered clay, to fill the uneven surface of the foundation.
2. “中塗 Nakanuri”: apply refined urushi.
3. “上塗 Uwanuri”: apply the urushi that has been filtered multiple times to remove impurities.
4. “蝋色仕上げ Roiro shiage: Begins with the abrading of the surface of "uwanuri 上塗り" urushi coating with togisumi "研炭 togisumi" charcoal to make it smooth and even. Then, followed by several cycles of “胴擦 Dōzuri” and “摺漆 suri urushi”. Final step will be “艶上げ Tsuyaage”.

   4.1 “胴擦 Dōzuri”: Using a cloth, the urushi surface is polished with a blend of tonoko (砥の粉 tonoko) powder and rapeseed oil. This process aims to eliminate scratches left by charcoal abrasion and to smooth the surface of the urushi coating.

   4.2 “摺漆 suri urushi”: It is a consolidation and strengthening process in which raw urushi is rubbed onto an urushi surface, after which any excess is wiped away. It is used also to fill small scratches resulting from last step, “胴擦 Dōzuri” polishing.

   4.3 “艶上げ Tsuyaage”: Following multiple rounds of "胴擦り dōzuri" (polishing) and "摺漆 suri urushi" (urushi rubbing), the urushi surface is polished to a high gloss by applying rapeseed oil combined with a small amount of "角粉 tsunoko" (deer antler powder) or a substitute superfine abrasive powder, using the fingertips or the palm of the hand.

Materials and Tools Used in the Production of Japanese Lacquerware:

1. Powder: "地の粉 Jinoko" is a powdered clay mixed with raw lacquer to create the "下地 shitaji" foundation. It is sifted through sieves to categorize it into three grades: coarse, medium, and fine. Compared to "砥の粉 Tonoko," Jinoko is relatively coarser in texture.

   "砥の粉 tonoko" refers to very fine clay obtained by sedimentation of "地の粉 jinoko" powdered clay or powder made by pulverizing fine grade whetstone. "砥の粉 tonoko" is a fine powdered clay mixed with raw lacquer to make "錆漆 sabi urushi".
2. Plaster burnishing: "砥石 Toishi" refers to whetstones used to abrade the hardened surfaces of "下地 shitaji" foundation layers. The main purpose is to smooth the surface to prepare it for the

next layer of application. Various grades of whetstones—coarse, medium, and fine—are selected based on the texture coarseness of the "下地 shitaji" being worked on.

3. Lacquer:

- "透漆 Suki urushi" (transparent urushi): also known as "木地呂漆 kijiro urushi", it's the refined urushi with semi-transparent brown color.
- "朱合漆 shuai urushi": also known as "艶透漆 tsuya suki urushi" (lustrous transparent urushi). The addition of a small amount of drying oil during urushi refining elevates the brightness, making the surface smoother. Some also mix with color pigments.
- "色漆 iro urushi": "透漆 Suki urushi" or "朱合漆 shuai urushi" mixed with pigments. In the past there were only five colors of urushi: red, brown, yellow, green and black.

4. Lacquering Buffing(remove scratches) and Polishing(creates glossy): "研炭 Togisumi" is the charcoal is used for abrading the hardened surfaces of urushi coatings. These charcoals are specially crafted to be soft enough to prevent deep scratches. The main goal of using charcoal for abrasion is to smooth the surface, ensuring proper adhesion of the next layer of urushi. Charcoals are cut into various sizes based on the shape of the object being polished. They are soaked in water and moved back and forth along the grain-end. Different hardness levels of charcoal are selected based on the specific requirements, including "朴炭 hōzumi", a hard charcoal made from magnolia wood, and "擦炭 surugazumi", a softer charcoal derived from the wood of the tung oil tree.

   "角粉 Tsunoko" is made by baking and grinding deer antlers into a fine powder, which is used to polish the surface of an urushi coating, enhancing its gloss in the final stage of the finishing process.

5. Pigments:

- Red: vermilion, mercury sulfide
- Brown(brownish red): red ochre, "弁柄 bengara"

  Red Ochre's primary component is iron oxide (Fe_2O_3), which appears bright red due to the oxidation state of trivalent iron (Fe^{3+}). The color of iron pigments depends on their oxidation states: Fe_2O_3 is red, FeO(OH) appears yellow, and mixtures of Fe_3O_4 or Fe_2O_3 with FeO(OH) can range from brown to reddish-brown. Components in lacquer, such as urushiol and organic acids, create a mildly acidic environment that promotes oxidation reactions in iron oxides, altering their color. Additionally, laccase enzymes in lacquer can indirectly affect the oxidation state of iron. Organic acids in lacquer can form complexes with iron, deepening the color or producing varied hues, while redox reactions promote the conversion of Fe^{2+} to Fe^{3+}, shifting the color from dark brown to red.
- Yellow: orpiment

- Green: orpiment + indigo
- Black: lampblack or pine soot
- "朱漆 shu urushi" (vermilion red urushi): Black urushi is used at middle lacquering stage "中塗り nakanuri, after which "朱漆 shu urushi" is applied as the final top lacquering "上塗り uwanuri", this process called "朱塗 shu urushi nuri". After, on top apply "透漆 Suki urushi" or "朱合漆 shuai urushi" on it, called "朱溜塗 shudame nuri".

  "朱漆 shu urushi" is categorized by color into four types: "本朱 honshu" (true vermilion), "赤口朱 akakuchishu" (reddish vermilion), "淡口朱 awakuchishu"(pale vermilion), and "黄口朱 kiguchishu"(yellowish vermilion). The latter three shades are collectively called "洗朱 araishu", which literally means "washed vermilion", characterized by a soft, slightly faded hue. A higher relative density of this pigment, as seen in "本朱 honshu", results in a deeper vermilion color, in another hand, a lower density yields a more yellowish tone.

6. Oil: When vegetable oils such as perilla oil, tung oil, and linseed oil are simmered at low temperatures for an extended period, their drying rates improve. By adding lead monoxide, the resulting "密陀油 mitsuda-yu" accelerates the drying process even further. Commonly used natural white pigments like "胡粉 gofun" (calcium carbonate) and white lead typically turn black when mixed with urushi, but they retain their white color when combined with mitsuda oil.

1.2.4 Degradation Mechanism of Lacquerware

The degradation of lacquerware can be primarily divided into physical, chemical, and biological factors (WEBB M. 2000).

8. **Physical Degradation:** Physical degradation of lacquerware is mainly caused by changes in temperature and humidity, as well as mechanical damage. Research indicates that lacquerware should be stored in an environment with a temperature between 15-25°C to minimize cracking and peeling caused by expansion and contraction. The relative humidity should be maintained between 50-60%. Excessive humidity (above 65%) can cause the lacquer to absorb moisture, leading to swelling, softening, and deformation, while low humidity (below 40%) can make the lacquer brittle and prone to cracking. The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) recommends avoiding drastic environmental fluctuations for lacquerware, with daily temperature changes not exceeding 2-3°C and relative humidity changes not exceeding 5%. Additionally, improper handling or operation can cause scratches, impacts, and damage to the surface of the lacquerware, compromising the integrity of the lacquer layer and affecting its appearance and structure.

9. **Chemical Degradation:** Chemical degradation of lacquerware is primarily caused by exposure to light, pollutants, and oxidation reactions. Prolonged exposure to ultraviolet (UV) and visible light can degrade the lacquer layer, resulting in fading, deterioration, brittleness, and powdering. Studies show that light intensity exceeding 200 lux accelerates the aging process of lacquerware. Acidic or alkaline gases, dust, and other pollutants in the air can cause chemical corrosion of the lacquer layer, leading to surface damage and discoloration. According to cultural heritage preservation standards, lacquerware should be stored in low-pollution environments, with concentrations of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) in the air kept below 0.01 ppm. Long-term exposure to air also leads to oxidation reactions, causing discoloration, loss of gloss, and powdering of the lacquer layer. These chemical degradation factors collectively affect the preservation and display of lacquerware.

10. **Biological Degradation:** Biological degradation of lacquerware is mainly caused by microbial and insect infestations. In environments with relative humidity exceeding 65%, lacquerware is susceptible to mold and bacterial attacks, which decompose the organic substances in the lacquer layer, leading to its deterioration and damage. The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) recommends regular inspection and cleaning of lacquerware to prevent mold growth. Wooden lacquerware may also suffer from insect damage, such as woodboring, which compromises the structural integrity of the lacquerware, making it fragile and unstable. To prevent insect infestations, lacquerware should be stored in dry, well-ventilated environments with relative humidity maintained between 40-60%. These biological degradation factors further weaken the physical and chemical stability of lacquerware, accelerating its degradation process. By controlling environmental conditions, avoiding direct sunlight, and conducting regular cleaning and inspections, the lifespan of lacquerware can be effectively extended, preserving its aesthetic appeal.

1.2.5 Connection Between Asian Lacquerware and Europe

1. Early 16th Century

When lacquerware from East Asia first arrived in Europe, it was highly prized for its flawless finish and light-reflecting qualities. With the discovery of a sea route around the southern tip of Africa and across the Indian Ocean by Portuguese explorers, lacquerware, along with other luxury goods such as silk and porcelain, was introduced to European elites. Asian lacquer was seen as a precious and mysterious material, and its rarity was further enhanced by the fact that the resin from the lacquer tree would harden during the long sea voyage, rendering it unusable (MORRALL A. 2009).

2. 1570 to 1630

Japanese lacquerware began to be exported to Europe through Portuguese traders. The Azuchi-Momoyama period (1573-1603) marked the beginning of Japanese lacquerware exports when Portuguese merchants and missionaries first introduced it to the European market. Due to its exquisite craftsmanship and unique aesthetics, this lacquerware quickly became popular among European nobility and the upper classes. This lacquerware, now referred to as “南蠻漆器 (Nanban shikki)”, which means "Southern Barbarian lacquerware" in Japanese, adopted Western forms such as cabinets and bowls, with decoration styles different from those used in Japan itself. The term "Nanban" was used to describe foreigners from the southern regions who arrived on ships, specifically refers to the Portuguese and Spanish who arrived in Japan during the 16th and 17th centuries, traveling via southern sea routes.

Figure 18 – "Illustration of the Southern Barbarians," 《南蠻圖》(Nanban Zu) (Nakamura Yoshisai: *Kunmo Zue*, Volume 4, Book 4 (People), Illustration of the Southern Barbarians, preserved in the National Diet Library, Kanbun 6 edition, page 10)

3. 1600 to 1602

The British East India Company was founded in 1600, and the Dutch East India Company (VOC) was established in 1602. These two companies became major trading and shipping enterprises in the following decades, competing with the Portuguese and establishing their own direct trade routes with Asia. They imported large quantities of goods, including lacquerware, and distributed them throughout Europe via their respective markets.

4. Early to Mid-17th Century

Japan began implementing a policy of isolation, limiting direct trade with Europe. However, the Dutch East India Company (VOC) maintained limited but stable trade through its trading post on Dejima, an artificial island in Nagasaki also known as Tsukishima. Dejima became the main channel for trade and cultural exchange between Japan and the outside world, being the only Japanese territory open to Westerners. As the Portuguese gradually lost their trading dominance in Japan, the Dutch took over in the mid-17th century, becoming the primary exporters of Japanese lacquerware. As Japanese lacquerware grew in influence in the European market, the term "Japan" gradually became synonymous with lacquerware (HIDAKA K. 2024).

5. Late 1630s

To cater to the tastes of the Dutch and other Northern European countries, Japanese lacquerware makers began to adopt a more pictorial style in gold on a black background for their export ware. These lacquerware items were highly valued in Europe, particularly in the Dutch market.

6. 1670s

The British East India Company began direct trade with Chinese ports, establishing trading posts in Taiwan in 1672, and later in Amoy (Xiamen), Zhoushan, and Canton (Guangzhou). They imported various Chinese lacquerware products, including large folding screens and lacquered panels used as wall paneling or veneers for English-made furniture. British artisans were also sent to China to ensure that Chinese lacquered furniture met the tastes of the Western market.

7. Around 1700 to Mid-18th Century

In Europe, inspired by imported samples, imitation lacquer furniture became a popular trend, especially in Britain. Lacquered bureau-cabinets, often painted in bright red with gold and colorful decorations, became fashionable. These British imitations of lacquerware were also exported to other European countries, such as Spain, Portugal, Italy, and Germany. As demand for Chinese lacquerware grew, many pieces made in China for export to Europe began to feature black and gold lacquer, imitating the more expensive and rare Japanese lacquerware. Chinese merchants and artisans became increasingly familiar with Western tastes and were able to supply furniture in complex Western forms, such as bureau-cabinets and folding tables. The main export regions for Chinese lacquerware included Jiangsu and Guangdong provinces, with craftsmen from Suzhou, Yangzhou, and Guangzhou particularly known for their intricate carving and lacquer painting techniques.

8. Late 19th Century to Early 20th Century

East Asian lacquerware continued to influence European art, with periodic revivals of interest. After Japan reopened its ports in 1853, Japanese products such as fans, silks, and lacquered boxes flooded into Europe. These items were exhibited in museums and sold in shops like Liberty's in London, becoming highly fashionable and influencing European decorative styles. The exquisite craftsmanship of East Asian lacquerware was widely displayed at international expositions, further enhancing its reputation in the global market. Not only Japanese and Chinese lacquerware flowed into Europe, but lacquerware from other Asian countries such as Burma (Myanmar), Thailand, Korea, and Vietnam also began to attract European interest. These lacquerware items, each with their unique craftsmanship and aesthetic styles, enriched the European market and promoted cultural exchange between East and West.

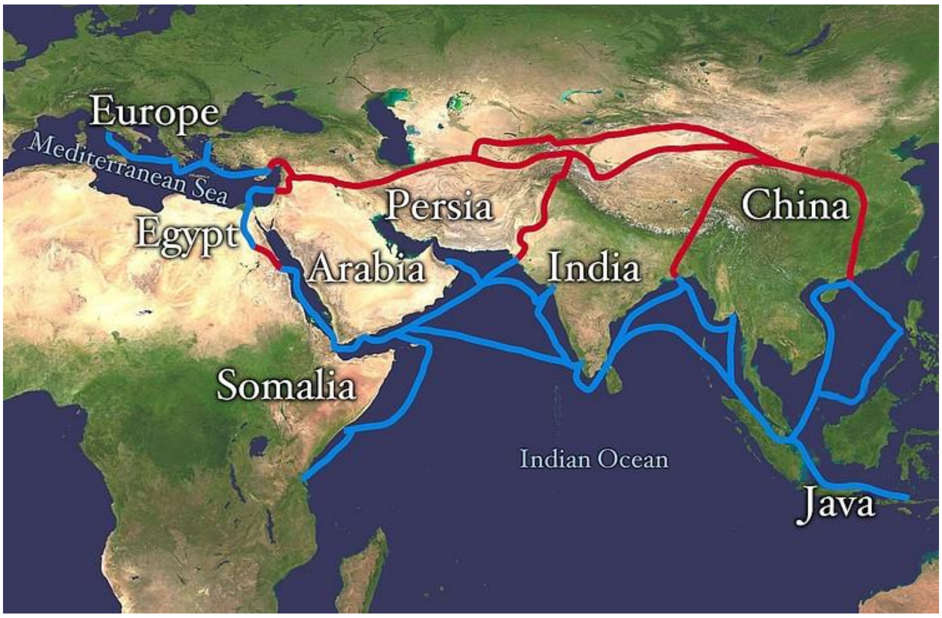


Figure 19 – The Overland Silk Road (red routes) and the Maritime Silk Road (blue routes) (by Whole World Land and Oceans) (CANEPA T. 2016)

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Chapter 2: The four lacquerwares from MAO

2.1 THE LACQUERWARE COLLECTIONS OF MAO [7]

Henry of Bourbon, Conte di Bardi, was born in Parma, Italy, and was the fourth son of Carlo III. In 1876, he married his second wife, Adelgunde of Bragança. In 1887, he began a world tour, collecting artworks in South-East Asia, China, Japan and the United States. These collections were later displayed at Palazzo Vendramin Calergi in Venice, that became the major showcase of his precious artworks since 1890.

Henry of Bourbon 's world tour (1887-1889) started on September 16, 1887, when he, his wife, and entourage departed from Trieste on the Lloyd ship. After some days, they crossed the Suez Canal and the Red Sea to Aden. In October 1887, he visited Sumatra, Java, and Singapore. On October 1888, he arrived in Hong Kong. In China, he visited Shanghai, Tientsin, Peking, and Canton. In February 1889, the count arrived in Nagasaki, Japan, and began extensive exploration of Japan, visiting Kobe, Kyoto, Tokyo, and Osaka. In the end of September 1889 they left Japan, stopped in Hawai islands, before heading to the United States, concluding their rich and colourful Asian journey.

Henri died in 1905 and after his death, his Widow sold the Asian collection (nearly 30.000 pieces) to the antique dealer Franz Trau. Trau entrusted a first catalogue of the collection to Justus Brinckmann and his Japanese assistant Shinkichi Hara: the cataloguing, still preserved at the Museum, was not completed. Probably in 1907, Trau published an illustrated catalogue in different languages, to attract potential buyers. The items were bought by museums and private collectors in Italy and Europe, with the sales process recorded in a 200-page transaction note. Among them, the Museum Für Kunst und Gewerbe in Hamburg, the Museum für Natur-, Völker- und Handelskunde, and many others.

During World War I, the collection was considered an enemy property and seized by the Italian State. In the 1920s, efforts were made by the Superintendence office to ensure the proper allocation of the Trau collection, thanks to the Superintendent Gino Fogolari, who understood the importance of the collection. In 1925, the collection was transferred from Palazzo Vendramin Calergi to Ca' Pesaro, with relocation costs covered by the government and the Ministry of Education. Subsequently, Ca' Pesaro underwent restoration and display works, including the removal of few walls, construction of a larger staircase and exhibition areas. Fogolari entrusted the works and the choice of the pieces to expose to Nino Barbantini (1884-1952). Barbantini's work and contributions in Venice included organizing and exhibiting the 18th-century museum (Palazzo Rezzonico) and participating in multiple art projects such as the Museo Vetrario di Murano.

[7] (SPADAVECCHIA F. 1999) (BOSCOLO M. M. ,2020)

For the musicological project Barbantini used the cataloguing by Brinckmann and probably asked some experts. However, the provenance of many works still remain uncertain, due to insufficient documentation. Therefore, scientific research methods are hoped to be used to identify the origin and craftsmanship and materials of these items.

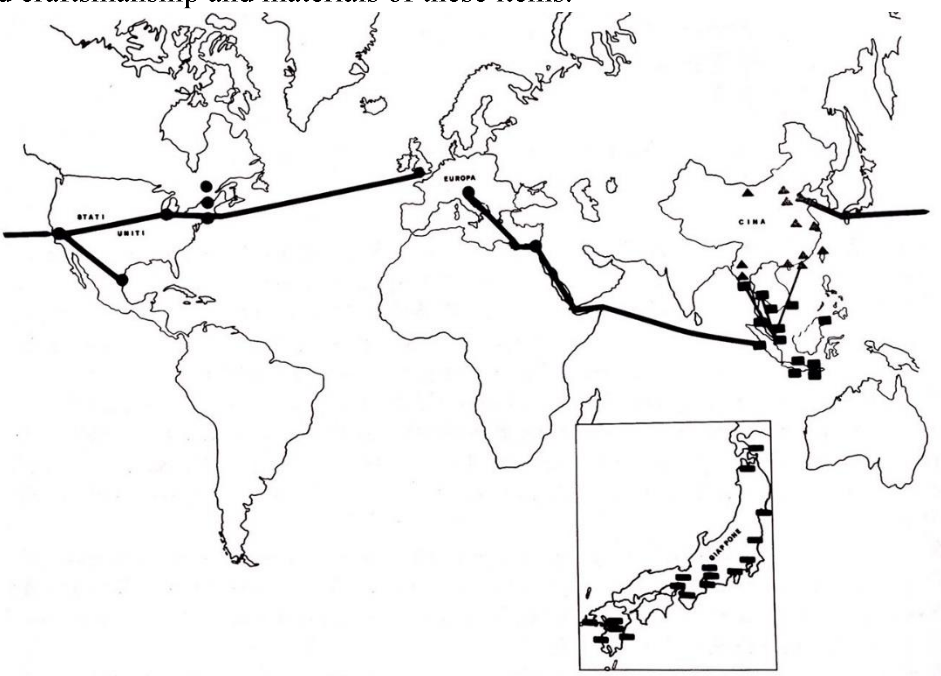


Fig. 2 - Itinerario del "viaggio intorno al mondo" da Trieste a Southampton, 1887-1889 (pp. 16-18).

Figure 20 – The itinerary of the journey around the world from Trieste to Southampton, 1887-1889. MUSEO D'ARTE ORIENTALE, 2000, *La Collezione Bardi: Da Raccolta Privata a Museo dello Stato*, p. 14

2.2 ICONOGRAPHIC INTERPRETATION

	Brush holder	Fan shape covered box	Box with drawers	Polychrome plate
Museum No.	inv. 10736/10410	inv. n. 10721/10368	inv. n. 10781/10355	inv. n. 10766
Code	BH	FB	DR	PP
Size	Φ13.2cm, H 13cm, THK 0.8cm	H 6.7cm, W 8.3cm	L 19cm, W 19cm, H 12.8cm	Φ17.8cm, H 3cm
Picture				

Table 03 – The four lacquerware collections from Museo d'Arte Orientale (by Wei-hsin Wu and Shang-ying Liu)

This section will provide a detailed analysis of the decorative appearance of four lacquerware pieces, exploring the unique characteristics of each piece. This includes their shapes, patterns, colors, and the historical and cultural significance of their decorative elements, linking them to the context of the period in which they were created.

2.2.1 BRUSH HOLDER , INV. 10736/10410

Figure 21 – Brush holder carving: Seven Sages of the Bamboo Grove

Figure 22 – Brush holder interior and bottom

The vertical pen holder, carved in openwork style, features a panoramic depiction of the "Bamboo Grove Seven Sages" *竹林七賢 (Zhú Lín Qī Xián)* (SU J. 2017) (XU T. 2021). The scene is rich in spatial layers, including distant mountains, pavilions, bamboo forests, and large rocks. Inside the pavilion, there is a desk with books and paintings, and beside it, the seven sages are engaged in various activities such as playing chess, viewing scrolls, and appreciating paintings, accompanied by young attendants. The brown sections are carved to represent the sky with cloud patterns, the black sections depict water surfaces with water wave patterns, and the red ground is carved with hexagonal turtle shell patterns.

The *"Bamboo Grove Seven Sages" 竹林七賢 (Zhú Lín Qī Xián)* originates from the tale of seven sages from the Wei and Jin dynasties. These individuals, facing political adversity, chose to retreat from the mundane world and live secluded in a bamboo grove. They pursued a life of freedom, independence, and naturalism, opposing the constraints of social norms and advocating for individual freedom and intellectual liberation. The seven sages refer to *阮籍 (Ruǎn Jí), 嵇康 (Jī Kāng), 山濤 (Shān Tāo), 劉伶 (Liú Líng), 阮咸 (Ruǎn Xián), 向秀(Xiàng Xiù), and 王戎 (Wáng Róng)*. They frequently gathered under the bamboo grove, indulging in carefree enjoyment, hence they are known as the "Bamboo Grove Seven Sages".

"Bamboo Grove Neo-Daoism" refers to the philosophical school represented by *嵇康 (Jī Kāng)* and *阮籍 (Ruǎn Jí)*, which emphasizes the teachings of *《老子》(Lǎozǐ)* and《莊子》(Zhuāngzǐ). Laozi, attributed to the foundational text of Daoism, "Tao Te Ching"《道德經》(Dàodéjīng), emphasizes naturalness and non-action, while Zhuangzi's writings focus on individual spiritual freedom and harmony with nature. Neo-Daoism, a philosophical trend during the Wei and Jin periods, reflects the spiritual expression of that era. Starting from the *正始时期 (Zhengshi period)* of the Wei dynasty (240-249 AD), Neo-Daoism experienced unprecedented development, becoming a powerful ideological current of the time. Scholars such as *王弼 (Wáng Bì)* and *郭象 (Guō Xiàng)* expanded upon the ideas in these texts, integrating them with contemporary social and philosophical issues, thereby shaping the evolution of Daoist thought.

The "Bamboo Grove Seven Sages" often appear as a decorative theme in many Chinese artworks, depicted as a group of simply dressed literati in a lush bamboo forest, reciting poetry, playing musical instruments, viewing scrolls, and playing chess. Their lifestyle, free from social constraints and embracing tranquility and inactivity, reflects their pursuit of freedom and a peaceful, reclusive life.A similar style and themed work can be found in the mid-Qing Dynasty red lacquer pen holder with the "Bamboo Grove Seven Sages" motif, housed in the Palace Museum.

Figure 23 – Red lacquer pen holder with the "Bamboo Grove Seven Sages" motif (Beijing Palace Museum, edited by Chen Lihua. 2008, *200 Carved Lacquer Pieces You Should Know*, Taipei: Artist Publishing House.)

2.2.2 Fan shape covered box , inv. n. 10721/10368

Figure 24 – Fan Shape Covered Box interior and lid

Figure 25 – Fan Shape Covered Box

The carved polychrome fan-shaped box features plum blossoms and a poem by Emperor Qianlong of the Qing Dynasty on the lid, set against a background of brown diamond fret patterns. The sides of the box and the lid share the same decorative style. The bottom and the interior of the box are lacquered in black.

In both Chinese and Japanese cultures, plum blossoms symbolize strength, purity, perseverance, and renewal. Known as the "flower of winter" and the "flower of courage," plum blossoms bloom in the end of winter or the very early start of spring, are often associated with the transition from winter to spring, symbolizing resilience and hope as they are among the first flowers to bloom after the cold winter months. They are also seen as symbols of gentlemanly conduct, representing nobility, integrity, and virtue. In the literature, art, and culture of China and Japan, plum blossoms are frequently depicted and celebrated as symbols of virtue and spiritual strength.

Emperor Qianlong, whose personal name was Hongli Aisingioro (愛新覺羅 弘曆, Hónglì) (Manchu language: ᡥᡠᠩ ᠯᡳ), was the fifth emperor of the Qing Dynasty of China, reigning from 1735 to 1796 with the era name 乾隆 (Qiánlóng). Emperor Qianlong had a great fondness for the carved lacquerware of the Ming Dynasty and composed dozens of poems praising these exquisite works. He not only amassed a large collection of Ming Dynasty carved lacquer pieces but also often inscribed his poems and writings on these precious artifacts. His calligraphy was carefully added to the original lacquerware, reflecting his deep admiration and appreciation. Several pieces of Ming Dynasty carved lacquerware that survive today bear his inscriptions, showcasing both the artistic legacy of the Ming period and the Qing dynasty's imperial patronage (YANG Y. 2018). During the Qing Dynasty, the economy flourished, and the lacquerware manufacturing industry saw significant development, with both imperial and civilian production. According to the "The Collected Statutes of the Qing Dynasty with Illustrations" *《大清會典事例》(Dà Qīng Huìdiǎn Shìlì)*, royal utensils of the Qing Dynasty were made by the Imperial Household Department, with the "Lacquer Workshop" being responsible for lacquerware production. The manufacturing priorities for lacquerware varied among the three prosperous Qing emperors: 康熙 (Kāngxī), 雍正 (Yōngzhèng), 乾隆 (Qiánlóng). According to records from the Lacquer Workshop, the first two emperors almost did not produce carved lacquerware. However, during the same period, carved lacquer production was popular in regions like Jiangnan (Suzhou, Yangzhou). Emperor Qianlong had a passion for carved lacquerware and often issued specific design requirements, resulting in the creation of many exquisite carved lacquers (red and polychrome). These items, ranging from large furniture to small jewelry boxes, were meticulously crafted and luxurious. The Imperial Household Department set up an official workshop in Suzhou to produce court lacquerware and issued regulations like the "Regulations of the Ministry of Works" *《工部則例》(Gōngbù Zélì),* "Regulations for the Employment of Lacquer Workers" *《漆工用工則例》(Qīgōng Yònggōng Zélì),* "Regulations for the Valuation of Lacquer Work in the Yuanmingyuan" *《圓明園漆作價值則例》(Yuánmíngyuán Qīzuò Jiàzhí Zélì)*. These documents detailed the materials and techniques for making gray bodies *(灰胎, huī tāi)*, lacquered bodies *(漆胎, qī tāi)*, and gilding *(描金, miáo jīn)*. Gray bodies refer to an unpainted lacquerware base made from gray clay or pottery, which forms a hard base after firing. Lacquered bodies are bases that have been coated with lacquer, often made from Urushi, to provide protection and shine. Gilding involves applying gold leaf or gold powder to lacquerware for decorative purposes, adding a luxurious appearance. In the later years of Qianlong's reign, carved lacquer production declined, and by the end of the Qing Dynasty, these techniques were almost lost (CHEN L., BEIJING PALACE MUSEUM, 2008) (LIU L., FU J. 2023)

Below is my translation and annotation of the poem on the box:

Figure 26 – Poem on the lid of Fan Shape Covered Box

和李嶠雜詠詩百二十首韻 其九十七 李
120 rhymes of Li Qiao's miscellaneous poems, the ninety-seven of which with Li Qiao's, 《Plum》
弘曆〔清代〕
By Hónglì (Emperor Qianlong of Qing Dynasty, China)

御詠李花
Imperial Ode to the Plum Blossom
含暉臨綺埒，發綵及芳辰。
The sun shines on the beautiful low wall, and the colorful clouds merge on the spring scenery.
與月色無別，因風影似新。
Bathed in the moonlight, the light and shadow become as clear as if newly formed.
百顆紫陽戲，各種上林春。
Fields of hydrangeas are in full bloom, with various hues of spring seen throughout the palace gardens.
慎矣<u>整冠者*</u>，鄙哉<u>鑽核人*</u>。
Be cautious of those who arrange their hats carefully, and look down on those who are stingy and selfish.

Annotation:
整冠者*: The literal meaning is "a person who arranges their hat." This term originates from the idiom *"整冠納履" (zhěng guàn nà lǚ)*. This idiom metaphorically describes actions that easily arouse suspicion. The phrase "整冠納履" comes from the *"Collection of Yuefu Poems·Xianghe Songs VII·The Conduct of a Gentleman"《樂府詩集·相和歌辭七·君子行》 (Yuèfǔ Shījí·Xiāng Hé Gēcí*

Qī·Jūnzǐ Xíng): “君子防未然，不處嫌疑間，瓜田不納履，李下不正冠。” This means "A gentleman takes precautions before things happen, avoiding suspicious situations. He would not open his shoes in a melon field, nor adjust his hat under a plum tree."
鑽核人*: The literal meaning is "a person who extracts the pit from a plum." This term originates from the idiom *“賣李鑽核” (mài lǐ zuān hé)*. The story is found in the *"Kindergarten Learning Qionglin, volume 4: Flowers and trees" 《幼學瓊林·卷四·花木類》(Yòuxué Qiónglín·Juǎn Sì·Huāmù Lèi)*. During the Jin Dynasty, the Rong family had a fine plum tree. To prevent others from obtaining this excellent variety, they would extract the pit before selling the plums. This later became a metaphor describing a stingy and selfish person.

Poetry appreciation and analysis:
“Harmony with Li Jiao's Collection of Miscellaneous Poems in 120 Rhymes” 《和李嶠雜詠詩百二十首韻》 was composed by the Qianlong Emperor of the Qing Dynasty (Hongli). This collection comprises 120 poems, each written in response to one of the poems in Tang poet Li Jiao’s *“Collection of Miscellaneous Poems”* 《雜詠》. Poem ninety-seven in this collection is titled *“Li”* 《李》 and celebrates the plum fruit. Rather than a standalone book, this work is a series of matching poems created by the Qianlong Emperor as a tribute to Li Jiao’s collection.
The third line of the poem points out that in the palace, everything appears as beautiful and delightful as blooming flowers, reminiscent of spring. However, the tone sharply shifts in the fourth line, warning to beware of those who harbor ill intentions beneath their beautiful exterior. The abrupt transition between the third and fourth lines, unlike the gradual buildup found in many poems, can be interpreted as the emperor's deliberate intention to inject a sense of caution. This sudden shift is meant to jolt the listener, using metaphor to warn them.

In the early Ming Dynasty, lacquer boxes were relatively flat and mainly came in three shapes as mentioned in the book *《燕閒清賞箋》(Yàn Xián Qīng Shǎng Jiān)*: the "sugarcane segment" style (cylindrical, flat-topped, straight-sided), the "steamed bun" style (round, slightly domed lid, walls tapering down), and the "interlocking" style (with an additional layer between the lid and the base). During the late Ming Dynasty, trays and boxes became more common, with a variety of shapes and sizes, including round boxes, square boxes, octagonal boxes, silver ingot-shaped boxes, Fangsheng shape boxes, and begonia-shaped boxes.

In the Qianlong period of the Qing Dynasty, carved lacquer boxes not only inherited some traditional shapes but also introduced many new forms, such as fish-shaped boxes. There were also boxes imitating scrolls, bookcases, and fan shapes, as well as various fruit shapes like peach, pomegranates, lotus leaves, gourds, and melon shapes. Due to Emperor Qianlong's fondness for antiques, many carved lacquer items were also made in the shapes of ancient porcelain, jade, and bronze artifacts. Although a large number of carved lacquer items were produced during the Qianlong period, those with poetry as their main theme were extremely rare. This is because engraving complex characters and phrases on small items is highly challenging. A reference work is the Qing Dynasty Qianlong period red lacquered flower and poetry brush pot, featuring themes of narcissus, osmanthus, chrysanthemums, plum blossoms, and orchids, accompanied by corresponding poems by Qianlong emperor.

Figure 27 – Carved Red Lacquer Brush Holder with Floral and Poetic Motifs (Beijing Palace Museum, edited by Chen Lihua. 2008, *200 Carved Lacquer Pieces You Should Know*, Taipei: Artist Publishing House.)

2.2.3 BOX WITH DRAWERS , INV. N. 10781/10355

Figure 28 –Box with Drawers: tray, box, drawer

Figure 29 – Box with Drawers

Figure 30 – Box with Drawers top view

The square red lacquer box with four drawers (externally decorated to appear as eight drawers) have red lacquer on the exterior and black lacquer on the interior. The overall decoration features octagonal, hexagonal, swastika, and fret patterns.

From the top view, the character "祿" (Lù), symbolizing wealth and prosperity, is visible in the center. In Chinese culture, the deities *福 (Fú), 祿 (Lù), and 壽 (Shòu)* are commonly associated with good fortune, wealth, and longevity. The overall design forms a large swastika (卐), within which are inscribed the "Eight Treasures of Daoism," representing the attributes of the Eight Immortals. The Eight Immortals are deities in Daoism, each symbolizing different demographics such as male, female, young, old, rich, and poor. Since the Eight Immortals were ordinary people who attained immortality, their characteristics are closely related to the common folk. In traditional Chinese culture, the Five Elements theory describes the natural world's functioning and categorizes things into five types, believing that these types interact in a cycle of generation and overcoming. The Five Elements include Metal, Wood, Water, Fire, and Earth. Each element has its unique properties and corresponding natural phenomena. The descriptions of the Eight Immortals include elements and trigrams related to the Five Elements.

The Eight Immortals, in the order of their attainment of immortality, are: *李鐵拐 (Lǐ Tiěguǎi) (Humble), 鐘離權 (Zhōnglí Quán) (Wealthy), 藍采和 (Lán Cǎihé) (Poor), 張果老 (Zhāng Guǒlǎo) (Old), 何仙姑 (Hé Xiāngū) (Female), 呂洞賓 (Lǚ Dòngbīn) (Male), 韓湘子 (Hán Xiāngzi) (Youthful), and 曹國舅 (Cáo Guójiù) (Noble)*. Their magical items are respectively: gourd, palm leaf fan, flower basket, fish drum, lotus flower, sword, bamboo flute, and jade tablet(yin-yang tablet). *李鐵拐 (Lǐ Tiěguǎi)* uses an iron crutch for his foot, representing the pliable metal of the *Dui trigram 兌卦*（☱）, which symbolizes soft metal distinct from the hard metal of the *Qian trigram 乾卦*（☰）. *鐘離權 (Zhōnglí Quán)* was a fierce general before becoming a hermit, with his palm leaf fan able to control fire, representing the *Li trigram 離卦*（☲）, which symbolizes fire. *藍采和 (Lán Cǎihé)* carried a flower basket filled with divine herbs, representing soft wood of the *Xun trigram 巽卦*（☴）, which symbolizes wood. *張果老 (Zhāng Guǒlǎo)*'s fish drum could produce sacred sounds and predict the future, representing hard wood of the *Zhen trigram 震卦*（☳）, which symbolizes wood. *何仙姑 (Hé Xiāngū)*'s lotus flower symbolizes purity and self-cultivation, representing the *Kun trigram 坤卦*（☷）, which symbolizes earth. *呂洞賓 (Lǚ Dòngbīn)*'s sword, called the Pure Yang Sword, represents the sharp metal of the *Qian trigram 乾卦*（☰）, capable of exorcising demons, which symbolizes metal. *韓湘子 (Hán Xiāngzi)*'s flute could make flowers bloom in winter, symbolizing the nurturing aspect of water, which generates wood in the Five Elements, represented by the *Kan trigram 坎卦*（☵）, which symbolizes water. *曹國舅 (Cáo Guójiù)*, of noble status, used his wealth to help the poor, carrying a jade tablet representing the essence of the mountain in the *Gen trigram 艮卦*（☶）, which symbolizes earth and earth in the Five Elements.

In traditional Chinese paintings and carvings, the Eight Immortals often symbolize good fortune or auspiciousness, depicted directly as the *"Visible Eight Immortals" 明八仙* or through their magical items as the *"Hidden Eight Immortals" 暗八仙*. The items are interspersed with bats, which symbolize *"福" (fú, fortune)* due to the homophonic relationship between "*bat"蝠 (Fú)* and "*fortune" 福 (fú)*. Additionally, the inverted position of bats has homophonic relationship between *"arrive"到 (dào)* and "*invert"倒 (dào),* representing *"the arrival of fortune" 福到 (fú dào)*. After Buddhism entered China, the swastika (卐) was translated as "virtue," and Empress Wu Zetian of the Tang Dynasty associated it with *"萬" (wàn, ten thousand)*, symbolizing infinite virtues and fortune. All the symbolic patterns on this lacquerware are inscribed within the swastika, which in Chinese (卐 wàn) sounds like *"萬" (wàn, ten thousand)*, representing the boundless extension of all blessings within.

A similar piece with comparable form and decorative technique is in a private collection in France: the Qing Dynasty Qianlong period red carved lacquer square box with "Eternal Fortune and Longevity" motif. It also features a red lacquer square tray and box with four drawers. From the top view, the center displays the symbol for *"wealth"*, with peaches and bats carved within the large swastika, symbolizing *"eternal fortune and longevity"福壽萬代 (fú shòu wàn dài).*

Similar to the *"Eight Treasures of Daoism" 道教八寶 (Dàojiào Bābǎo)*, but often confused with them, are the *"Eight Auspicious Symbols of Tibetan Buddhism" 藏傳佛教的八吉祥*. However, these can be distinguished by the imagery of the treasures.

Eight Treasures of Daoism: gourd, palm leaf fan, flower basket, fish drum, lotus flower, sword, bamboo flute, and jade tablet (yin-yang tablet). Eight Auspicious Symbols of Tibetan Buddhism treasure: parasol, golden fish, conch shell, treasure vase, lotus flower, endless knot, victory banner, dharma wheel. Seven Lucky Gods of Japan: sea bream, small mallet, long spear, biwa (lute), peach, leaf fan, crane, treasure ship.

"Eight Auspicious Symbols of Tibetan Buddhism" 藏傳佛教的八吉祥, also known as the *Ashtamangala (Sanskrit: अष्टमंगल, Tibetan: བཀྲ་ཤིས་རྟགས་བརྒྱད)*, are often used as decorative motifs in temples, religious artifacts, ritual objects, stupas, as well as in the homes, clothing, and artwork of Tibetan and Mongolian people. These eight symbols represent good fortune, completeness, and happiness in Buddhism. Jainism and Hinduism also have their versions of the Ashtamangala, which slightly differ from the Tibetan Buddhist ones.

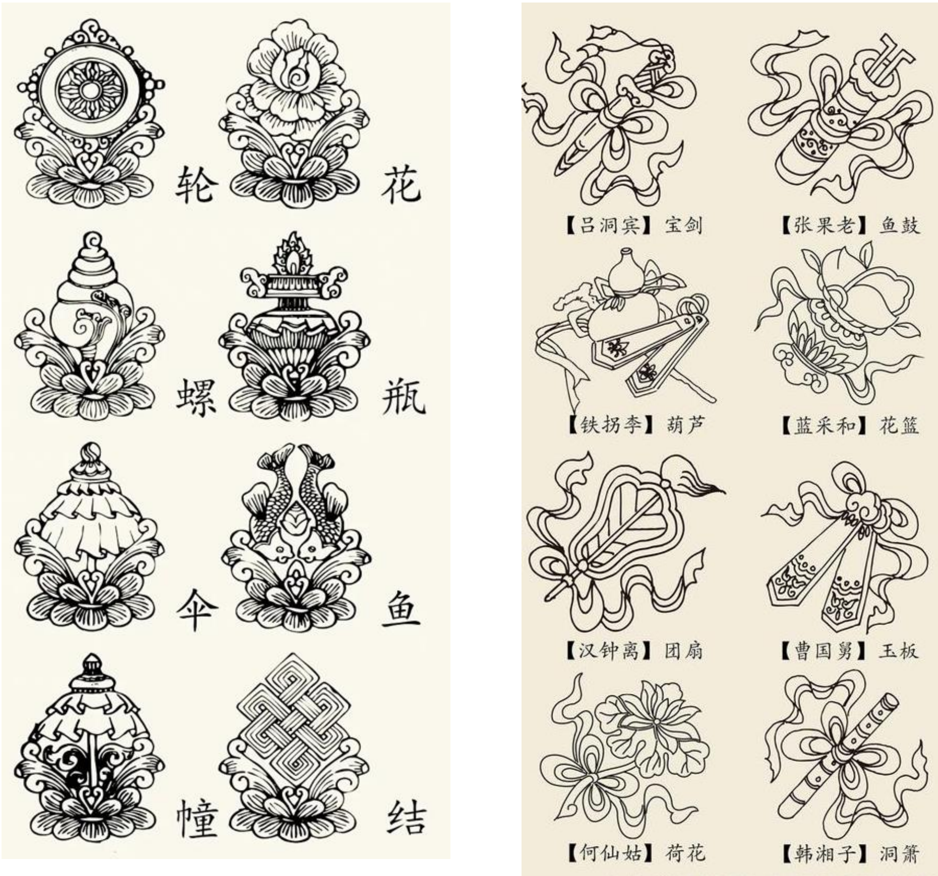


Figure 31 – Left: *"Eight Auspicious Symbols of Tibetan Buddhism" 藏傳佛教的八吉祥. Right: "Eight Treasures of Daoism" 道教八寶 (Dàojiào Bābǎo)* (The Chinese Classic Pattern Book)

Figure 32 – From the top view of Box with Drawers, the center displays the symbol for *"wealth" or "property"* (The Chinese Classic Pattern Book)

2.2.4 POLYCHROME PLATE , INV. N. 10766

Figure 33 – Polychrome Plate front

Figure 34 – Polychrome Plate bottom

It's a carved colorful lotus round lacquer plate. The center of the plate features a large lotus flower with richly layered petals, using orange-yellow, dark red, and green colors to create a three-dimensional effect. Surrounding the central lotus are various flowers and leaves of different sizes, with red and black flowers interspersed among green leaves, creating a striking visual contrast. The overall design is dominated by red, black, orange-yellow, green, and dark red, showcasing a strong color contrast and a rich visual effect. The bottom of the plate is lacquered black, and the convex bottom is lacquered red with engraved "tang grass patterns" 唐草纹样 (からくさ, Karakusa).

"Tang grass patterns", although named after the Tang dynasty of China, can trace its origins back to ancient Greece and Rome. It was introduced to China via the Silk Road and further developed during the Tang dynasty before being transmitted to Japan. It is widely used in traditional arts and crafts. Thus, the tang grass pattern is a product of multicultural exchange.

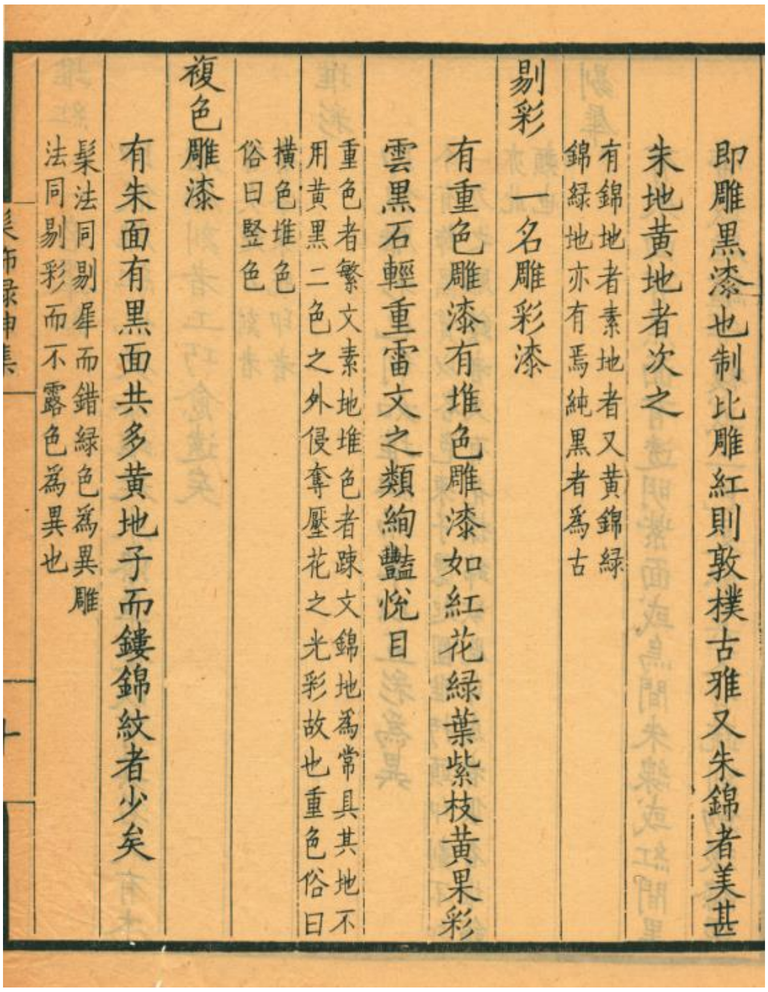
Chinese carved lacquerware 雕漆 (Diāoqī) and Japanese 彫漆 (Chōshitsu) differ slightly in their definitions and techniques. Chinese carved lacquer is further divided into several types: Pure red lacquer carving known as "剔紅" (Tīhóng), yellow lacquer carving called "剔黃" (Tīhuáng), black lacquer carving called "剔黑" (Tīhēi), multi-colored lacquer carving called "剔彩" (Tī cǎi), and alternating red and black lacquer layers carved to produce red and black striped patterns known as "剔犀" (Tīxī). The 剔彩 (Tī cǎi) technique is subdivided into two types: "重色雕漆" (Zhòngsè diāoqī) and "堆色雕漆" (Duīsè diāoqī). "重色雕漆" (Zhòngsè diāoqī) emerged during the 宣德時期(Xuande period), 1425-1435AD, of the Ming Dynasty. It involves layering different colored lacquers in a specific order, with each color being applied in several layers to a certain thickness before moving to the next color. Then, according to the color requirements of the pattern, the layers above the desired color are carved away, revealing the needed color. The details are then carved, resulting in a multicolored effect with various lacquer layers. The typical lacquer colors for “剔彩 (Tī cǎi)” are red, yellow, green, purple, and black. "堆色雕漆" (Duīsè diāoqī) involves first applying a single color of lacquer to a certain thickness, then carving out areas of the pattern that need different colors, filling them with the required colors, and carving the details.

The Chinese book "Records of Lacquering"*《髹飾錄》 (Xiūshì Lù)* mentions (HUANG C., YANG M. 2021):

「剔彩，一名雕彩漆，有重色雕漆，有堆色雕漆，如紅花、綠葉、紫枝、黃果、彩雲、黑石及輕重雷文之類，絢艷恍目」

"剔彩 (Tī cǎi), also known as carved colorful lacquer, includes 重色雕漆 (Zhòngsè diāoqī) and 堆色雕漆 (Duīsè diāoqī), such as red flowers, green leaves, purple branches, yellow fruits, colorful clouds, black stones, and light and heavy thunder patterns, which are dazzling and eye-catching."

Carved urushi in Japan known as "彫漆" (Chōshitsu)" , it is the techniques carved the design into a thick coating made of color urushi 色漆(iro urushi) layer. The thick coating made with single color, called "piled black 堆黒(tsuikoku)", "piled black 堆朱(tsuishu)", "piled yellow 堆黄(tsuiō)", "piled green 堆緑(tsuiryoku)". Similar to the Chinese technique "剔彩 (Tī cǎi)" , this method in Japan is called "紅花緑葉(kōka ryokuyō)", which uses the same terms described in the previous paragraph about Chinese "*剔彩 (Tī cǎi)*" from the "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* . The phrases "紅花、綠葉", literally means "red flowers, green leaves".



即雕黑漆也制比雕紅則敦樸古雅又朱錦者美甚
朱地黃地者次之
有錦地者素地者又黃錦綠錦綠地亦有焉純黑者爲古
剔彩 一名雕彩漆
有重色雕漆有堆色雕漆如紅花綠葉紫枝黃果彩雲黑石輕重雷文之類絢豔悅目
重色者繁文素地堆色者疎文錦地爲常其地不用黃黑二色之外侵奪壓花之光彩故也重色俗曰橫色堆色俗曰竪色
複色雕漆
有朱面有黑面共多黃地子而鏤錦紋者少矣
髹法同剔犀而錯綠色爲異雕法同剔彩而不露色爲異也

Figure 35 – *剔彩 (Tī cǎi)* (from "Records of Lacquering" *《髹飾錄·坤集》(Xiūshì Lù·kūn jí.), "Carving and Engraving, Chapter 10" 雕鏤第十 (Diāo Lòu Dì Shí)*)

Later, a faster method was developed, which involves carving the wooden base first and then applying lacquer. This method is called *"彫漆" (Chōshitsu)"* in some regions, while in other regions, it is referred to as wood-carved tsuishu *"木彫堆朱"*. "堆漆(Tsuishu)" refers to a layered colored urushi technique, which apply hundreds layer of different color iro urushi to 5 - 7 mm thick, and sections are cut out and shows the color layers.

The Tokugawa Art Museum, Tokyo National Museum, Nezu Museum, and Kyushu National Museum in Japan all hold some Chinese carved lacquerware from the Song, Yuan, and Ming Dynasties. Japanese scholars' terminology for various types of Chinese carved lacquer does not correspond to the Chinese "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)*. For example, the Tokugawa Art Museum and Nezu Museum's "彫漆" (ちょうしつ, Chōshitsu) collection references various Japanese texts such as *《君台觀左右帳記》(Kundai Kan Sa U Chōki)*, *《佛日庵公物目錄》(Butsujian Kōbutsu Mokuroku), 《禪林小歌》(Zenrin Koka), 《室町殿行幸御籌記》(Muromachi-den Gyokō Gochūki), 《盡素往來》(Jinso Ōrai), 《異制庭訓往來》(Isei Teikun Ōrai), 《遊學往來》(Yugaku Ōrai), and 《下學集》(Kagaku-shū),* which document various names for carved lacquerware, including "剔紅" (ついこう, Tsuikō), "堆紅" (ついこう, Tsuikō), "堆朱" (ついしゅ, Tsuishu), "堆漆" (ついしつ, Tsuishitsu), "堆烏" (ついう, Tsuiu), "紅花綠葉" (こうかりょくよう, Kōka Ryokuyō), "金斑" (きんばん, Kinban), "黑金斑" (こくきんばん, Kokinkinban), "九連斑" (くれんだん, Kurendan), "桂漿" (けいしょう, Keijō), "犀皮（松皮）" (さいひ/まつかわ, Saibi/Matsukawa), "綴金" (ついきん, Tsujikin), and "鎏金" (りゅうきん, Ryūkin). In the definition of Chinese lacquer techniques: “堆起”(Duīqǐ), or "piled lacquer," involves layering lacquer and using tools to create raised patterns. “填炭” (Tiánkàn) inlays materials like gold or mother-of-pearl into carved grooves. “斒斕” (Bānlán) uses different colored lacquers to create vibrant, colorful designs. This reflects Japan's classification of various Chinese techniques like 堆起 (Duīqǐ), 填炭 (Tiánkàn), and 斒斕 (Bānlán) under the broad category of 彫漆 (ちょうしつ, Chōshitsu).

Japanese "彫漆" (Chōshitsu) techniques were initially influenced by China, but Japanese craftsmen later adapted them to local needs and aesthetics, creating a unique style. 彫漆 (Chōshitsu) flourished during the Edo period (1603 - 1868), primarily using red and black lacquer, sometimes complemented by other colors and gold and silver decorations. This technique emphasizes multiple layers of polished lacquer, with each layer meticulously polished to achieve a sense of depth and dimension. Due to the hardness of the lacquer surface formed by this method, craftsmen can carve out intricate and durable patterns.

In contrast, Chinese carved lacquer often incorporates oils, which slow the curing process, allowing carving in a semi-dry, soft state. This results in softer three-dimensional effects and rich layers in the patterns. In terms of color usage, Japanese "彫漆" (Chōshitsu) tends to use fewer colors than the richly varied Chinese carved lacquer, focusing more on the depth and durability of the lacquer layers.

The center of this round carved lacquer plate features a large lotus flower, surrounded by intricate floral and leaf patterns. In both Chinese and Japanese cultures, the lotus, which emerges unstained from the mud, symbolizes auspiciousness, purity, and elegance. In Buddhist culture, the lotus is a significant symbol representing purity, transcendence, and rebirth, as it blooms beautifully even in muddy waters.

2.2.5 Style analysis

According to the "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)* written by Huang Cheng in the Ming Dynasty, carved lacquer originated in China during the Tang Dynasty, evolving from the Warring States period technique of engraved painting. Engraved painting involved carving a certain pattern on the body before applying the lacquer. The Tang Dynasty innovated this craft by applying dozens or even hundreds of layers of lacquer on the body, allowing it to partially dry, and then carving patterns into the surface to create a three-dimensional relief effect. Types of carved lacquer include: pure red lacquer carving known as *"剔紅" (Tīhóng)*, yellow lacquer carving called *"剔黃" (Tīhuáng)*, black lacquer carving called *"剔黑" (Tīhēi)*, multi-colored lacquer carving called *"剔彩" (Tī cǎi)*, and alternating red and black lacquer layers carved to produce red and black striped patterns known as *"剔犀" (Tīxī)*. In Japan, *剔犀 (Tīxī)* products are named *"屈輪" (Guri)* according to their patterns. Carved lacquer production began in the Tang Dynasty, developed through the Song and Yuan Dynasties, and reached unprecedented heights during the Ming Dynasty. In the early Qing Dynasty, carved lacquer flourished again due to Emperor Qianlong's admiration for Ming lacquer.

During Japan's Kamakura period, Mahayana Buddhism's Zen sect was introduced from China's Southern Song Dynasty. In 1187, the Japanese monk Eisai received the heart seal of the Linji sect's Huanglong school in China and, after returning to Japan, promoted Zen practices, founding the Kennin-ji in Kyoto in 1202. Alongside Zen, the famous carved red lacquer technique *"剔紅"(Tīhóng)* was also introduced to Japan. After its introduction, the technique evolved into two branches: *"鎌倉彫" (かまくらぼり, Kamakura-bori)* and *"堆朱 楊成" (ついしゅ ようぜい, Tsuishu Yōsei)*. Kamakura carving involved carving the wood base first, then applying lacquer, which was more time and material-efficient compared to the traditional Chinese *剔紅 (Tīhóng)* technique and allowed for mass production. The other branch retained the traditional Chinese *剔紅 (Tīhóng)* technique, known in Japan as *堆朱 (ついしゅ, Tsuishu)*. The founder of Japanese *堆朱 (Tsuishu)* carving was *長充 Chōjū*, a retainer of the Ashikaga clan. In 1360, he made the first *堆朱 (Tsuishu)* piece, receiving praise from the shogun. He adopted the name *楊成 (Yáng Chéng)* by combining characters from the names of two famous Yuan Dynasty Chinese lacquer carvers, *張成 (Zhāng Chéng)* and *楊茂 (Yáng Mào)*, and added the surname "堆朱" (Tsuishu). Since then, his descendants have been known as *"堆朱楊成" (ついしゅ ようぜい, Tsuishu Yōsei)*. Thus, Japanese *"堆朱楊成" (ついしゅ ようぜい, Tsuishu Yōsei)'s* technique is indistinguishable to the Chinese *剔紅 (Tīhóng)* technique.

Figure 36 –"Red Lacquer Tray with Pine, Bamboo, and Plum " 松竹梅堆朱盆(しょうちくばいついしゅぼん, Shōchikubai Tsuishu Bon). Edo period, *堆朱陽成 Tsuishu Yōsei*. (Image No.: C0027368; Collection No.: H-361; Tokyo National Museum)

Japan's representative carved lacquerware includes "高岡漆器" (たかおかしっき, Takaoka shikki) and "輪島漆器" (わじまぬり, Wajima nuri). Both involve pre-carving the wooden base, which is the main difference from Chinese carved lacquer. Takaoka lacquerware originates from Takaoka City, Toyama Prefecture, and dates back to 1609. It uses hard woods like cypress and cedar for the wooden base, which are meticulously carved into the desired shapes. Multiple layers of raw lacquer are then applied, usually 20 to 30 layers. Each layer must be fully dried, carefully polished, and buffed to ensure a smooth surface and even adhesion, resulting in a lacquer surface with depth and gloss. Wajima lacquerware 輪島塗 comes from Wajima City, Ishikawa Prefecture, with a history dating back to 1524. Its production process is similar to that of Takaoka lacquerware, with a unique feature being the use of *輪島じのこ (Wajima Jinoko)*, a diatomaceous earth from Wajima's Komine Mountain. This earth, after being steamed and crushed, is used as a base powder to increase the strength and durability of the lacquerware.

The carving styles of Chinese lacquerware differ among the Song, Yuan, Ming, and Qing Dynasties. The Song Dynasty continued the Tang Dynasty's style, which resembled printed plates with shallow carvings, mostly preserved in Japan today. Yuan Dynasty lacquerware featured thick lacquer layers with smooth, rounded, and blunt main patterns, finely polished to reveal the lacquer's inner luster. The detailed background patterns were intricately carved, and both China and Japan regard Yuan Dynasty lacquerware as unmatched masterpieces. From the Song and Yuan Dynasties to the Yongle and Xuande periods of the Ming Dynasty, Chinese *剔紅 (Tīhóng)* lacquerware peaked. Early Ming Dynasty pieces had thicker lacquer layers, up to a hundred layers, showcasing clear pattern layers and fine carving. Mid-to-late Ming pieces had fewer lacquer layers, less prominent layering, sharp carving edges, and less emphasis on polishing. During Emperor Qianlong's reign in the Qing Dynasty, carved lacquer combined these characteristics with thick lacquer layers, rich pattern layers, but often lacked thorough polishing. The carvings had sharp, steep edges and intricate, densely engraved scenes. The Qianlong style might have been influenced by the Ming Dynasty, or possibly by Southern ivory carvers recruited to carve lacquerware, resulting in intricate, sharp-edged patterns similar to ivory carvings.

In terms of themes, the brush holder depicts the "Seven Sages of the Bamboo Grove," still a representation of the Daoist philosophical thoughts of Laozi and Zhuangzi. The fan-shaped covered box features a poem by Emperor Qianlong, likely indicating it was made in China, as the poem is not widely known abroad. During Emperor Qianlong's reign, lacquer carving reached unprecedented refinement, and he frequently commissioned exquisite treasure boxes, such as the Qing Dynasty Zitan Treasure Box in the National Palace Museum in Taipei, one of the finest pieces in treasure box collections. Based on style and design, the box with drawers likely originates from Suzhou during the Qianlong period. Japanese *彫漆 (ちょうしつ, Chōshitsu)* primarily uses red and black lacquer, so the polychrome plate with rich colors is likely a Chinese product.

The three *剔紅 (Tīhóng)* carved lacquer pieces feature many traditional patterns. Both Chinese and Japanese patterns have similarities, such as tortoise shell patterns and tang grass patterns. Based on the themes and styles, they resemble Ming and early Qing Dynasty lacquerware. During the early Qing Dynasty, Emperor Qianlong's fondness for lacquerware led to extensive production, often imitating Ming styles. Ming lacquer is dark red with heavy, solemn patterns, while Qing lacquer is bright red with elaborate and delicate patterns. Qing imperial lacquer has thick lacquer layers, bright colors, fine carvings, complex compositions, and high-relief figures with three-dimensional faces. Besides scenery, the flat areas are often engraved with fine patterns like brocade designs and swastikas, characteristic of Qing lacquer. Qing lacquer themes include landscapes, flowers, poems, ancient beasts, immortals, and auspicious symbols. Based on appearance, the four pieces are close to Qing Dynasty lacquer, but since Japan has similar techniques, scientific analysis are necessary to fully understand these lacquerware pieces.

Chapter 3 : The Scientific methods

This chapter introduces the scientific principles of the analytical methods and instrumentation used for analyzing the four lacquerware collections from MAO, which are divided into two main categories: non-invasive and micro-invasive techniques. Non-invasive techniques, including Digital Optical Microscopy, Fiber Optic Reflectance Spectroscopy (FORS), and Infrared External Reflectance (ER-FTIR), allow for the examination of surface characteristics and material composition without altering or damaging the sample. They have also the advantage of being portable, so they can be used in situ. Micro-invasive techniques require small samples : we employed Micro-FTIR, Micro-Raman, Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS), Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS), and Electron Paramagnetic Resonance (EPR) for more in-depth analysis, revealing crucial information about the chemical composition and degradation processes of the lacquer layers. By integrating these scientific methods, we gain insights into the information that various instruments can provide in lacquerware research, thus achieving a more comprehensive understanding of lacquerware

3.1 NON-INVASIVE METHODS

3.1.1 DIGITAL OPTICAL MICROSCOPE

The working principle of a digital microscope is based on optical and digital imaging technology. The light source illuminates the sample surface, and the reflected light is focused through an optical lens onto a digital sensor (such as CMOS or CCD). The sensor converts the light signal into digital image data, which is then instantly transmitted to a computer or display device for viewing and storage. The high resolution and magnification of the digital microscope allow it to capture fine details of the sample.

We use a Dino-Lite microscope equipped with standard light and UV illumination (wavelength: 390–400 nm). When using UV light to examine lacquerware, different depths and shades reflect varying material properties and compositions. Under UV light, brighter areas may indicate parts with different chemical compositions that respond strongly to UV, while darker areas may represent materials with weaker UV penetration.

3.1.2 FIBER OPTIC REFLECTANCE SPECTROMETER

In order to identify in situ and in non-invasive way, the pigments in lacquerwares, we used Fiber Optic Reflectance Spectroscopy. FORS is based on the principles of reflectance spectroscopy and is used to analyze the optical properties of a sample. First, the light source directs light through a fiber optic cable to the sample surface, where the light is either reflected, absorbed, or transmitted. The reflected light then travels back through the fiber optic to the dispersive element. The dispersive element (diffraction grating) separates the reflected light into different wavelengths, which are then detected and recorded by an array of CCD detectors. Each CCD detector measures the intensity of light at each wavelength and sends this data to a computer for further analysis. This method offers high precision and is non-destructive, enabling the analysis of pigment composition without damaging the sample. Finally, the spectral data is transmitted to a computer for further processing and analysis. The technique is specifically useful for the identification of pigments, dyes and colored substances.

We used the Ocean Insight HR2000+ Fiber Optic Spectrometer, working in the wavelength range 300-1100 nm, equipped with a deuterium-halogen UV-Vis-NIR light source, DH-2000, covering the full range between 300 and 900 nm, with a max power of 200 W. FORS spectra were then acquired in the range 300-900 nm, using the fiber optic reflection probe R200-7. to identify pigments in lacquerwares.

3.1.3 INFRARED EXTERNAL REFLECTANCE (ER - FTIR)

In order to characterize in situ the organic materials (lacquer, additives, etc.) of the four artifacts, we used FT-IR spectroscopy, with external reflection (ER) module. FTIR analysis is particularly useful for the characterization of organic chemical compounds, allowing the detection of specific peaks related to the main functional groups present in different type of organic materials (lipids, proteins, polymers, etc.). The ER module allows for a completely non-invasive investigation of the sample surfaces and lacquer surfaces, being smooth polymers, are therefore an ideal choice for external reflection FT-IR, as these surfaces effectively reflect infrared light, yielding clear spectral data.

For in situ ER-FTIR measurements, we used a Bruker Alpha IR spectrometer, equipped with external reflection module. Spectra were acquired in the wavenumber range 500-6000 cm^{-1}, using the “pseudoabsorbance” (i.e., log(1/R), where R is the reflectance) on the y-axis of the spectra. No post-processing of the spectra was applied (i.e., Kramers-Kronig corrections) to minimize the introduction of artifacts.

3.2 MICRO-INVASIVE METHODS

3.2.1 MICRO-ATR

The small fragments were characterized with micro-ATR-FTIR investigations: in micro-ATR a high-refractive-index crystal is pressed directly against the sample and infrared radiation is made to pass through the crystal. Due to the phenomenon of attenuated total reflection, the infrared light undergoes internal reflection within the crystal, forming an evanescent wave that penetrates a few microns into the sample. The sample surface absorbs the infrared radiation from the evanescent wave, and the reflected radiation is collected and analyzed to produce a FTIR spectrum. We used a Nicolet spectrometer combined with a Continuum microscope, equipped with an MCT (mercury-cadmium-telluride) detector.

Typical conditions of acquisition were, for each spectrum: 128 scans, 400-4000 cm-1 range, spectral resolution of 4 cm-1.

3.2.2 SEM

The working principle of a Scanning Electron Microscope (SEM) involves using a focused high-energy electron beam to scan the sample surface. This beam interacts with the atoms in the sample, generating secondary electrons, backscattered electrons, and X-rays, which are recorded by specific detectors and used to form an image. Secondary electrons provide detailed surface images, backscattered electrons reveal compositional contrast, and X-rays enable elemental analysis.

Backscattered Electron Detector utilizes backscattered electrons (BSE), which are electrons scattered back to the surface when a high-energy electron beam interacts with the atomic nuclei of a sample. The BSE Detector (BESD) captures these signals, enhancing the detection around the electron beam. The intensity of the BSE signal correlates with the atomic number, making BSE imaging ideal for analyzing the distribution of components within a sample. This method is particularly useful for distinguishing materials based on atomic numbers, making it suitable for compositional mapping. BSE signals originate from deeper regions within the sample, allowing for internal structural imaging; however, it has a lower resolution compared to secondary electron (SE) imaging, which is better for observing fine surface details.

SEM-EDS (Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy) is a technique where a high-energy electron beam strikes a sample, transferring energy to its atoms and causing inner-shell electrons to emit characteristic X-rays. An EDS detector collects these X-rays to perform elemental analysis, identifying and quantifying the elements present. EDS is often paired with BSE (Backscattered Electron) or SE (Secondary Electron) imaging for a more comprehensive analysis. Elemental analysis with SEM-EDS provides both qualitative and quantitative data, allowing rapid micro-area analysis to determine a sample's chemical composition. Combined with SEM imaging, it offers insights into both morphology and composition. However, EDS has limitations, such as low sensitivity to light elements (e.g., H, He) and a shallow analysis depth of only 1-2 micrometers.

In SEM low vacuum mode, nitrogen gas is used to neutralize charge accumulation on the sample, reducing or eliminating charging effects. This allows non-conductive samples to be analyzed without a conductive coating, resulting in images that more accurately reflect the sample's true appearance by avoiding distortions or bright spots caused by charge buildup.

SEM analysis was conducted using an FEI Quanta 200F equipped with a field emission gun source, working in Low Vacuum Model. SEM images were acquired by collecting secondary electrons using an LFD detector operating in low vacuum conditions (HV: 25 kV, working distance 10.5 mm, spot size 3.5, 100Pa). Backscattered images were collected by using a solid-state detector (HV: 25 kV, working distance 10.5 mm, spot size 3.5).

3.2.3 MICRO - RAMAN

Initially, investigations with a portable Raman spectrometer (i-Raman pluse BWTek, laseer source at 785 nm), were tried to characterize in situ the lacquerware samples. Unfortunately, the excessive fluorescence from the lacquer surface prevented the acquisition of Raman signals above the background noise: actually, it happens often that on the outer surface of an object *patinas*, dirt and degradation by-products accumulate, resulting often in enhanced fluorescence effect and reduced Raman signal. Consequently, micro-Raman investigations were carried out only on the lacquer fragments using a more efficient bench Raman instrument, and the interference from surface fluorescence was avoided at most working on the section of the fragments (i.e., on the layers beneath).

The working principle of Raman is based on the Raman scattering effect, where photons interact with molecules in the sample through inelastic scattering, resulting in a change in photon energy, which is known as Raman scattering. The microscope detects the spectrum of the scattered

light to identify the vibrational modes of different molecules within the sample, thereby obtaining information about its chemical composition and structure.
We used a Renishaw inVia confocal Raman microscope with a 633 nm laser, widely employed to analyze the chemical composition and structural characteristics of lacquer layers. Laser power was set to 1% of the maximum value (10 mW) to avoid damages on the lacquer, with 10 sec. integration time. Microscope magnification was set to 5X or 10X for a general overview, and to 50X for investigations on specific areas.

3.2.4 PY-GC/MS

PY-GC/MS (Pyrolysis-Gas Chromatography/Mass Spectrometry) is a powerful analytical technique used to study complex organic materials. First, the sample is heated to a high temperature in the pyrolysis chamber, causing it to thermally decompose into smaller molecules (known as pyrolysates). These pyrolysates are then introduced into a gas chromatograph (GC) for separation, where different compounds in the mixture are gradually separated based on their volatility and polarity. Finally, the separated compounds enter a mass spectrometer (MS), where they are detected and identified according to their mass-to-charge ratio (m/z).

Analytical pyrolysis was carried out with a micro-furnace Multi-Shot Pyrolyzer EGA/Py-3030D (Frontier Lab) coupled to a gas chromatograph 6890 (Agilent Technologies, Palo Alto, CA, USA) and to an Agilent 5973 Mass Selective Detector operating in electron impact mode (EI) at 70 eV. The injector is a split/splitless injector used with at 1:10 split ratio and kept at 300 °C. The pyrolysis temperature was at both 600°C and 400°C and interface temperature was 280 °C. For the gas chromatographic separation, an HP-5ms fused silica capillary column (5%-diphenyl/95%-dimethyl polysiloxane, 30 m x 0.25 µm i.d., 0.25 µm film thickness (J&W Scientific, Agilent Technologies, Palo Alto, CA) with a deactivated silica pre-column (2 m x 0.32 mm i.d., (J&WScientific Agilent Technologies, Palo Alto, CA) was used. The carrier gas was used in the constant flow mode (He, purity 99.995%) at 1.0 mL $min^{-}1$. The chromatographic oven was programmed as follows: initial temperature 36°C, isothermal for 10 min; 25 °C $min^{-}1$ up to 100°C; 8 °C $min^{-}1$ up to 250 °C; 5 °C $min^{-}1$ up to 325 °C and isothermal for 5 min. The MS transfer line temperature was 280 °C; the MS ion source temperature was 230 °C, and the MS quadrupole temperature was 150 °C. The mass spectrometer operated in EI positive mode (70 eV) with a scan range m/z 50 - 650. MS spectra were recorded both in TIC (total ion current) and SIM (single ion monitoring).

1,1,1,3,3,3-hexamethyldisilazane (HMDS) was used as a silylating agent for the in situ derivatization of pyrolysis products.

3.2.5 EPR

Electron Paramagnetic Resonance (EPR) is a spectroscopic technique used to detect and study species with unpaired electrons (paramagnetic species), such as free radicals (peroxide radicals, phenolic radicals) and transition metal ions in a paramagnetic oxidation state ($Fe^{3+}, Cu^{2+}, Mn^{2+}$). EPR works by detecting transitions, induced by microwave radiation, between electron spin states, which are separated in energy by the application of a magnetic field. The magnetic field is swept during the measurement, while the microwave frequency is kept constant. When the energy of the microwave photon matches the energy difference between the aligned and opposed spin states of unpaired electrons (the resonance condition), absorption occurs. This absorption is then detected to generate an EPR spectrum, providing valuable information about the local environment, bonding, and electronic structure of the sample containing the paramagnetic species.

The EPR instrument consists of three main parts: a microwave bridge, where the microwave source and the detector are located; a strong magnet, in between of whose polar expansions a sample holder is place; the resonator, which is a sample holder connected with a waveguide to the microwave source and is specifically designed to enhance the microwave power on the sample. When the microwave absorption occurs, due to the resonance condition, a microwave reflected wave is also generated, which goes out from the resonator and is collected by the detector. The intensity of this reflected wave is just proportional to the microwave absorption by the sample.

For our EPR measurements, we used a Bruker ECS106 instrument, equipped with a TMR 9109 resonator, working at 9.56 GHz of microwave frequency. EPR spectra were acquired with 20 mW microwave power, 2 G of modulation amplitude, and a magnetic sweep of 100 G.

Chapter 4: Results

This chapter presents the results obtained from applying the scientific methods described in Chapter 3 to analyze the four lacquerware collections from MAO. Following the order of Chapter 3, we have divided the results into two main categories: non-invasive and micro-invasive investigations, highlighting the contributions and applications of different techniques in lacquerware research.

Overview of scientific methods applied to four lacquerwares:

	Brush holder	Fan shape box	Box with drawer	Polychrome plate
Digital microscope	O	O	O	O
FORS	O	O	O	O
ER-FTIR	O		O	O
Micro-ATR	O			
Micro-Raman			O	
SEM			O	
Py-GC/MS	O		O	
EPR			O	

Table 04– Overview of scientific methods applied to four lacquerwares collections from Museo d'Arte Orientale

4.1 NON-INVASIVE METHODS

4.1.1 DIGITAL OPTICAL MICROSCOPE

The Dino-Lite microscope provides detailed images of the carved lacquer surface. The UV illumination highlights the carving details and possible compositional differences in the lacquerware, revealing aspects of the craftsmanship and authenticity of the piece.

Brush holder, inv. 10736/10410

The surface of the brush holder (Figure 37) exhibits a richly decorated scene carved in red lacquer on a black lacquer background. Compared to the surface of other red lacquer objects, a relevant luster can be observed. Three micro pictures, taken in the positions shown in Figure 37, are particularly interesting and will be discussed. In Fig. 38 it is shown a detail of the grooves of the bamboo section: deposits of a transparent matter seem to be present, maybe a transparent lacquer, or films of drying oil, as drying oil was detected in ER-FTIR and Py-GC/MS analysis,

The DinoLite images unravel also the great ability of the artist, who carved even the finest details in the bamboo section (Fig. 38). Also, the images show possible “pentimenti”: e.g., near the tree beside the seated figure, a portion of the leaf pattern seems to be missing, either due to a manufacturing error or to a different stylistic choice, which is clearly visible under UV light (Fig. 39).

In Fig. 40, the microscope image allows one to appreciate how the facial muscles of the figures are intricately carved with distinct depth, adding a sense of volume and showcasing a high level of craftsmanship.

Figure 37 – Brush holder, inv. 10736/10410

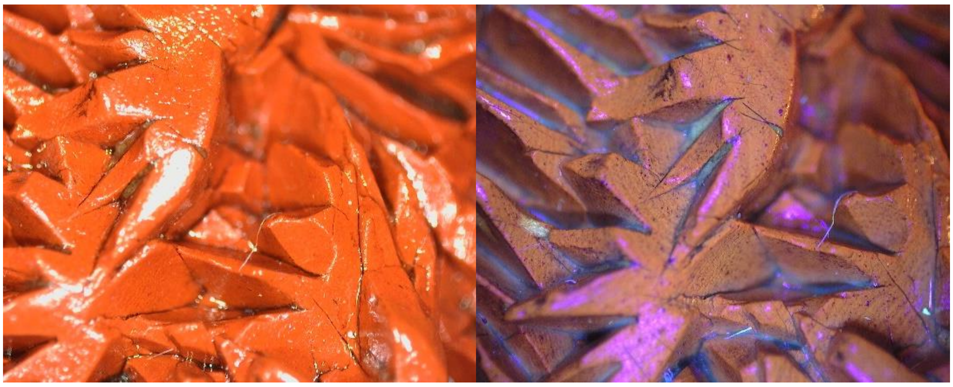


Figure 38 – Brush holder, spot (1). Left image: under normal lighting. Right image: under UV lighting.

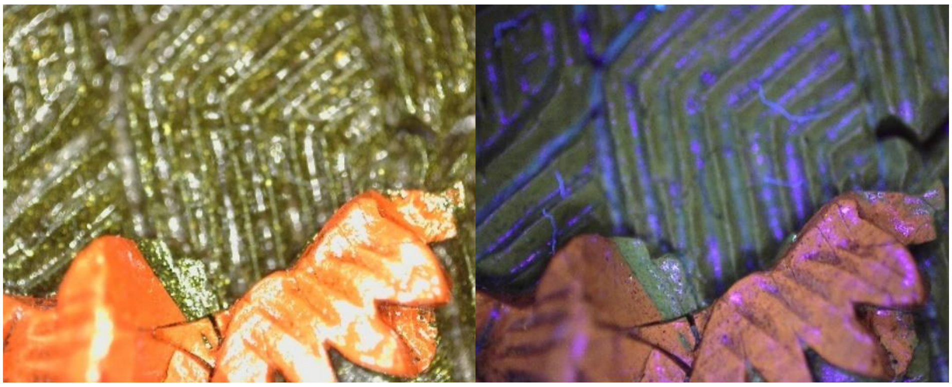


Figure 39 – Brush holder, spot (2). Missing leaf pattern due to manufacturing error.

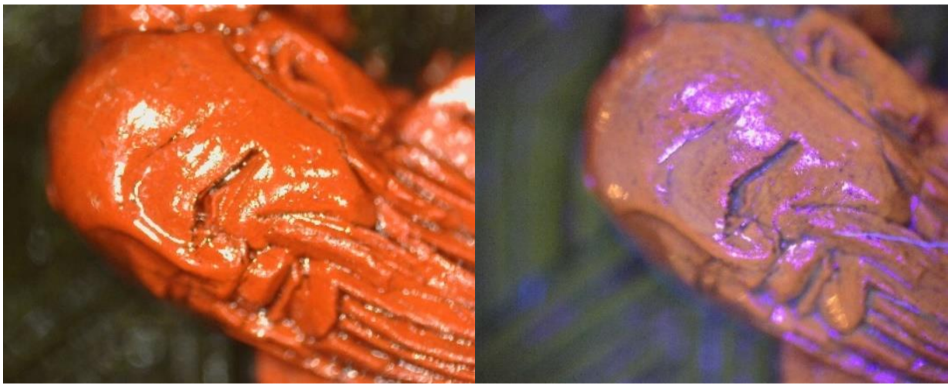


Figure 40 – Brush holder, spot (3). Intricate facial carving.

Fan shape covered box, inv. n. 10721/10368

In Fig.41 the overview of the drawing in the fan shape covered box is shown, with indicates three areas where DinoLite images were taken.

It is very interesting to note, in Fig. 42, how the carving style of the characters imitates calligraphy, conveying the sense of brushstrokes created with a soft brush, capturing the rhythm and pauses of traditional writing. The observed cracks may result from stress accumulation due to the force applied during the carving process, gradually manifesting, extending, and widening over time with environmental changes. These cracks highlight the authenticity of the piece, indicating that it is a genuine carved lacquer work rather than one produced by a mold.

In Fig. 43 it is shown how UV imaging can highlight details that are lost in natural light. Under natural light, the red lacquer layer exhibits a smooth texture, however, under UV light, the scraping marks on the surface of the petals become more visible, likely left by the craftsman during the process of removing and smoothing layers of lacquer to achieve the desired depth of the figure.

The sharp and clear carving along the edge of another section suggests that a design change may have occurred during the carving process of this leaf, with the artisan possibly adjusting the design details as they worked, or it may have been broken at a later stage (Fig. 44).

Figure 41 – Fan shape covered box, inv. n. 10721/10368

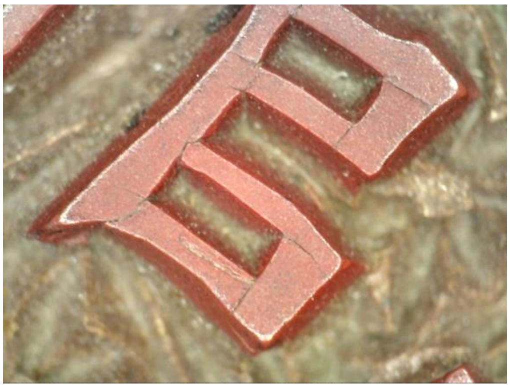


Figure 42 – Fan shape covered box, spot (1). Brushstroke-like carving style reflects calligraphy rhythm.

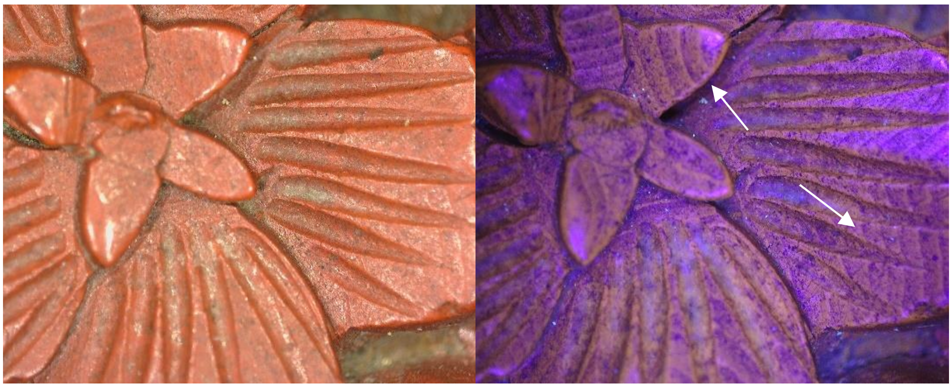


Figure 43 – Fan shape covered box, spot (2). UV light reveals scraping marks on red lacquer petals.

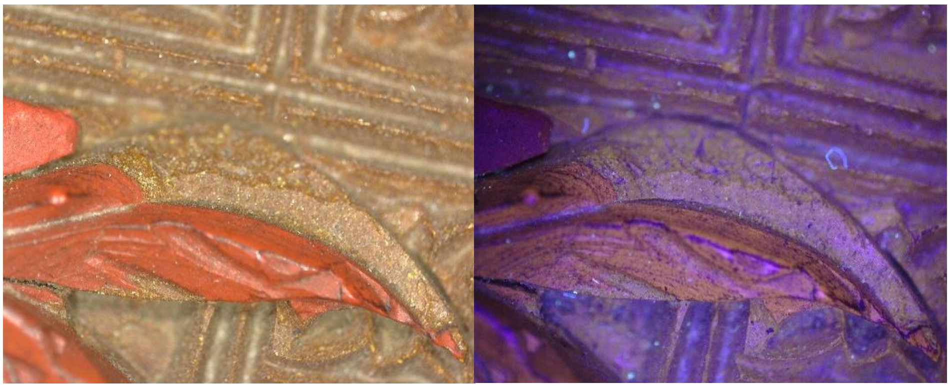


Figure 44 – Fan shape covered box, spot (3). Sharp carving suggests design change or later breakage.

Box with drawers, inv. n. 10781/10355

In Fig. 45 the overview of the drawing in the box with drawers is shown, with indicates three areas where DinoLite images were taken.

An indentation in the middle of the drawing is shown in Fig. 46: this might be a positioning point used by the artisan during the lacquer carving process to mark the center, a common practice in traditional lacquer carving to ensure high precision and symmetry, particularly for geometric patterns or complex designs. The positioning point aids in maintaining the balance of the pattern throughout the carving.

In the area shown in Fig. 47, it is evident the detachment of the red lacquer layer, with areas peeled off, exposing the black layer and the underlying plaster substrate, a condition typically caused by long-term wear, humidity fluctuations, or external forces compromising the lacquer's stability.

In Fig. 48 one can appreciate the intricate swastika pattern: some defects can be noticed, which may be due to an error made by the artisan during carving or could have been the result of long-term use, changes in storage conditions, or impact-related damage.

Figure 45 – Box with drawers, inv. n. 10781/10355

Figure 46 – Box with drawers, spot (1). Center indentation marks positioning for symmetrical carving.

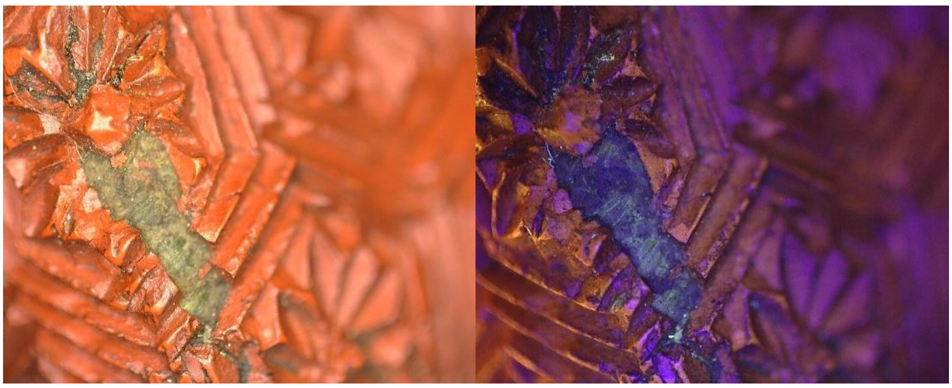


Figure 47 – Box with drawers, spot (2). Red lacquer detachment reveals black layer and plaster substrate.

Figure 48 – Box with drawers, spot (3). Swastika pattern 卍 defects due to carving error or wear.

Polychrome plate, inv. n. 10766

In Fig. 49 the luxurious and elegant drawing of the polychrome plate is shown, with indicated three areas where DinoLite images were taken.

Under UV light, certain regularly shaped areas of different colors (Fig. 50) exhibit an optical response distinct from the surrounding lacquer layers. The regularity of the marks suggests, as a possible hypothesis, that they derive from the original preparatory drawing, as it is well-known that the artisans sketched a design before lacquer carving.

The lacquer layers reveal a multi-layered structure, where the carved areas expose black and yellow lacquer layers beneath a red lacquer layer, with a green top layer, indicating that multiple colored lacquer layers were applied before carving, as usually carried out by lacquer artisans to create polychrome images. Signs of burnishing are also present, smoothing the carved edges (Fig. 51).

In the image of Fig. 52, the black lacquer layer beneath the red layer is visible, though in the middle black section, the abrasion was insufficient to fully expose the underlying black layer

Figure 49 – Polychrome plate, inv. n. 10766

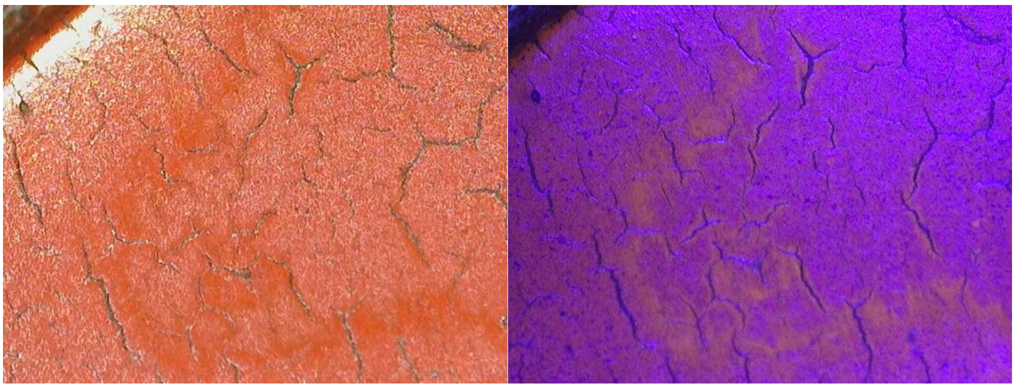


Figure 50 – Polychrome plate, spot (1). Distinct UV response indicates possible original design traces.

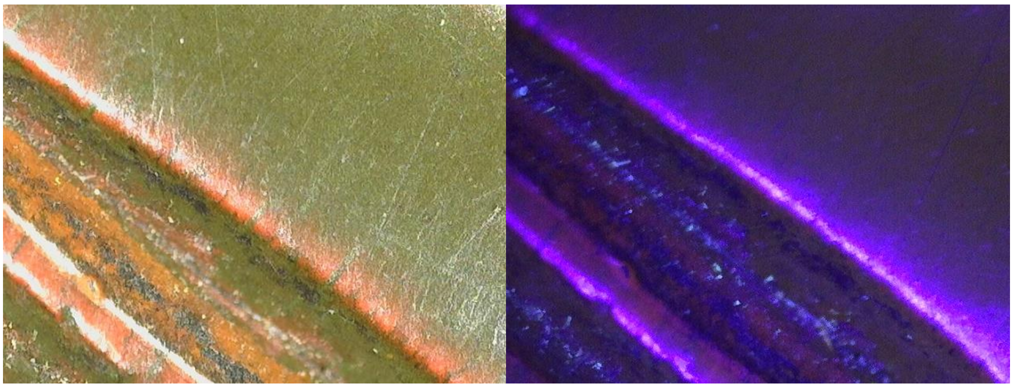


Figure 51 – Polychrome plate, spot (2). Multi-layer lacquer structure with burnished carved edges.

Figure 52 – Polychrome plate, spot (3). Black layer beneath red; middle black part shows incomplete abrasion.

4.1.2 Fiber Optic Reflectance Spectroscopy (FORS)

FORS investigations were applied in situ to characterize and possibly identify the pigments present in the four lacquerware objects. Due to the complicated mixture of substances, involving lacquer and mixture of pigments, the FORS analysis was difficult, and the results here presented should be supported by future XRF analysis on the same objects to be more reliable.

Brush holder, inv. 10736/10410

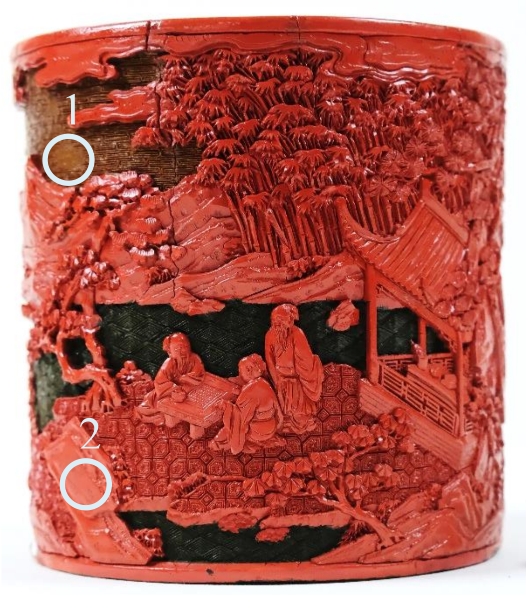


Figure 53 – Brush holder, inv. 10736/10410

In figure 53, two points are shown, where FORS spectra were acquired.

For the brown spot (1), a weak and noisy FORS spectrum was acquired (Fig. 54 left), not unexpectedly since FORS does not perform well for brown-black areas. For red, yellow, orange and brown pigments the FORS analysis is based substantially on the evaluation of the inflection points (i.e, points of maximum slope) of the curves. The FORS curve of the brown spot increases below 500 nm, and an inflection point (IP) at around 535 nm can be guessed, which matches the FORS inflection point expected for realgar. Realgar and orpiment were common pigments used in lacquerwares, and realgar is often found together with orpiment, since orpiment can easily turn into realgar. Due to the low intensity of the FORS curve, the presence of orpiment/realgar is just an educated guess. A second IP is observed around 564 nm, which matches well the IP of minium. Therefore, we can speculate that the brown area was obtained as a mixture of orpiment/realgar and minium, although other pigments (maybe earth pigments) could have been used as well.

The red spot (2) shows an IP between 595-600 nm (Fig. 54 right), which corresponds well to the inflection point of cinnabar, (the exact position of the inflection point depends on the specific type of cinnabar). Additionally, there is a second weak inflection point at 580 nm (well matching the expected inflection point for red ochre), suggesting a minor mixture of red ocher although this signal is weak. The region around 875 nm has too much noise to provide reliable information.

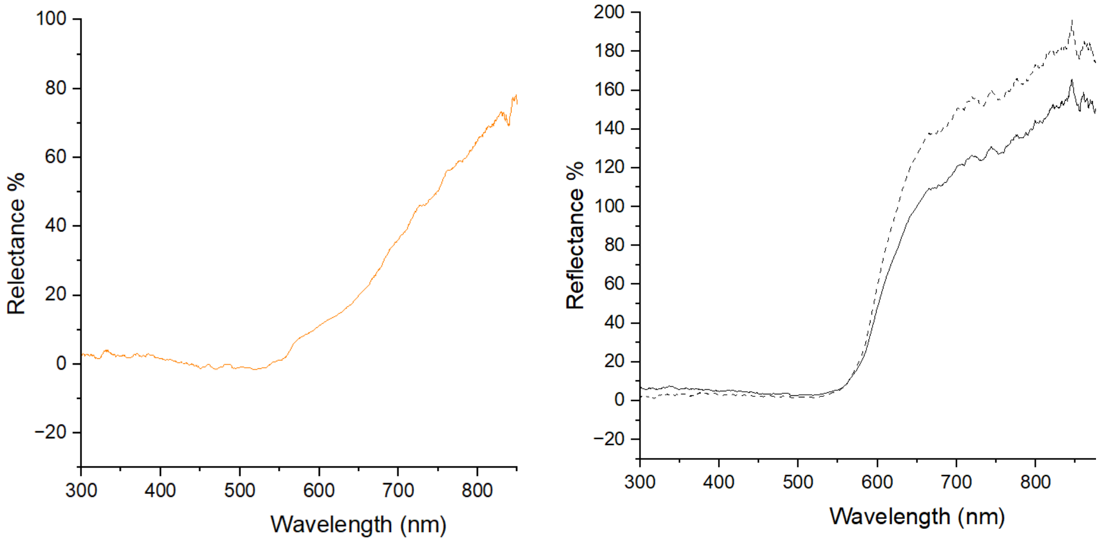


Figure 54 – Brush holder. Left: brown spot (1). Right: red spot (2).

Fan shape covered box, inv. n. 10721/10368

Figure 55 – Fan shape covered box, inv. n. 10721/10368

In figure 55, three points are shown, where FORS spectra were acquired.

For the red spot (1) on the flower of fan box lid, the FORS analysis (Fig. 56 left) showed a IP at 588 nm corresponding either to red ocher or to a cinnabar, being in between the expected values for red ochre and cinnabar. Another minor IP at 564 nm indicates the possible presence of minium.

For another red spot (2) on the edge of fan box lid, inflection points were observed at 564 nm for minium and again at 586 nm.

For the brown spots (3), a single inflection point at 563 nm was identified reliably in the spectra, indicating the presence of minium (Fig. 56 right).

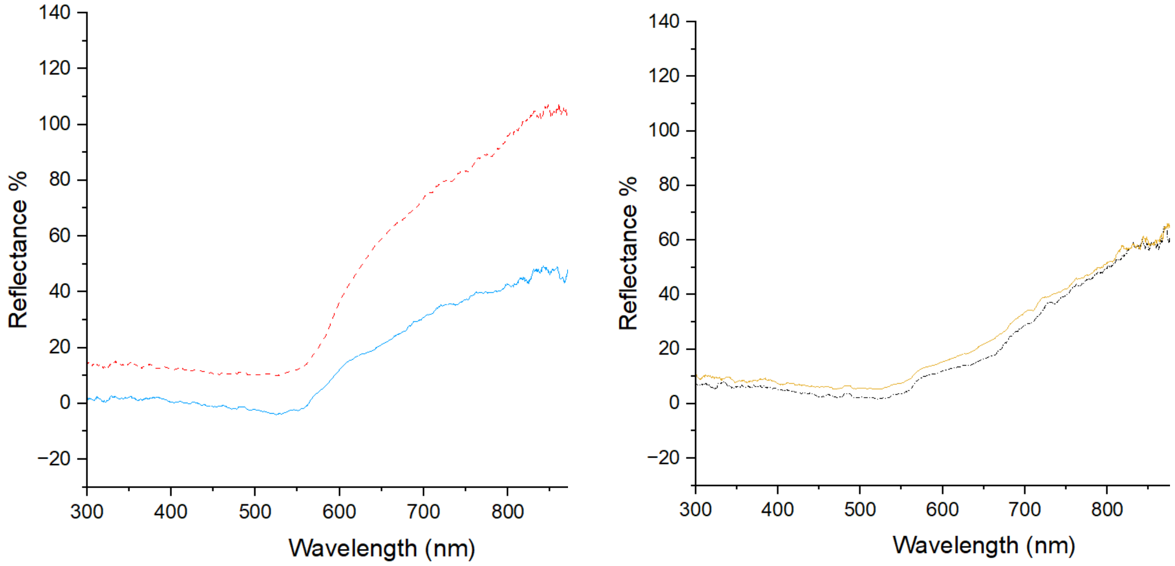


Figure 56 – Fan shape covered box. Left: red spot (1) (red dotted line), red spot (2) (blue line). Right: brown spots (3).

Box with drawers, inv. n. 10781/10355

Figure 57 – Box with drawers, inv. n. 10781/10355

In figure 57, two points are shown, where FORS spectra were acquired.

For the red spot (1), which is at the top of the middle of "Box with drawers", the FORS spectrum showed a single IP at 588 nm corresponding possibly to red ocher, or a mixture red ochre-cinnabar.

For another red spot (2), more inflection points were observed. The IP at 580 nm corresponds well to red ochers, indicating the presence of this pigment. An IP at 560 nm indicates the presence of minium, while a small IP at 540 nm suggests a possible minor amount of yellow ocher.

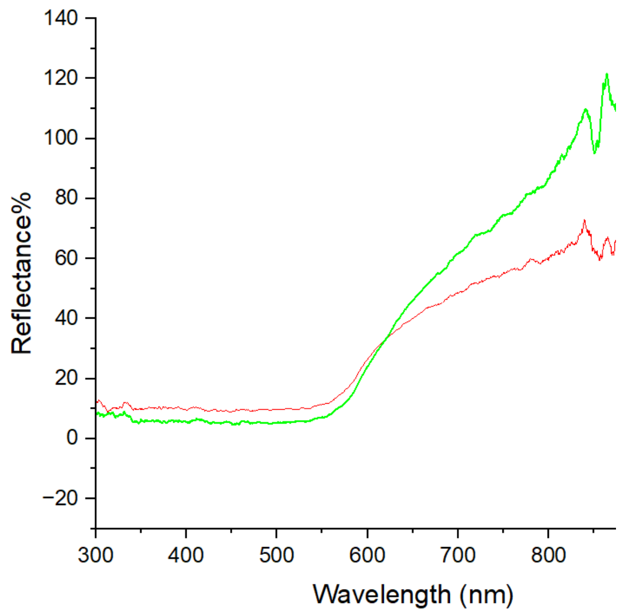


Figure 58 – Box with drawers. Red spot (1) (green line). ed spot (2) (red line)

Polychrome plate, inv. n. 10766

Figure 59 – Polychrome plate, inv. n. 10766

In figure 59, six points are shown, corresponding to the various colors of the dish, where FORS spectra were acquired.

For the red border (1), (Fig. 60) the FORS profile corresponds perfectly to a mixture of yellow and red ochre pigments, with the typical two maxima expected for ochres, and inflection point at 545 nm typical of yellow ochre (ACETO M. 2014).

For the red spot (2), at the bottom side of the plate, the FORS spectrum shows a clear IP at 592 nm, well matching cinnabar, and another possible minor IP at 574 nm suggesting the presence of a small amount of ocher.

For another red spot (3), inflection points were observed at 592 nm (cinnabar) and 562 nm (minium).

For the red spot (4), a single IP was observed at 592 nm corresponding to cinnabar.

For the yellow spot (5), the spectral profile looks complex, with several inflections point, but the main IP points are at 475 nm, 563 nm, 592 nm. The inflection point at 475 nm is close to that expected for a Sienna pigment, or other pale yellow ochre pigment, while the other IP points could be assigned to minium and cinnabar.

For the green spot (6), a complex spectrum was observed, with a maximum around 600 nm, a deep minimum around 650 nm (although an artifact from the lamp hampers a good identification) and an inflection point at around 475 nm. Considering the shape of the entire curve and the presence of the minimum at about 650 nm, it could correspond to a green color created by a mixture of indigo and orpiment, or indigo and a yellow ochre (VERRI G. et al., 2020), but it is only an educated guess.

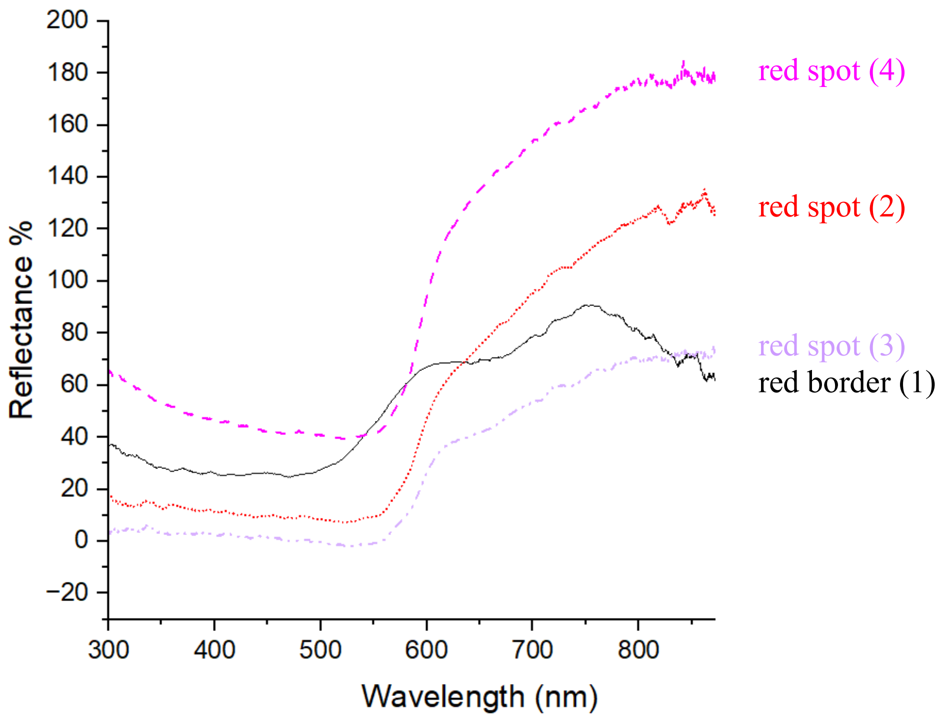


Figure 60 – Polychrome plate. Red border (1), red spot (2), red spot (3), red spot (4).

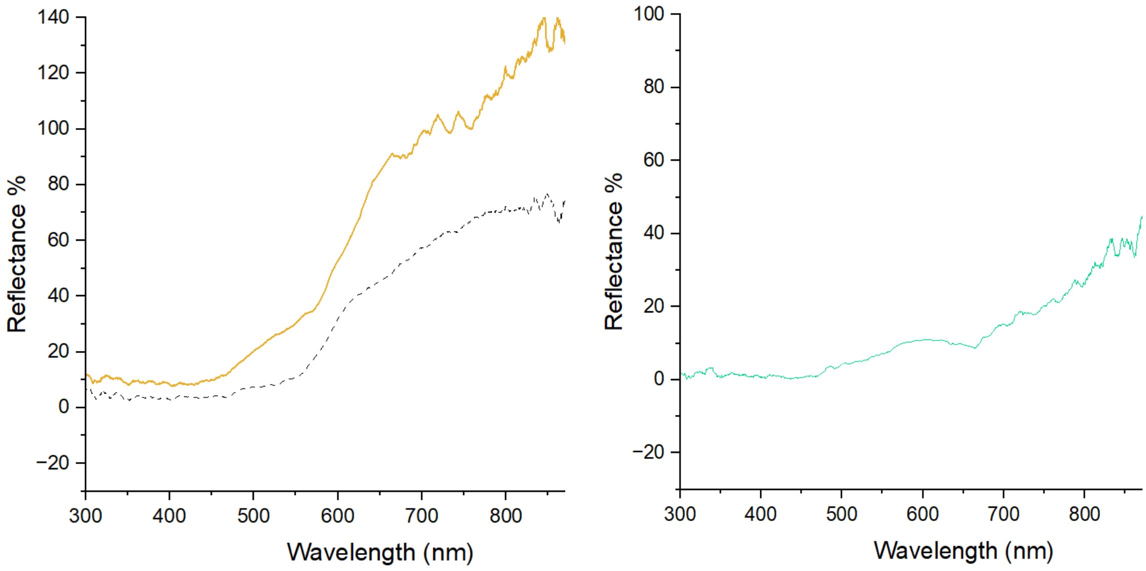


Figure 61– Polychrome plate. Left: yellow spots (5). Right: green spot (6).

4.1.3 INFRARED EXTERNAL REFLECTANCE (ER-FTIR)

Brush holder, inv. 10736/10410

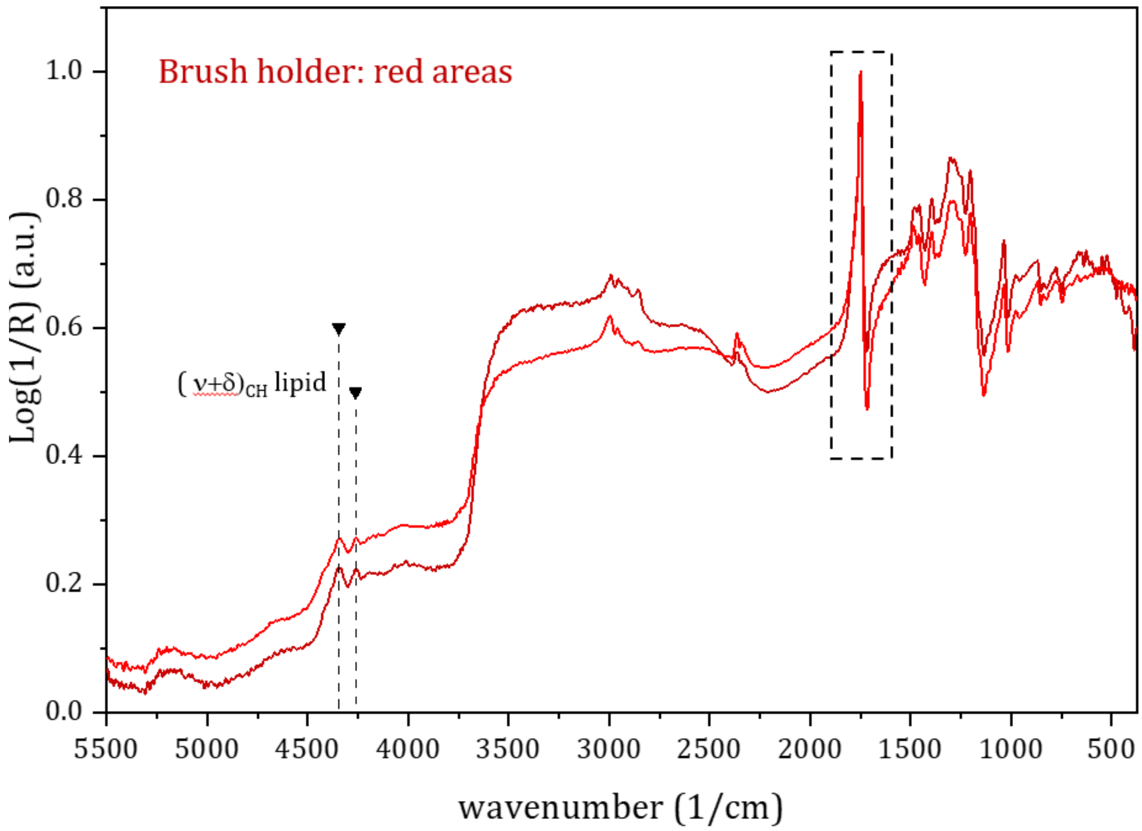


Figure 62– ER-FTIR spectra of Brush holder red area

The ER-IR spectra collected from the red areas display an intense, distorted absorption centered around 1735 cm⁻¹, which can be attributed to the asymmetric stretching of the ester group (R-C(=O)-O-R'). According to the literature (ROSI F., DAVERI A., MORETTI P., BRUNETTI B.G., MILIANI C. 2016), this signal, along with the characteristic absorption at 4346 and 4263 cm⁻¹, ascribable to the combination band of the stretching and bending mode of CH group, suggest the presence of a lipid.

No clear evidence of polymerized catechol was observed, suggesting that the surface may be treated with a lipid, likely a siccative oil. The lipid signals dominate the spectrum, overshadowing other potential components in the lacquer mixture.

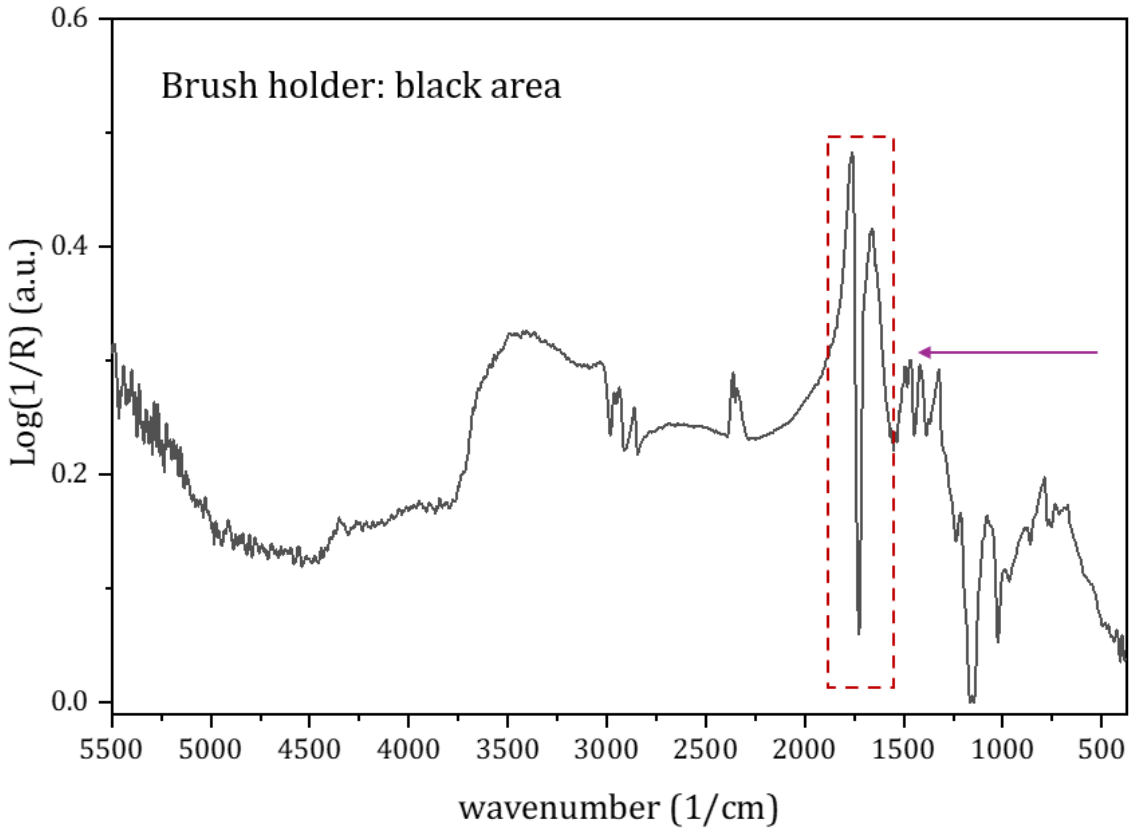


Figure 63– ER-FTIR spectra of Brush holder black area (Brush holder bottom)

The ER-IR spectrum collected from the black area is similar to that from the red area, dominated by an intense, distorted absorption peak around 1735 cm⁻¹, which can be attributed to the asymmetric C=O stretching in ester groups.

It is worth observing that the asymmetric C=O stretching is not associated with the well resolved combination bands at 4346 and 4263 cm⁻¹, typical of lipid-based binder. This evidence, together with the spectral features in the fingerprint region, allow us to suppose the presence of a synthetic polymer. Based on the Py-GC/MS results, the black area indeed contains an acryl-based varnish, suggesting that this synthetic polymer might have been applied in a previous restoration.

Additionally, a distorted signal is observed around 1600 cm^{-1}. This absorption cannot be attributed to the acryl-based varnish but is likely due to C=C stretching in the aromatic ring skeletal vibrations of polymerized catechol derivatives (FRADE J.C., et al., 2009).

- Brush Holder red and black areas comparison:

Red Area: The spectrum shows a predominance of lipid absorptions, indicating the use of siccative oil in this area. The red area has a carved layer, which likely requires additional oil.

Black Area: The spectrum reveals signals of an acryl-based varnish along with polymerized catechol signals, likely related to a previous restoration intervention.

Box with drawers, inv. n. 10781/10355

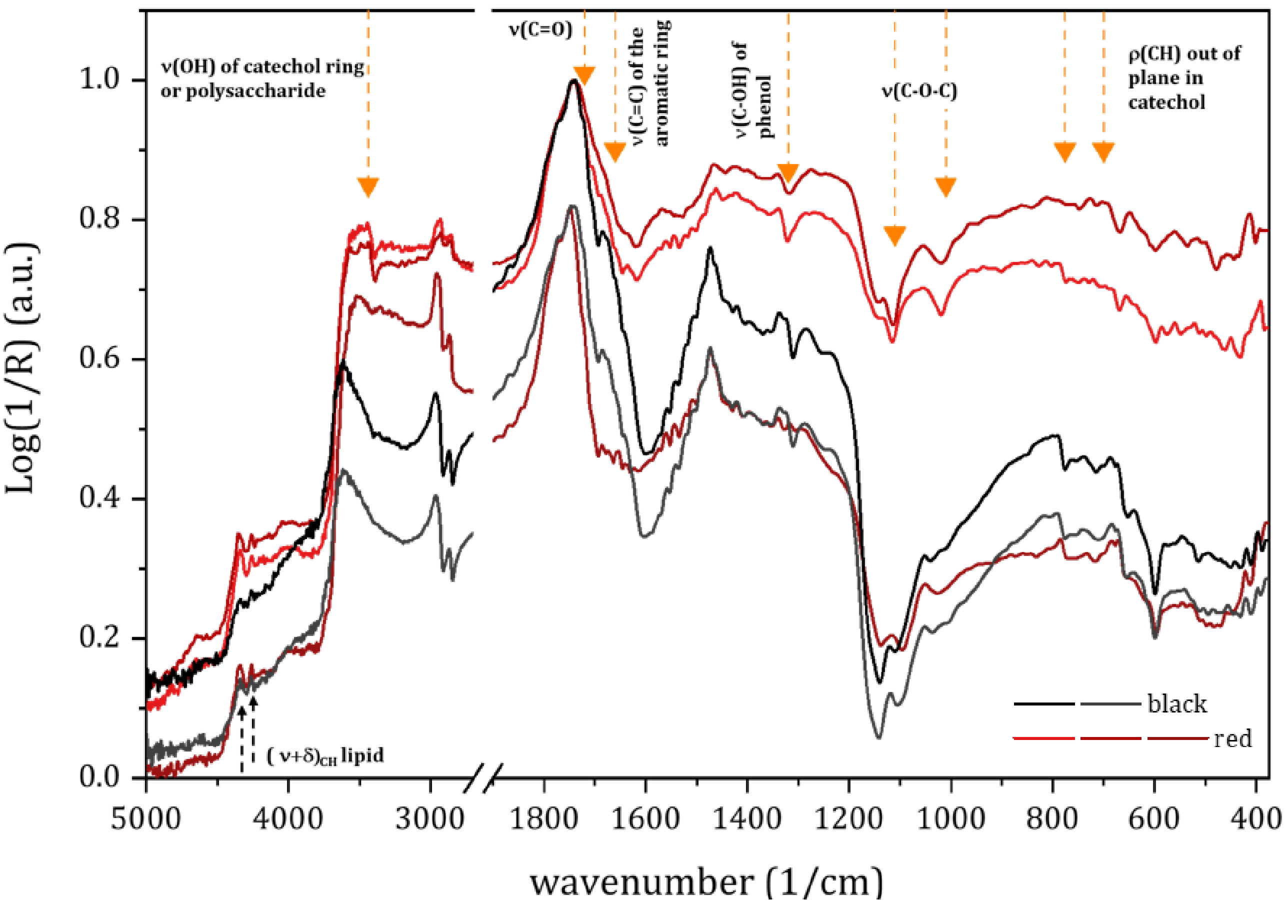


Figure 64 – ER-FTIR spectra of Box with drawers

The spectra collected from both the black and red areas of Box with drawers exhibit the same characteristics. The spectrum is dominated by an intense, distorted, and complex absorption around

1735 cm⁻¹, attributable to an ester asymmetric stretching. This evidence, together with the doublet at about 4346 and 4263 cm⁻¹ suggests a possible lipid component, as mentioned before. However, all spectra also display weak but distinctive signals that may be attributed to polymerized catechol derivatives, as illustrated in figure 64.

Polychrome plate, inv. n. 10766

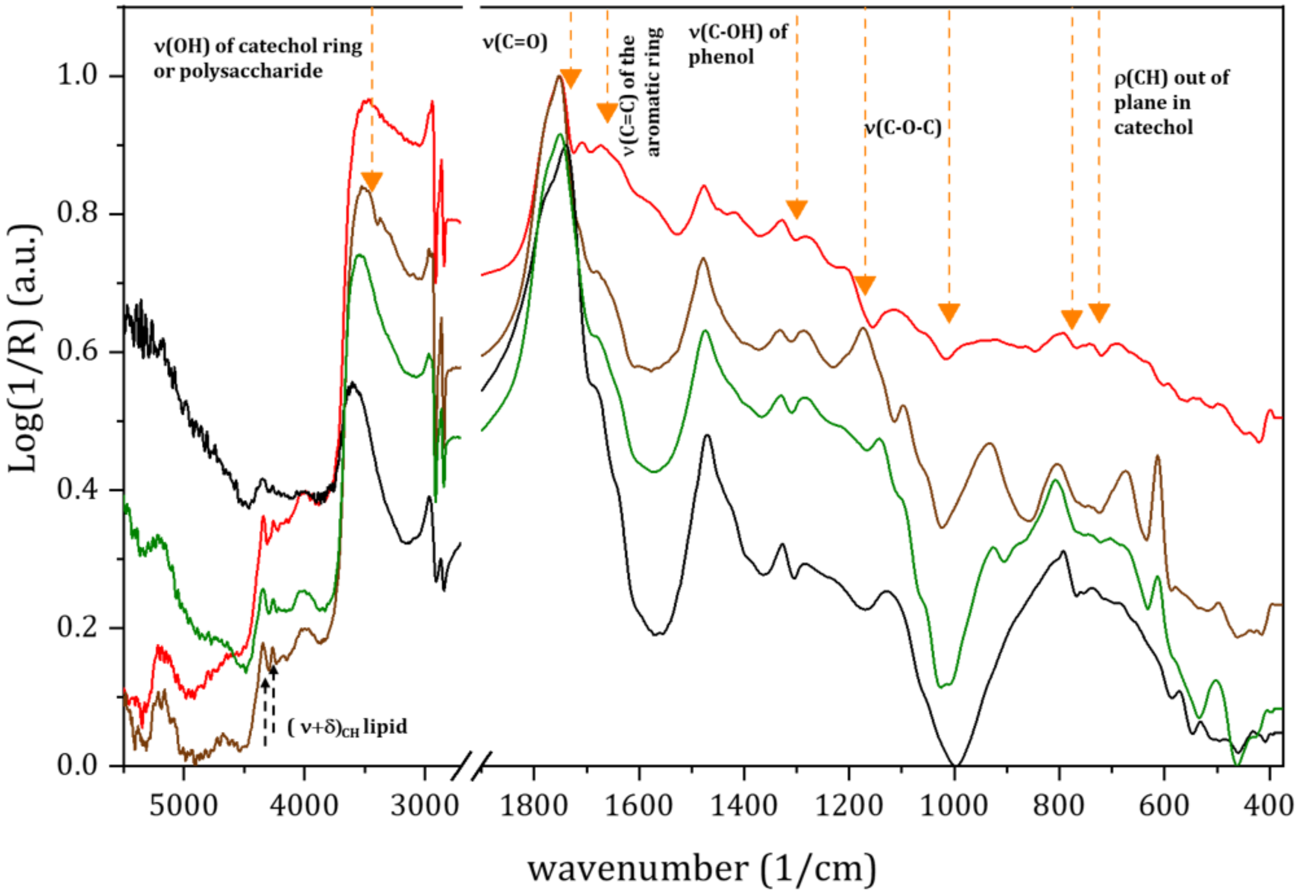


Figure 65– ER-FTIR spectra of Polychrome plate

Similarly to the previous spectra, all spectra of Polychrome plate exhibit the typical absorption of lipid and polymerized catechol derivative, as reported in figure 65.

4.2 MICRO-INVASIVE INVESTIGATIONS

4.2.1 MICRO – ATR

Brush holder, inv. 10736/10410

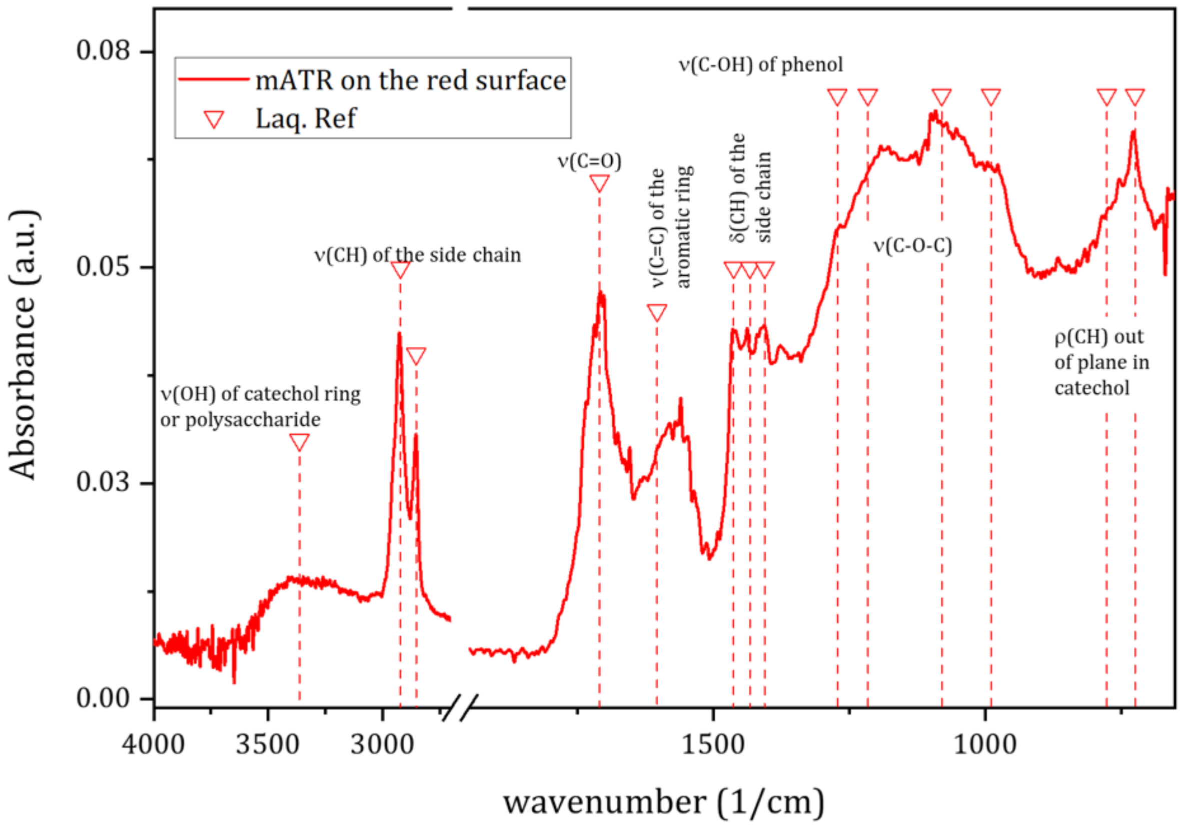


Figure 66– Micro-ATR spectra of Brush holder after Chloroform treatment

A micro-ATR analysis was conducted on a small fragment of the red lacquer. Chloroform treatment was applied directly to this microsample to extract the possible soluble constituents. The spectrum revealed significant signals corresponding to polymerized catechol derivatives (COZZANI C., ZOLEO A., PINTUS V., NODARI L., DI MARCO V. 2024) , displaying several key absorption peaks:

Wavenumber (cm^{-1})	**Peaks Assignment**
3401	O-H stretching of catechol ring or polysaccharides
3032	H-C=C-H (cis) stretching of side chain double bond
2933	C-H stretching asymmetric of CH2 and CH3 of the side chain
2858	C-H stretching symmetric of CH2 and CH3 of the side chain
1704	C=O stretching of acid
1565	C=C stretching of the aromatic ring skeletal vibrations of the polymerized catechol derivatives

1735	(C=O shoulder) C=O stretching of ester unit
1600	(C=O shoulder) or C=C stretching of aromatic ring
1462	C-H bending (asymmetric) of side chain
1435	C-H bending (asymmetric) of side chain
1407	C-H bending (asymmetric) of side chain
1264	C-OH stretching of catechol and phenols
1180	C-O-C stretching of polysaccharides
1091	C-O-C stretching of polysaccharides
749	C-H bending vibration of aromatic ring or substituted benzene skeletal vibrations
725	C-H bending vibration of aromatic ring or substituted benzene skeletal vibrations

Carved lacquer is a traditional East Asian craft that involves stacking multiple layers of lacquer, with each layer intricately carved to reveal the layers beneath. In this technique, oils are often added to improve the workability and durability of the lacquer. These oils make the lacquer more flexible, easier to mold and carve, and enhance the final product's gloss. However, over time, these oils may oxidize or hydrolyze, depending on factors such as the original formulation, environmental conditions, and the structure of the lacquer layers. This oxidation process can result in new or intensified absorption in the FTIR spectrum, particularly in the range associated with C=O stretching vibrations. The strong absorption at 1704 cm^{-1} indicates the presence of ester acid groups (-COOH). Indeed, this absorption peak is associated with the C=O stretching vibration of carboxylic acids, which may be degradation products formed from drying oils due to prolonged oxidation in the presence of light and air. Another possibility is that partial hydrolysis of drying oils or fatty esters occurred, which is related to the lacquer's manufacturing environment, as raw lacquer inherently contains a small amount of moisture, and its urushiol requires a high-humidity environment to promote enzymatic oxidative polymerization, gradually curing into a polymer. (TANAKA Y. 2010) (SMITH M., FUSTER L. 2012) (DUPUIS A., SABLIER J. 2006)

Furthermore, the main signals due to polymerized catechol derivatives were detected. A significant absorption at 1565 cm^{-1} corresponds to the C=C stretching vibration of the aromatic ring skeleton in polymerized catechol derivatives, a key component in traditional East Asian lacquer. Catechols undergo oxidative polymerization to form a hard and durable surface, and the strong peak at this wavenumber suggests a high concentration of these polymerized structures within the lacquer. Additionally, the absorption around 1600 cm^{-1} can be attributed to aromatic C=C bonds, further indicating the presence of aromatic structures.

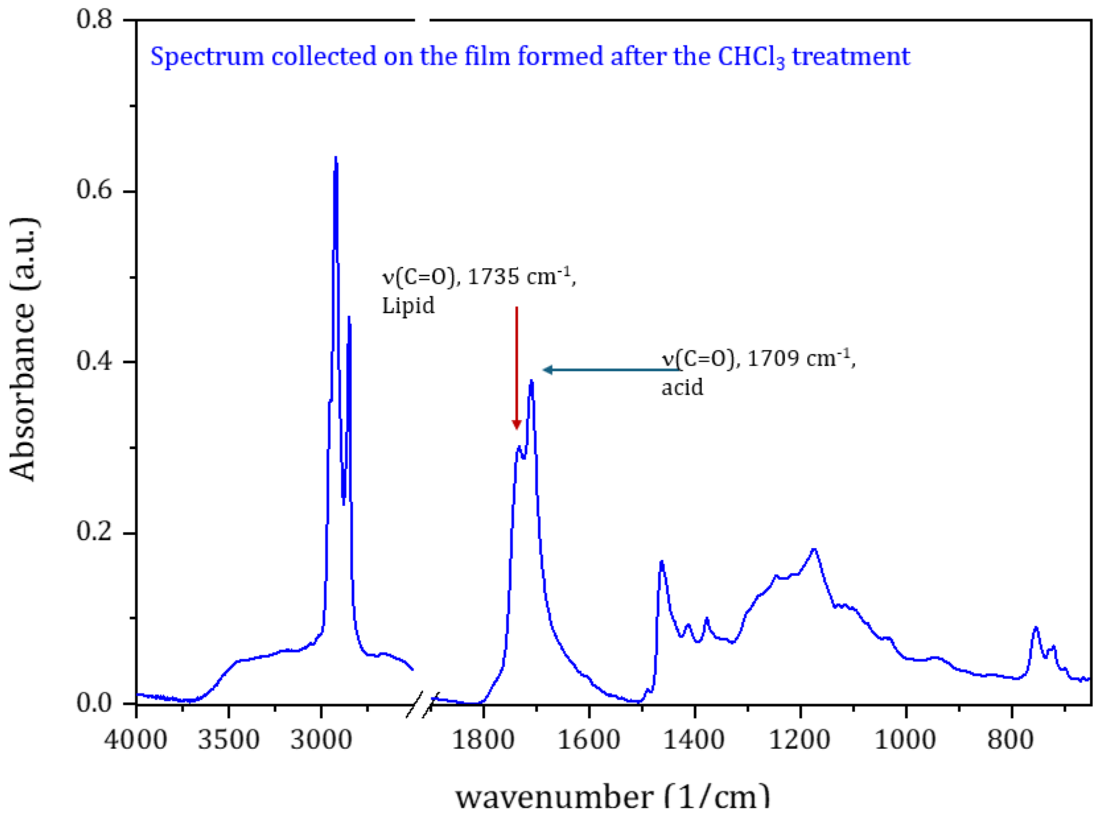


Figure 67– Micro-ATR spectra of film of Brush holder red lacquer sample after Chloroform treatment

Wavenumber (cm^{-1})	**Peaks Assignment**
1735	C=O asymmetric stretching of ester
1709	C=O asymmetric stretching of carboxylic acid or carbonate

A second spectrum was acquired on a film formed after evaporation of the chloroform used to extract the more hydrophobic organic components. The spectrum is shown in Fig. 67 and exhibits a significant increase in acidic and lipid components, further supporting the hypothesis that the sample may contain drying oils or fatty acids, as indicated by the peaks at 1735 cm^{-1} and 1709 cm^{-1}.

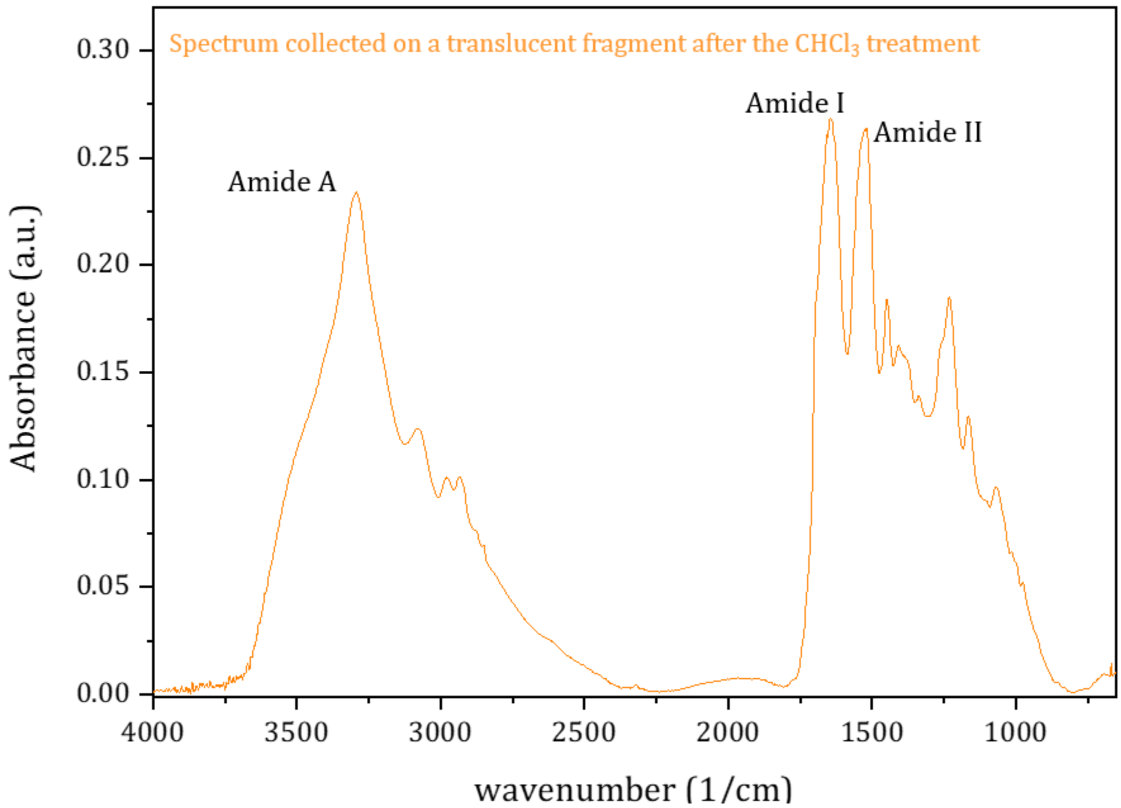


Figure 68– Micro-ATR spectra of a translucent fragment of Brush holder red lacquer sample after Chloroform treatment

Wavenumber (cm^{-1})	**Peaks Assignment**
3291	N-H stretching of amide
1643	Amide I
1520	Amide II

In Figure 68 it is shown the micro-ATR spectrum acquired on a translucent fragment of the Brush holder red lacquer. Specific spectral absorptions indicate the presence of proteins in the red lacquer sample, that is N-H stretching 3291 cm^{-1}, Amide I (1643 cm^{-1}) and Amide II (1520cm^{-1}). These amide peaks confirm the existence of proteins in the sample, suggesting that these proteins may originate from adhesives or additives incorporated into the lacquer formula.

According to historical recipes, the additive could be either animal glue or egg whites. However, after $CHCl_3$ treatment, a translucent fragment remained, which is more characteristic of animal glue, as egg whites are brittle and less likely to leave such residues.

4.2.2 SEM

Applied scanning electron microscopy (SEM) analysis on a micro sample of Box with drawers. SEM-SE provides high-resolution imaging of surface morphology. Using the BSE detector on the complete micro sample, we achieve contrast based on atomic number, enabling us to distinguish components in deeper sample regions. Subsequently, we embed the micro-sample in resin, cut it to obtain a cross-section, and then use SEM-EDS for chemical composition analysis in micro-areas, allowing precise identification of elements within three layers.

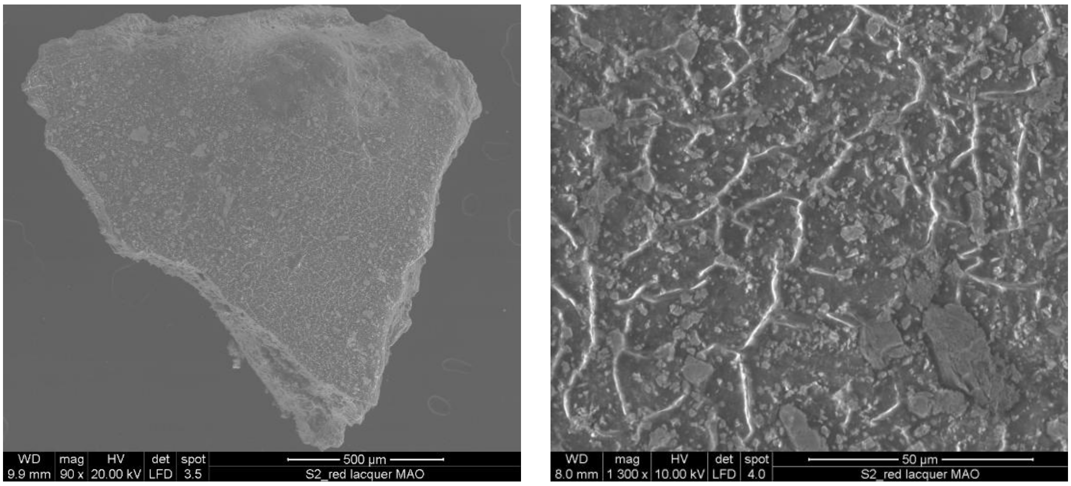


Figure 69 – Left: SEM-SE images (90x). Right: SEM-SE image(1300x) reveals fine microcracks on the surface.

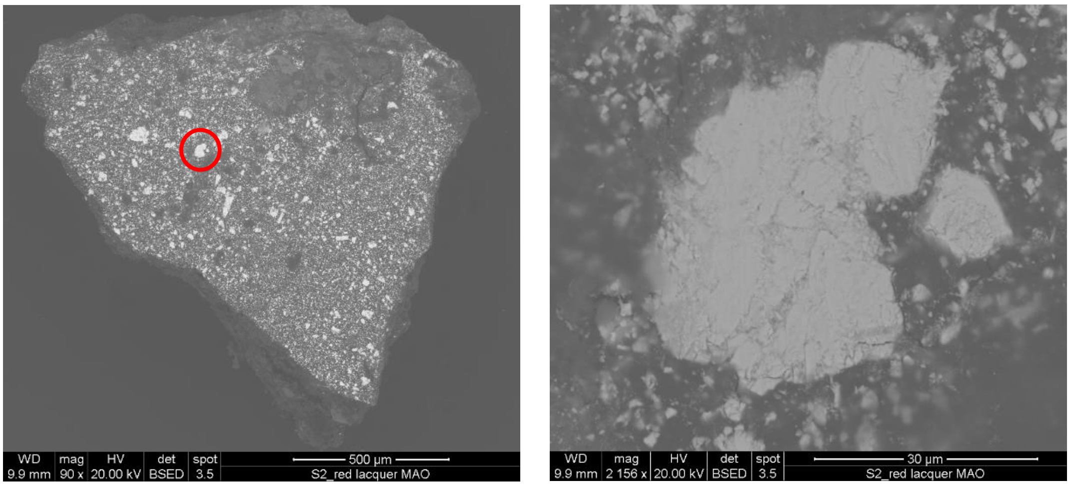


Figure 70 – Left: SEM-BSE images(90x). Right: SEM-SE image(2156x) showing the aggregate (red circle) of the micro sample.

In figure 69 the SEM-SE image on the left (90x) shows the morphology of the lacquer micro sample, it is noticeable that the sample exhibits a slightly raised or protruding feature. With the image (1300x) reveals fine microcracks on the surface of the lacquer.

In figure 70 the SEM-BSE image shows the presence of various aggregates within the sample and, in figure 70, right, a SEM-SE detailed image of such an aggregate is shown.

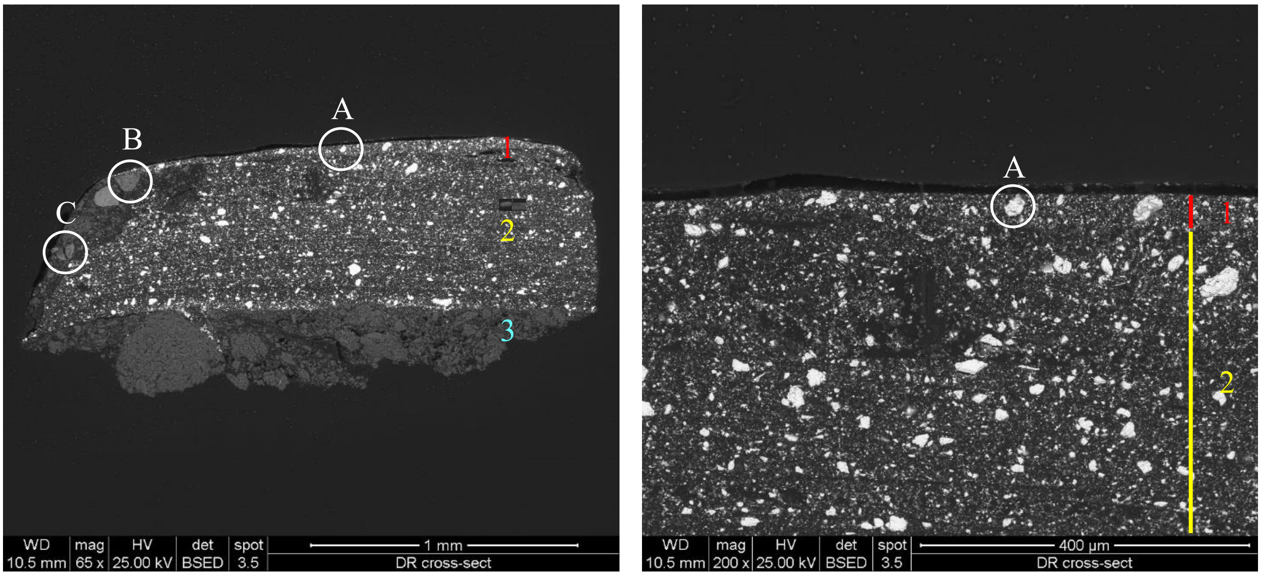


Figure 71– Left: SEM micrograph of the whole cross-sectioned sample, showing three layers: 1, 2, 3; Bigger inclusion at area A, area B, area C. Right: showing close-up of layer 1, layer 2 and area A

In the SEM micrograph of the cross-section (figure 71), three distinct layers are clearly visible:

Layer 1: mainly pigment (finer particles)

Layer 2: clay (probably) and pigment

Layer 3: ground clay

The particles, looking white in the SEM image, observed in Layer 1, exhibit a high atomic weight, appearing exceptionally bright in the SEM-BSE imaging. These particles are primarily composed of mercury (Hg) and sulfur (S), according to the SEM-EDS investigation (figure 73) indicative of cinnabar particles.

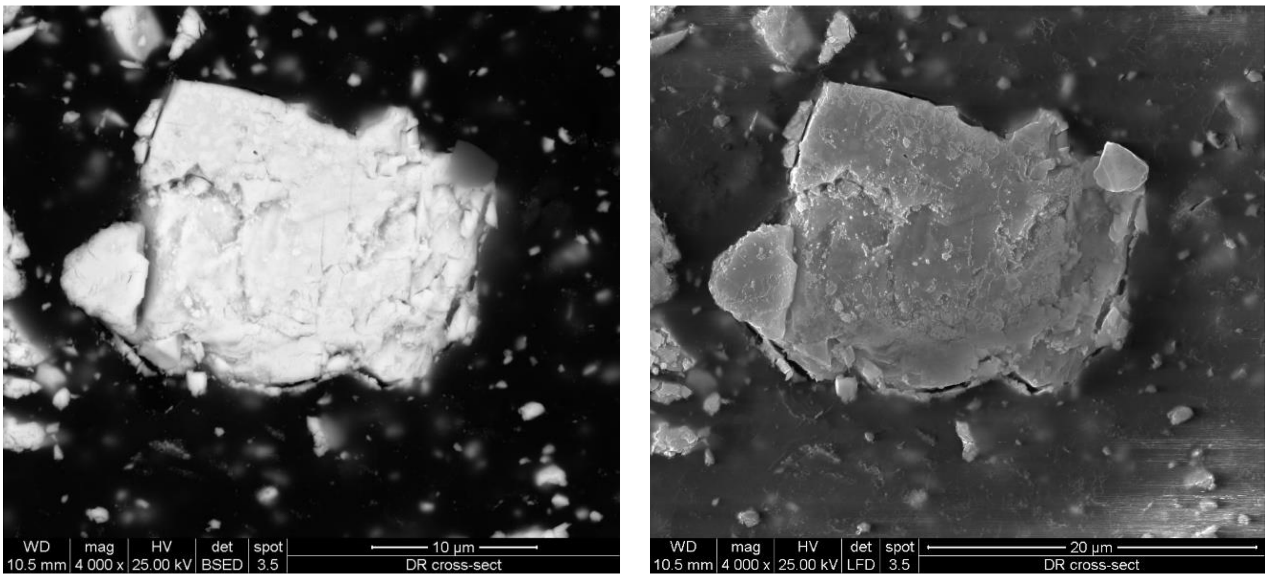


Figure 72 – Left: SEM-BSE image shows white particles at area A. Right: SEM with low vacuum detector (LFD) image.

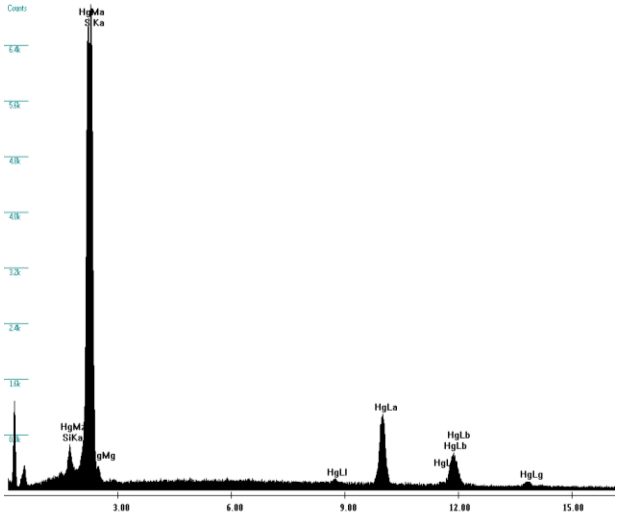


Figure 73 – EDS of the particles at area A

The SEM images illustrate the presence of clay particles at Layer 2 (see figure 74 related to area B). The primary composition (Figure 75) includes Fe, Si, and Al, while less abundant elements such as Mg, P, Hg, S, K, Ti, and Mn are also present. In addition to the clay particles, particles similar to those observed in Layer 1, identified as pigment particles, are also visible in the Figure 74.

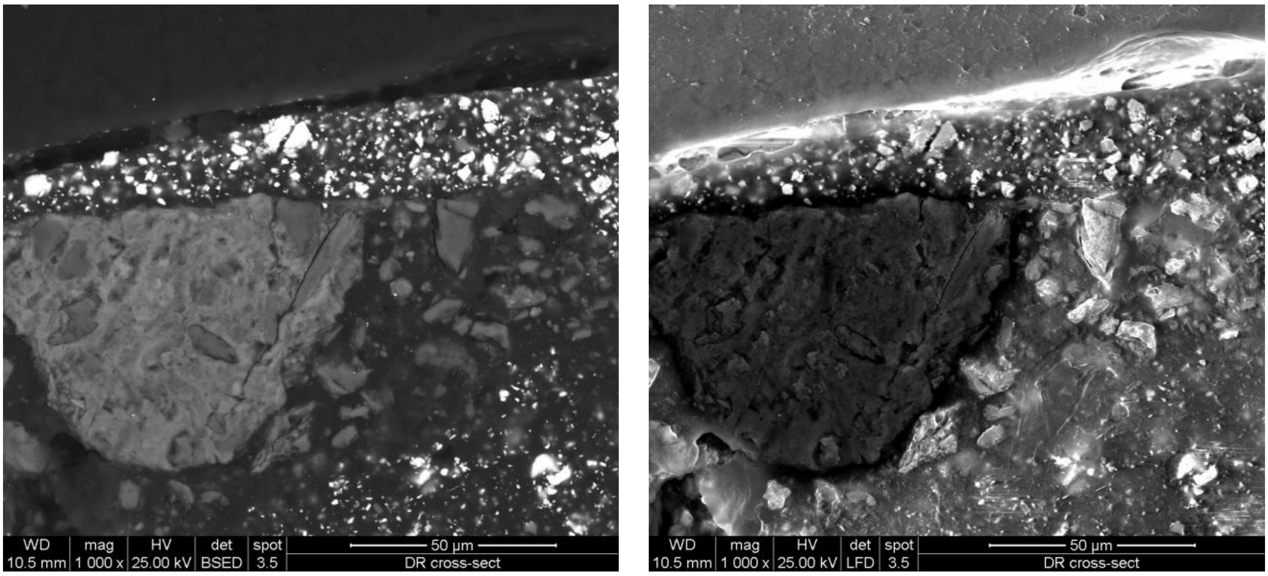


Figure 74 –SEM-BSE image shows area B**.** Right: SEM with low vacuum detector (LFD) image.

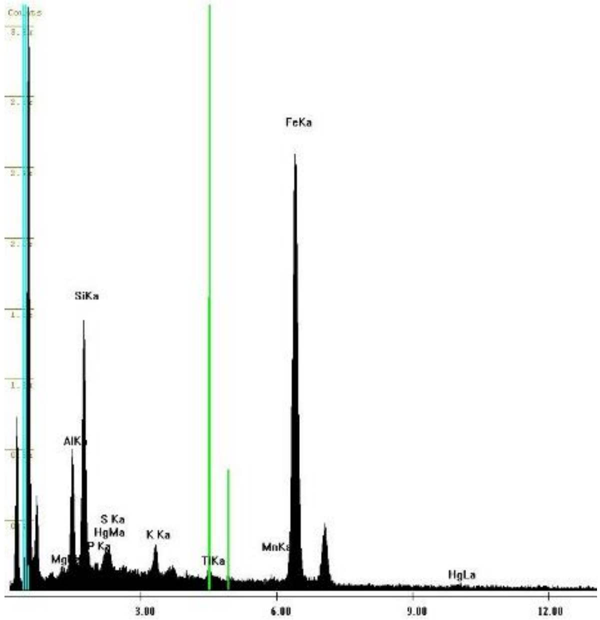


Figure 75 – EDS of the particles at area B

In area C of the figure 76, the different particles contained in layer 2 are highlighted: actually, distinct compositions are found in the labeled regions (a), (b), (c), (d), and (e). According to EDS analysis (see Appendix I) regions (a) and (d) are dominated by Si, Mg, and Al, indicating the presence of clay particles. Regions (b) and (c) exhibit a mix of clay particles and iron compounds. Region (e) is characterized by a dominance of Fe, representing iron compounds with a minor contribution from clay particles. In addition to the clay particles, "white" particles similar to those observed in Layer 1, identified as pigment particles (HgS), are also visible in the SEM images across this area.

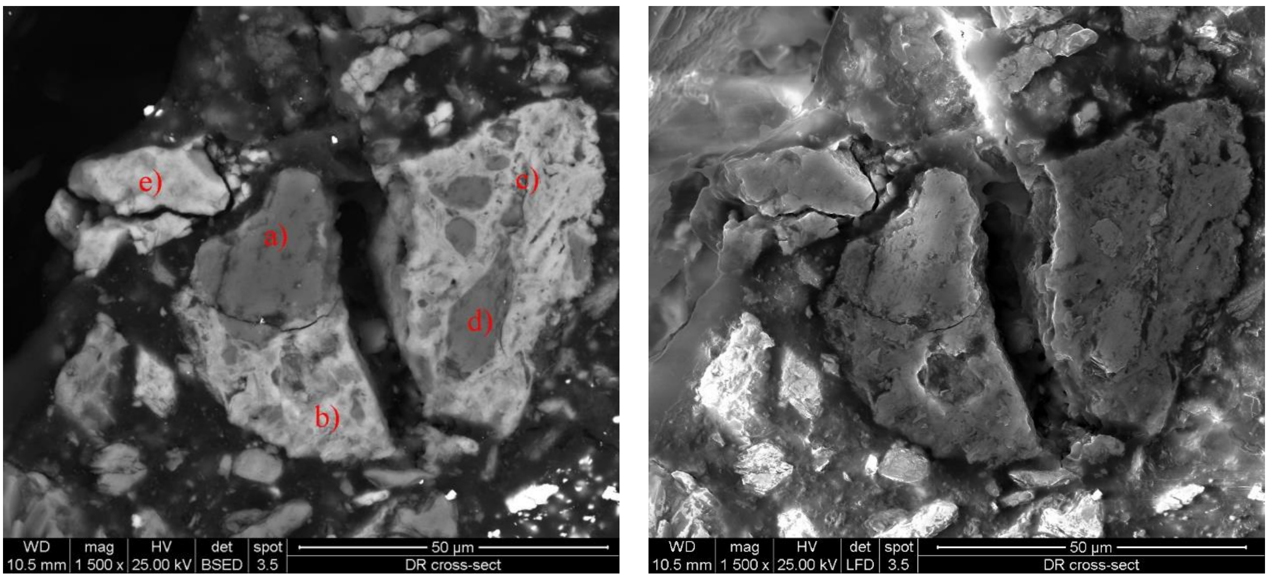


Figure 76 – Left: SEM-BSE image shows area C with labeled regions (a), (b), (c), (d), and (e) representing different areas for elemental analysis. Right: SEM with low vacuum detector (LFD) image

Area		Elements
area A	“white” particles	**S, Hg**
area B	Particles	**Fe, Si, Al,** Mg, P, Hg, S, K, Ti, Mn
area C	a)	**Si**, Mg, Al, P, Hg, S, K, Ca, Ti, Mn, Fe
	b)	**Fe, Si, Al,** Mg, P, Hg, S, K, Ca, Ti, Mn
	c)	**Fe, Si, Al,** Mg, P, Hg, S, K, Ca, Ti, Mn
	d)	**Si**, Mg, Al, P, Hg, S, K, Ca, Ti, Mn, Fe
	e)	**Fe,** Mg, Al, Si, P, Hg, S, K, Ca, Ti, Mn

4.2.3 MICRO-RAMAN

Through Raman spectroscopy, we can non-destructively identify pigments in lacquerware, such as cinnabar, and other components. The microscope also allows for the analysis of the multilayer structure of lacquer, distinguishing the compositional differences between layers and precisely targeting various inclusions within the lacquer layers to determine their components.

When observing the cross-section of the “Box with drawers” micro-sample under Raman spectroscopy, as we know previously with SEM, it shows three layers: 1, 2, 3.

Layer 1: Finer particles

Layer 2: Red layer (including red layer, dark red spots, white spots)

Layer 3: Black layer (including black layer, transparent crystals)

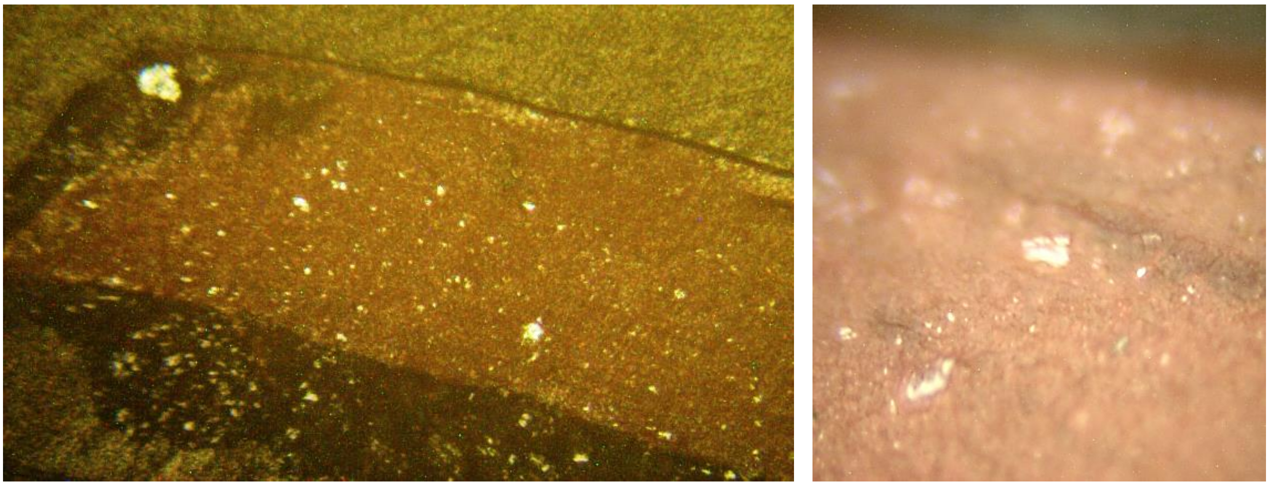
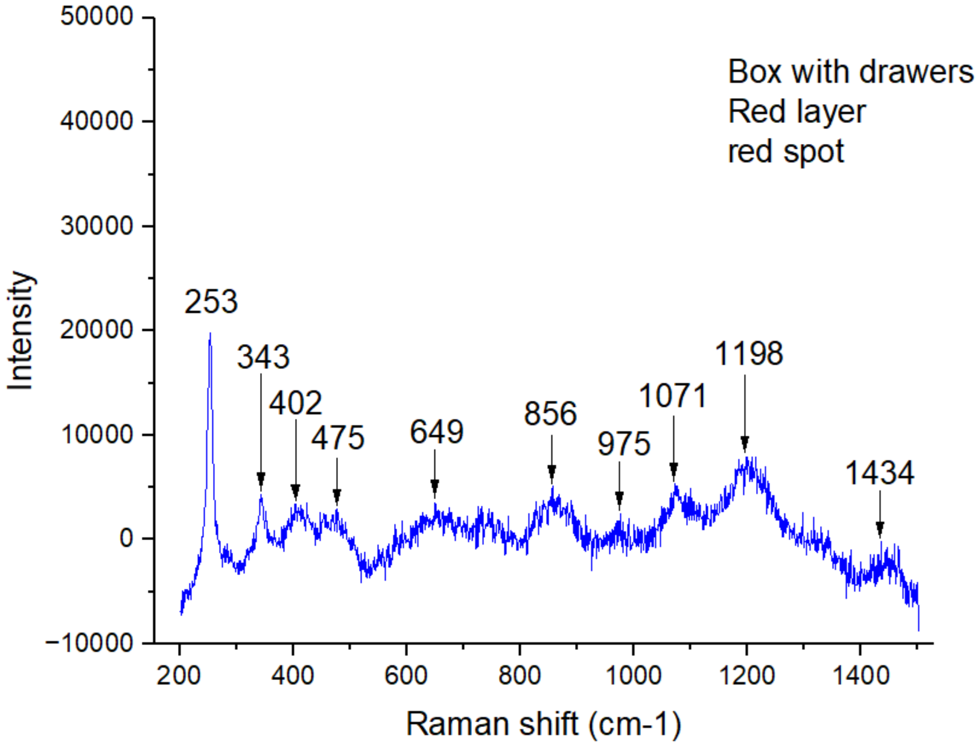


Figure 77 – Left: Cross-section of the Box with drawers’ micro sample at 5x magnification under Raman spectroscopy. Right: Close-up of white aggregate.

Layer 1 is very thin and was not analyzed further with Raman, since SEM analysis provided clear indication that only cinnabar was present as a pigment.

1. **Layer 2: Red layer (red spots, dark red spots, white spots):**

- **Layer 2 red spot**: 253 cm^{-1}, 343 cm^{-1}, 402 cm^{-1}, 475 cm^{-1}, 649 cm^{-1}, 856 cm^{-1}, 975 cm^{-1}, 1071 cm^{-1}, 1198 cm^{-1}, 1434 cm^{-1}

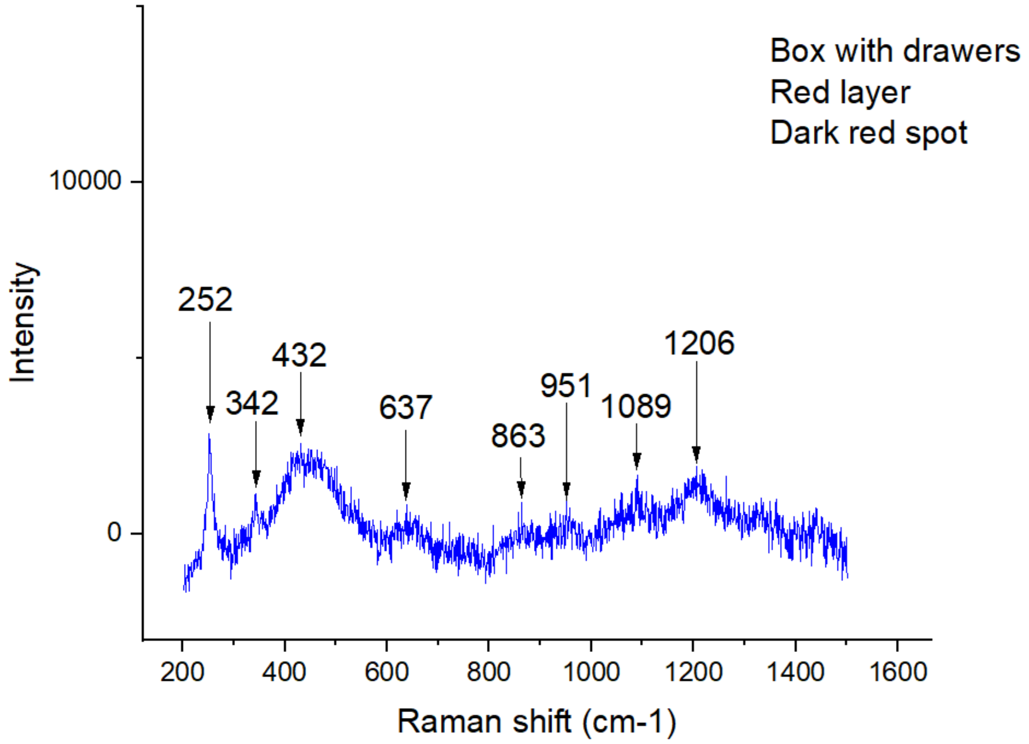


Raman Shift (cm^{-1})	**Description**
252	Main peak - Cinnabar (HgS)
343	Minor peak - Vibration mode of Cinnabar (HgS)
402	Iron oxide - Goethite (FeO(OH)) or Hematite (Fe_2O_3)
475	C-C or C-O stretching - from organic compounds
649	Iron oxides - related to Fe-O vibrational modes
856	C-H bending - from organic materials
975	C-C or C-O stretching - in organic materials
1071	C-O stretching - in organic compounds, possibly related to urushi
1198	C-H bending or C-O stretching - related to organic compounds
1434	C=C stretching - aromatic ring structure

The Raman spectrum of a red spot in Layer 2 shows characteristic peaks at 253 cm^{-1} and 343 cm^{-1}, indicating the presence of cinnabar (HgS). The spectrum also shows a peak at 402 cm^{-1}, associated with goethite or limonite (FeO(OH)). The broad peak around 649 cm^{-1} is generically related to iron oxides (maghemite, magnetite, goethite, etc.). The broad peak at 475 cm^{-1} suggests

C-C stretching in long-chain organic compounds, while 856 cm⁻¹ indicates C-H bending. Peaks at 975 cm⁻¹ and 1071 cm⁻¹ likely correspond to C-O or C=O stretching, related to the urushi matrix. Additional peaks at 1198 cm⁻¹ and 1434 cm⁻¹ indicate C-H bending and C=C stretching.

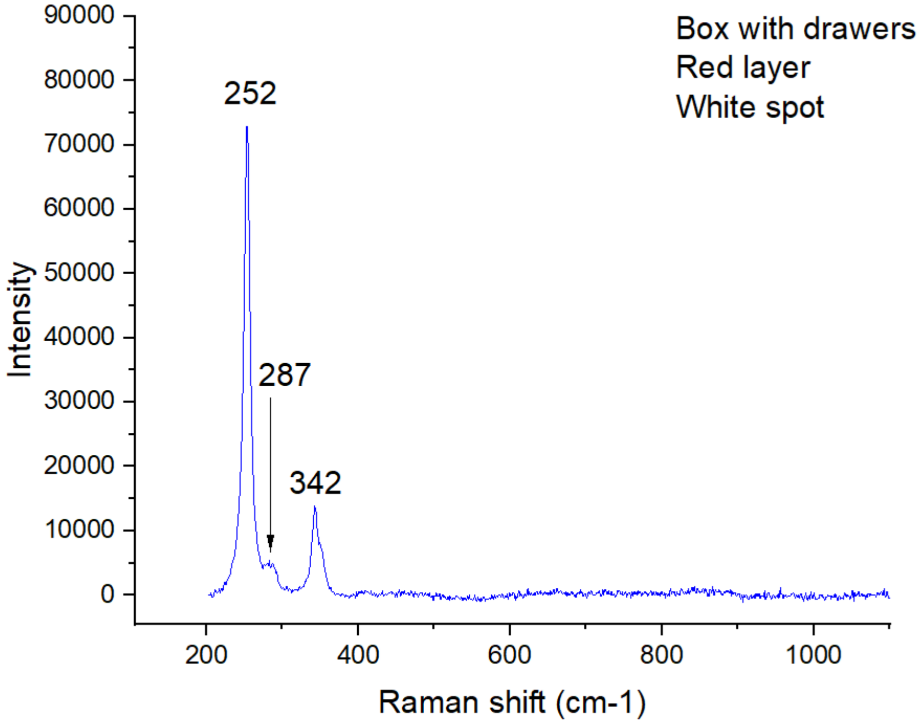
- **Layer 2 dark red spot**: 252 cm⁻¹, 342 cm⁻¹, 432 cm⁻¹, 637 cm⁻¹, 863 cm⁻¹, 951 cm⁻¹, 1089 cm⁻¹, 1206 cm⁻¹



Raman Shift (cm⁻¹)	Description
252	Main peak - Cinnabar (HgS)
342	Minor peak - Vibration mode of Cinnabar (HgS)
432	Goethite (FeO(OH)) or magnetite/maghemite (Fe_3O_4)
637	Si-O-Al vibrational modes from clay
863	C-H bending - in organic compounds
951	C-H bending or C-O stretching - related to organic materials
1089	Calcite ($CaCO_3$)
1206	Phenolic stretching - in catechol polymers of urushi

The Raman spectrum of the dark red spots in Layer 2 shows peaks at 252 cm⁻¹ and 342 cm⁻¹, indicating cinnabar (HgS). A peak at 432 cm⁻¹ suggests goethite (FeO(OH)) or magnetite/maghemite (Fe_3O_4). A peak at 637 cm⁻¹ corresponds to Si-O-Al vibrational modes from clay. Organic components are marked by peaks at 863 cm⁻¹, 951 cm⁻¹, and 1206 cm⁻¹, while the peak at 1089 cm⁻¹ indicates calcite ($CaCO_3$).

- **Layer 2 white spots**: 252 cm^{-1}, 287 cm^{-1}, 342 cm^{-1}

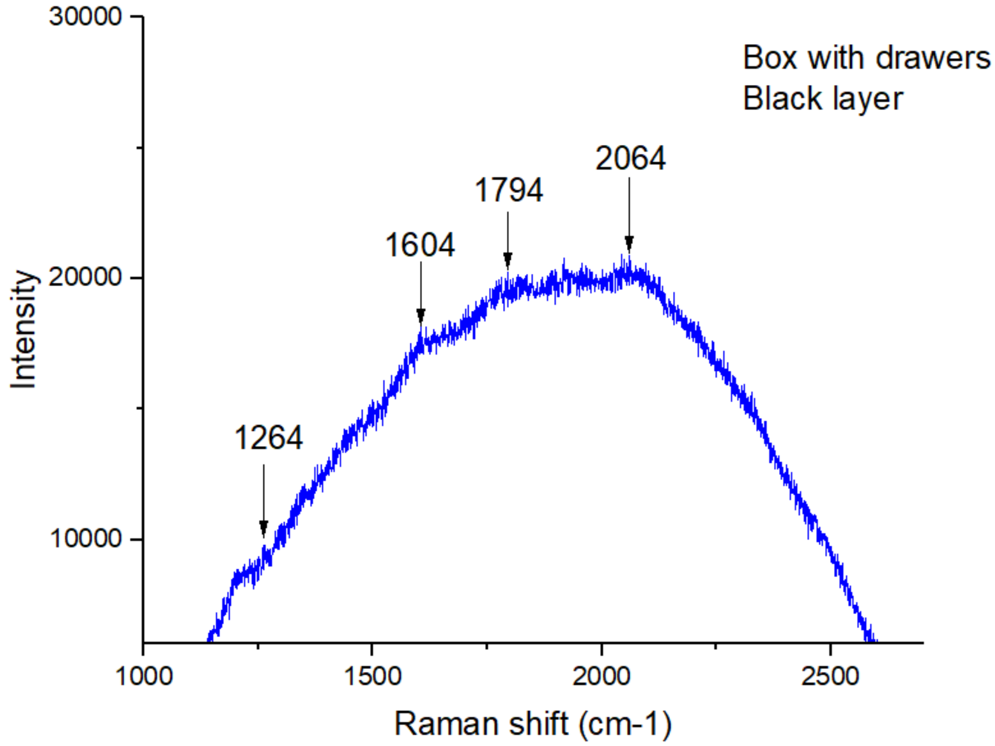


Raman Shift (cm^{-1})	Description
252	Main peak - Cinnabar (HgS)
287	Minor peak - Vibration mode of Cinnabar (HgS)
342	Minor peak - Vibration mode of Cinnabar (HgS)

The white spots on the red cinnabar lacquer layer can be explained by two possible reasons, while still exhibiting a strong cinnabar (HgS) signal in the Raman spectrum. First, crystalline cinnabar particles or micro-protrusions may be present on the surface, enhancing the Raman scattering signal. Although these areas may appear lighter or white to the naked eye, the crystallinity amplifies the characteristic Raman signal of cinnabar. Second, the white spots may result from the formation of secondary degradation compounds, such as mercurous chloride (Hg_2Cl_2, calomel), which typically forms when cinnabar is exposed to chlorine-containing compounds, humidity, or light. Calomel has a peak below 200 cm^{-1} (not detectable with our Raman set-up) and a second peak at 274 cm^{-1} which are in between the strong peaks of cinnabar at 252 and 287 cm^{-1}, therefore barely visible. Despite the white spots on the surface, the underlying cinnabar retains its Hg-S bonds, allowing the Raman spectrum to still detect the cinnabar signal.

2. Layer 3: Black layer (black areas, black-gray areas, transparent crystals)

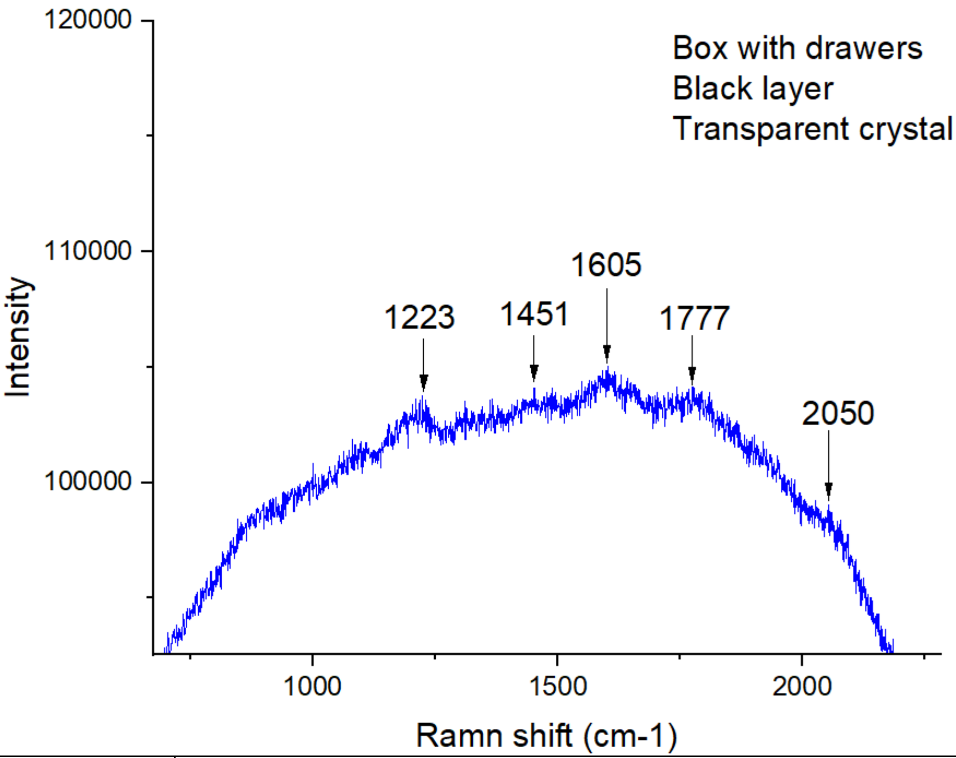
- **Layer 3 black areas**: 1264 cm⁻¹, 1604 cm⁻¹, 1794 cm⁻¹, 2064 cm⁻¹



Raman Shift (cm^{-1})	Description
1264	D-band - disordered carbon, possibly from carbon black or soot
1604	G-band - graphitic carbon, likely from carbon black or soot
1794	C=O stretching - carbonyl compounds from oxidation or degradation
2064	C≡C or C≡N triple bonds - trace impurities or amorphous carbon

The Raman spectrum of the black lower layer shows a strong fluorescence background with some broad carbon-related peaks at 1264 cm^{-1} (D-band) and 1604 cm^{-1} (G-band)(WU S., CHENG P., LI T., YANG Y., TIE F., JIN P. 2022), indicative of disordered and graphitic carbon, respectively. These features suggest the presence of carbonaceous materials, likely originating from traditional black pigments such as soot. The peak at 1794 cm^{-1} points to C=O stretching, potentially from carbonyl compounds formed through oxidation or degradation processes, while the 2064 cm^{-1} peak corresponds to C≡C or C≡N bonds, hinting at the presence of triple bond structures. These findings are consistent with the use of carbon black or soot in the lacquer layer, often produced by incomplete combustion of organic materials.

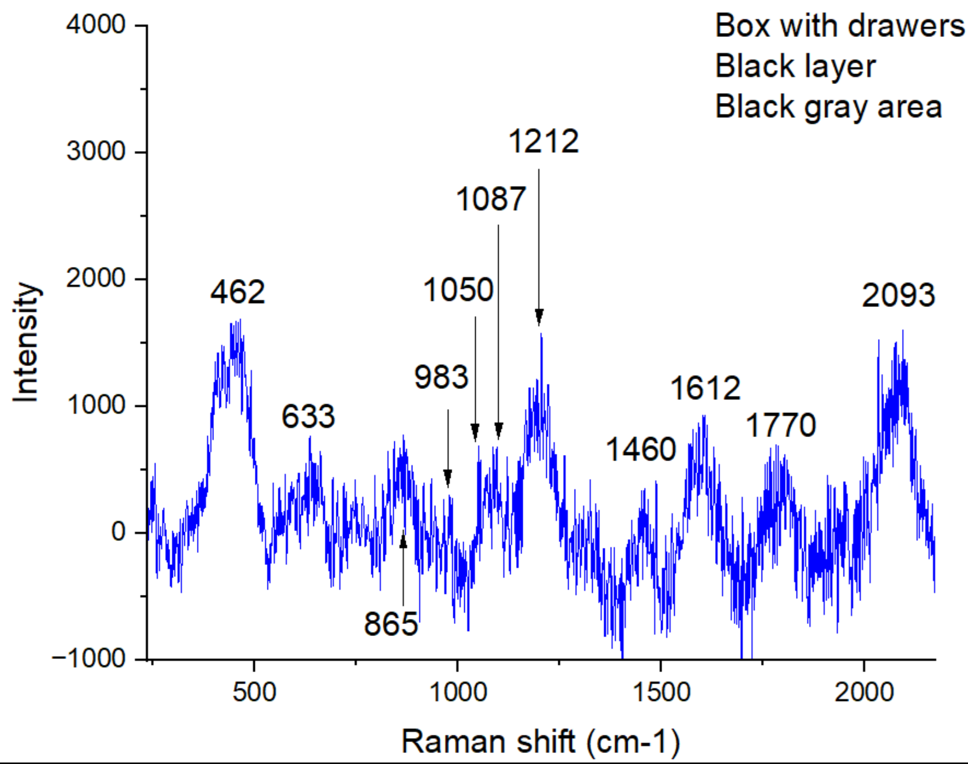
- **Layer 3 transparent crystal**: 1223 cm⁻¹, 1451 cm⁻¹, 1605 cm⁻¹, 1777 cm⁻¹¹, 2050 cm⁻¹



Raman Shift (cm⁻¹)	Description
1223	C-H bending - from the benzene ring in urushiol
1451	C-H bending or C=C stretching - double bonds and C-H in the aromatic ring of urushiol
1605	C=C stretching - aromatic ring in urushiol
1777	C=O stretching - carbonyl compounds from oxidation or degradation
2050	C≡C or C≡N

The Raman spectrum reveals characteristic peaks of lacquer, such as the C-O bond stretching at 1223 cm⁻¹ (1200-1300 cm⁻¹ range), associated with the structural features of organic components. Additionally, the C=C bond stretching at 1605 cm⁻¹ (1600-1650 cm⁻¹) from aromatic rings in urushiol and the C-H bending at 1451 cm⁻¹ (1400-1500 cm⁻¹) indicate alkyl chain structures within the lacquer. The C=O bond vibration at 1777 cm⁻¹ (1700-1800 cm⁻¹) suggests oxidation or aging, as it indicates an increase in oxygen-containing functional groups. Although the lacquer layer appears black, certain components like urushiol may crystallize into transparent crystals over time or under specific conditions, possibly due to the separation of organic components as black pigments settle or degrade. Another explanation is that the transparent crystal might be transparent urushi that did not fully mix with black pigments during the production process. The usage of refined transparent urushi in the upper lacquer layers in both Chinese and Japanese practices. The description and terminology are referenced earlier in Section "1.2.3 Manufacturing Process and Materials of Lacquerware."

- **Layer 3 black-gray area:** 462 cm^{-1}, 633 cm^{-1}, 865 cm^{-1}, 983 cm^{-1}, 1050 cm^{-1}, 1087 cm^{-1}, 1212cm^{-1}, 1460cm^{-1}, 1612cm^{-1}, 1770cm^{-1}, 2093 cm^{-1}



Raman Shift (cm^{-1})	**Description**
462	Quartz (SiO2)
633	Si-O-Al vibrational modes from clay
865	C-H bending - from organic compounds
983	C-C or C-O stretching - in organic materials
1050	C-C or C-O stretching - in saturated bonds or C-O in urushi
1087	Calcite ($CaCO_3$)
1212	Phenolic stretching - in catechol polymers of urushi
1460	Phenolic stretching - related to catechol in urushi
1612	C=C stretching - aromatic rings in urushiol or carbon black
1770	C=O stretching - carbonyl compounds from oxidation or degradation
2093	C≡C or C≡N triple bonds, suggesting trace impurities or amorphous carbon

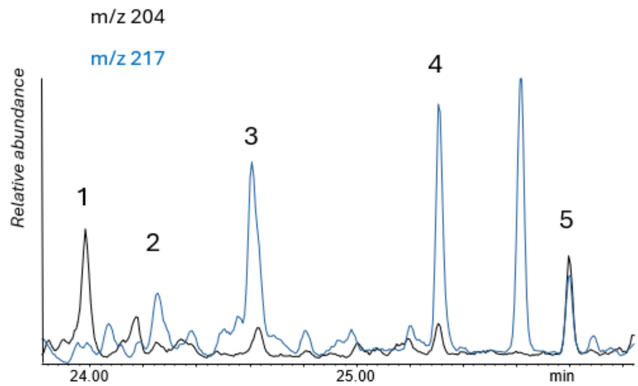
The Raman spectrum of the black-gray area reveals several characteristic peaks, indicating a complex composition. The 462 cm^{-1} peak corresponds to quartz (SiO_2), and 633 cm^{-1} is linked to Si-O-Al vibrational modes from clay. Organic components are suggested by 865 cm^{-1} (C-H bending) and peaks at 983 cm^{-1} and 1050 cm^{-1} (C-C or C-O stretching, possibly related to urushi).

The 1087 cm^{-1} peak confirms calcite ($CaCO_3$), while 1212 cm^{-1} and 1460 cm^{-1} reflect phenolic stretching in urushi's catechol polymers. The 1612 cm^{-1} peak is associated with C=C stretching in urushiol's aromatic rings and/or amorphous carbon black, and 1770 cm^{-1} suggests C=O stretching from oxidation products. Finally, the 2093 cm^{-1} peak, linked to C≡C or C≡N triple bonds, hints at trace impurities or amorphous carbon.

4.2.4 PY – GC/MS

Applied py – GC/MS on micro samples of Brush holder red lacquer sample (BHR), Brush holder black lacquer sample (BHN) and Box with drawers (DR).

All samples presented complex pyrolytic profiles, with pyrolytic markers of several organic materials. Figure 78 shows the extracted ion chromatograms (m/z 217 and 204) of sample BHN, where anhydro sugars, the pyrolysis products of a polysaccharide material, are clearly visible.



peak #	compound
1	1,6-anhydro-D-galactopyranose (2 TMS)
2	1,4-anhydro-b-D-glucopyranose (2 TMS)
3	1,6-anhydro-b-D-glucopyranose (2 TMS)
4	1,4-anhydro-b-D-glucopyranose (3 TMS)
5	1,6-anhydro-b-D-glucopyranose (3 TMS)

Figure 78: Extracted ion chromatograms of ions with m/z 217 and 204 for sample BHN. Peaks labelled with a number can be ascribed to the compounds reported in the table on the right. Mass spectra attribution was based on (MATTONAI M., TAMBURINI D., COLOMBINI M.P., RIBECHINI E. 2016)

A drying oil was also identified in the three samples, evidenced by the detection of palmitic and stearic acids, as well as short chain linear saturated and unsaturated monocarboxylic acids, peaking at 7/8 carbon atoms. These compounds are derived from the pyrolysis of an oil polymeric network (TAMBURINI D., et al., 2016). The extracted ion chromatograms (m/z 117) of BHN and BHR are shown in Figure 79.

Samples BHN and DR showed an analytical interference that prevented the efficient silylation of acidic moieties. As a result, azelaic acid, the primary oxidation product of a siccative lipid, was detected only at trace levels in BHN (Fig 79), while the pyrolytic profile of sample DR presented only non-derivatized fatty acids, as shown in the extracted ion chromatograms (m/z 60) in Figure 80.

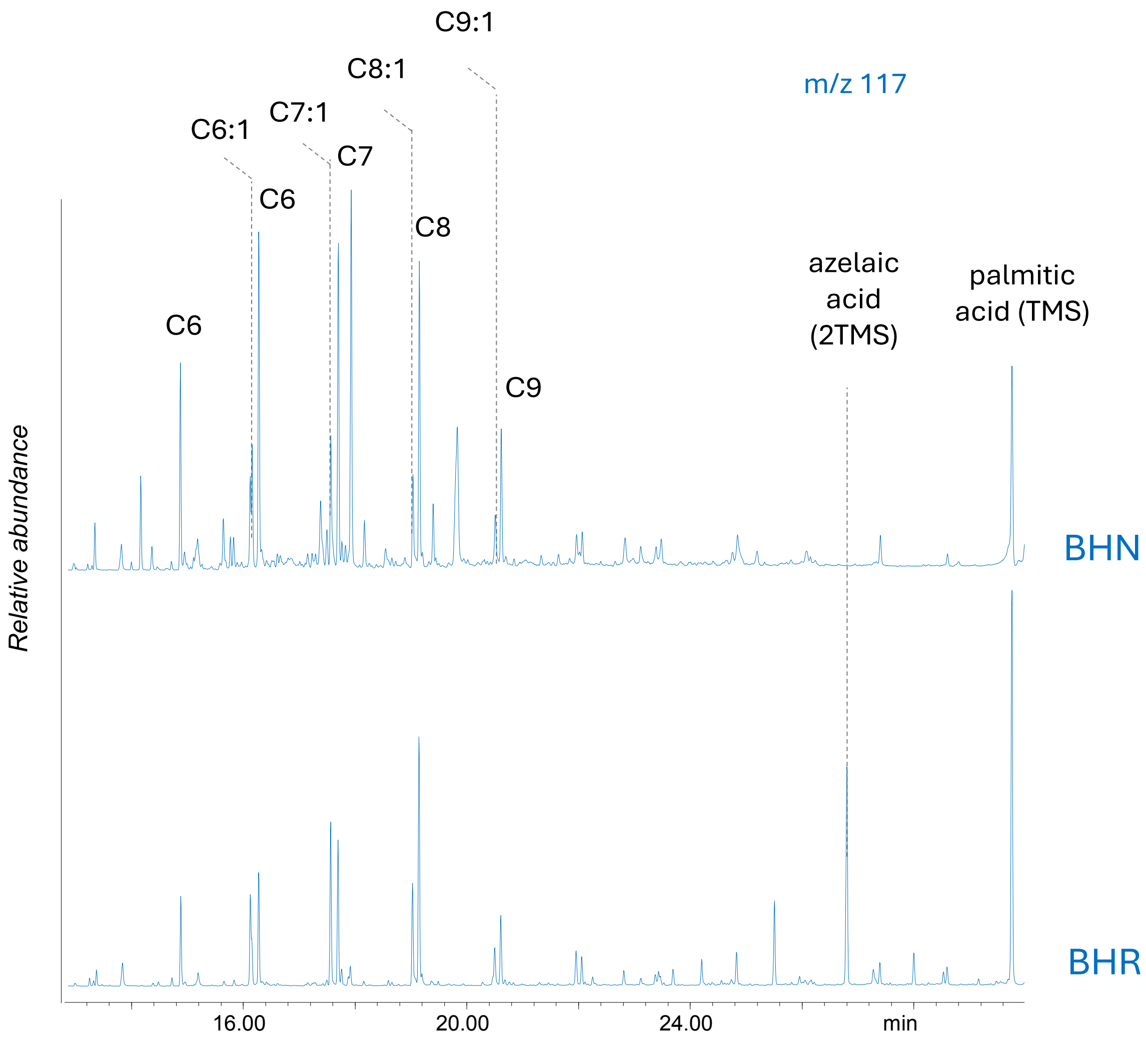


Figure 79: Extracted ion chromatograms of m/z 117 for samples BHN and BHR. Cn is the TMS derivative of a linear saturated monocarboxylic acid with n atoms of carbon. Cn:1 is a TMS derivative of a linear unsaturated monocarboxylic acid with n atoms of carbon and one unsaturation at position n.

Proteins were also detected in all samples. In particular, the presence of alkyl pyrroles and 2,5- diketopiperazines (with the most abundant being Cyclo(Pro-Gly)) enable the identification of animal glue (ORSINI A., PARLANTI F., BONADUCE I. 2017). Urushiol, which is from *Toxicodendron verniciflua* trees, was detected in all samples. Samples BHN and BHR shows the presence of mono-TMS alkylcatechols, with a peaking at 3-heptylcatechol (Fig 81) (TAMBURINI D., BONADUCE I., RIBECHINI E., GALLEGO C., PÉREZ-ARANTEGUI J. 2020).

Additionally, Mono-TMS 3-pentadecyl phenol and mono-TMS 3-pentadecenyl phenol, molecular markers of urushi, were also detected in samples BHN and DR (Fig 82) (TAMBURINI D. 2021).

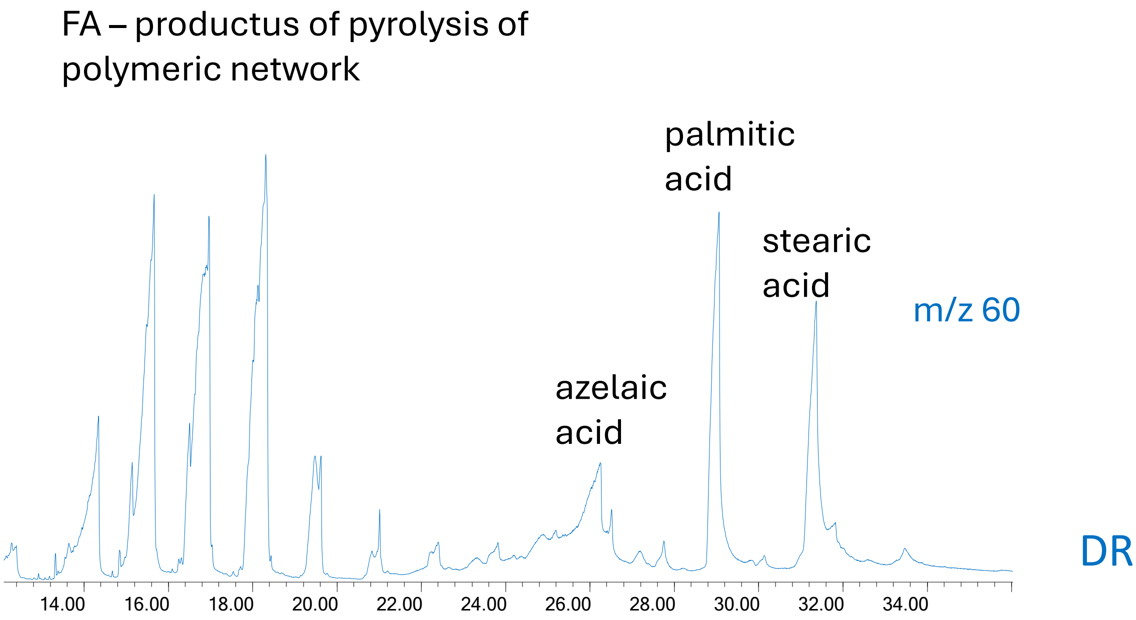


Figure 80.: Extracted ion chromatograms of m/z 60 for sample DR.

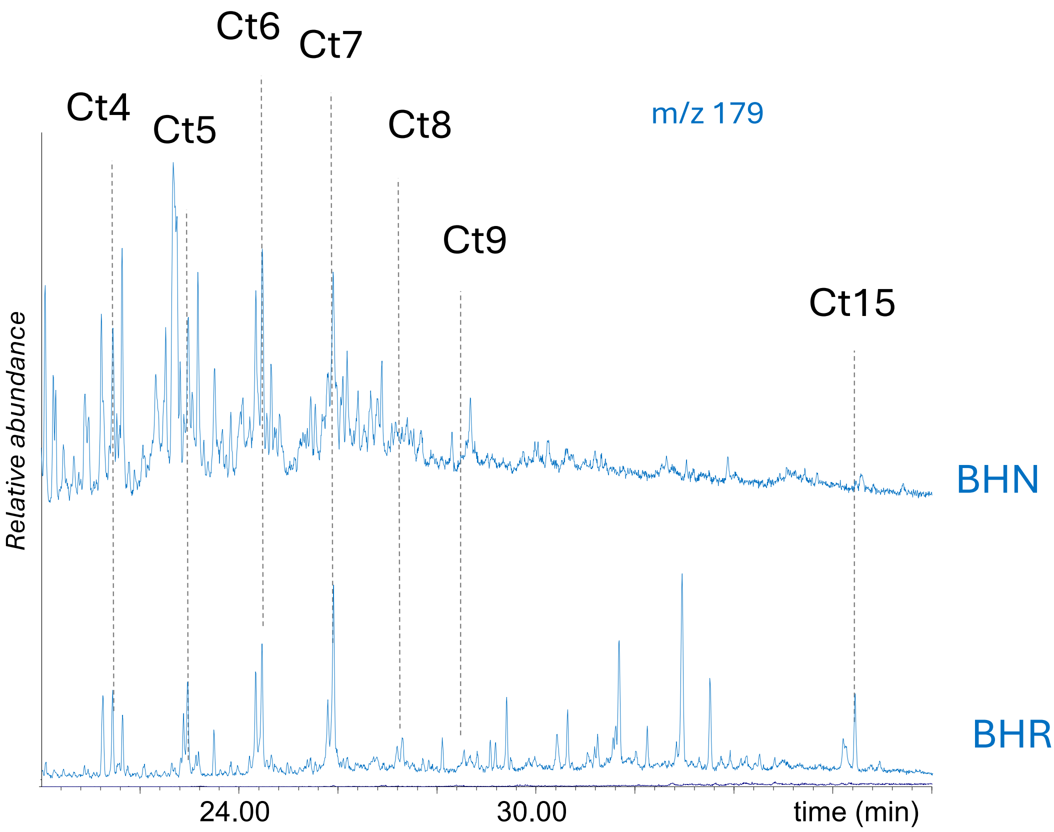


Figure 81: Extracted ion chromatogram of i*m/z* 179 for samples BHN and BHR, showing Ct4 (3-butylcatechol (TMS)), Ct5 (3-pentylcatechol (TMS)), Ct6 (3-hexylcatechol (TMS)), Ct7 (3-heptylcatechol (TMS)), Ct8 (3-octylcatechol (TMS)), Ct9 (3-nonylcatechol (TMS)), Ct15 (3-pentadecylcatechol (TMS)) and mono-TMS 3-pentadecyl phenol.

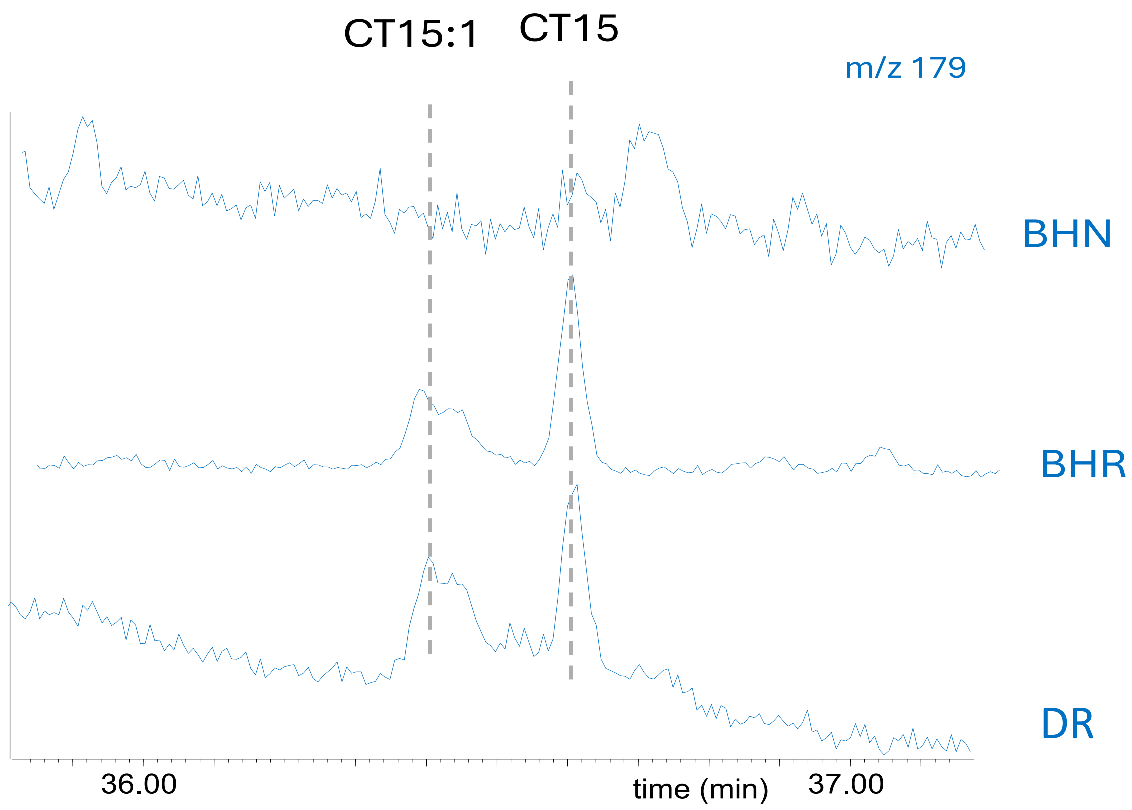


Figure 82: Extracted ion chromatogram of i*m/z* 179 for samples BHN and BHR and DR, showing mono-TMS 3-pentadecyl phenol and mono-TMS 3-pentadecenyl phenol

Molecular markers of an acrylic resin were detected in BHN, as well as acetins, which are typical plasticizers of polyvinyl acetate. The presence of synthetic materials explains the issues with silylation occurred during the analysis of BHN. The analytical interference observed also in sample DR suggest the simultaneous occurrence of synthetic materials. This hypothesis is supported by the presence of several peaks in the pyrogram, ascribable to aromatic molecules, although their full structures have not yet been elucidated. Further analyses are needed to confirm this hypothesis.

Sample	**Materials content**
BHN	Urushi, drying oil, animal glue, anhydro sugars, acrylic resin
BHR	Urushi, drying oil, animal glue
DR	Urushi, drying oil, animal glue

4.2.5 EPR

In figure 83 it is shown the CW-EPR spectrum acquired at room temperature on the fragment from the “Box with drawers”. The main signal is a single line centered at 340.8 mT, corresponding to a species with a g = 2.0045. The g-factor, analogous to the chemical shift in NMR, characterizes the type of radical, and the g-value for the observed signal perfectly matches the value expected for a catechol radical, like the urushiol. The asymmetrical line shape of the main signal also suggests the presence of small hyperfine couplings, as expected for catechol radicals, where hyperfine couplings with the ring protons are expected. In literature, catechol radicals of the type shown in figure 84(a) have been thoroughly investigated with CW-EPR (KALYANAMARAN B. et al., 1985) due to their biological relevance. To the best of our knowledge, however, a full EPR characterization of urushiol-type radicals (figure 84(b)) has not yet been carried out. The magnetic parameters for catechol derivative radicals as shown in figure 84(a) are known, and typical hyperfine couplings are between 0.02 and 0.08 mT for the H_a and H_c hydrogens (*ortho* hydrogens), while the hyperfine couplings with H_b (*para* hydrogen) and H_d (β-hydrogens) are between 0.3 and 0.5 mT. Starting from these values, the main signal in figure 83 could be simulated with a best fit procedure, with the parameters reported in table 05. Although not perfect, the simulation catches the main features of the signal, and the best-fitted values are close to the expected for catechol-type radicals.

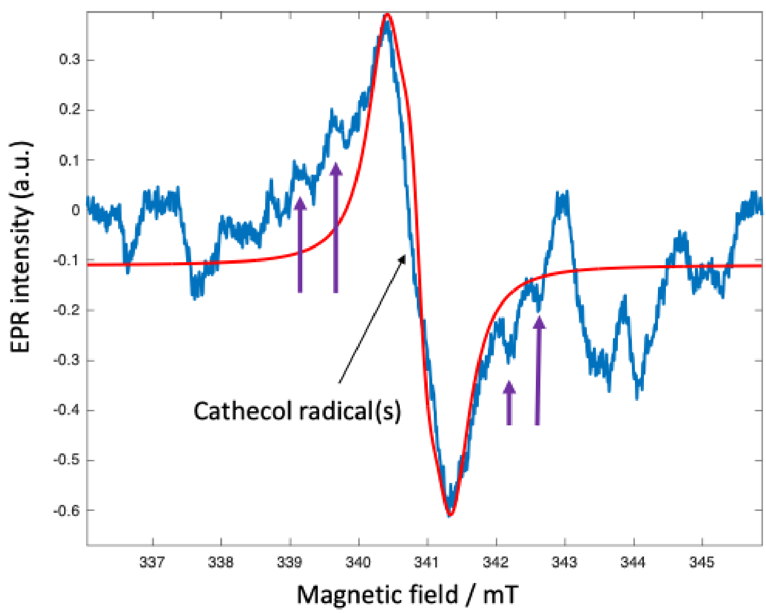


Figure 83: CW-EPR spectrum of “Box with drawers” fragment (blue line) with overlapped the simulation (red line).

Other signals are observed in the CW-EPR spectrum: the small lines, indicated by the purple arrows in figure 83, are symmetrically placed around the main signal, and could be related either to other catechol-type radicals characterized by strong hyperfine couplings or to radical dimers of catechols, as expected from radical-initiated polymerizations.

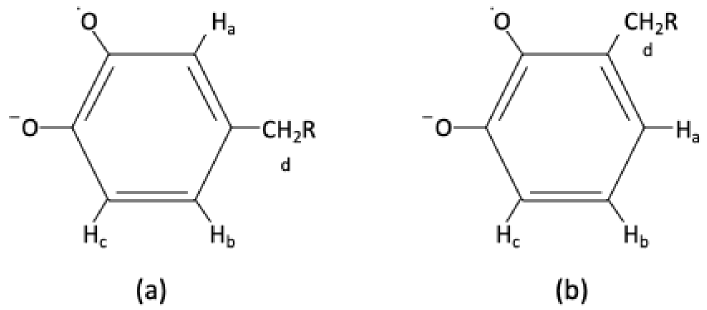


Figure 84: Chemical structure of biologically relevant catechol radicals (a) and urushiol radicals (b).

A_{Ha}	A_{Hb}	A_{Hc}	A_{Hd}	*g-factor*
0.76 mT	3.65 mT	0.76 mT	3.12 mT	2.0045

Table 05 Parameters used in the simulation of the CW-EPR spectrum (A = hyperfine coupling constant)

Chapter 5: Discussion

Overview of scientific methods applied to four lacquerwares:

	Brush holder	Fan shape box	Box with drawer	Polychrome plate
Digital microscope	O	O	O	O
FORS	O	O	O	O
ER-FTIR	O		O	O
Micro-ATR	O			
Micro-Raman			O	
SEM			O	
Py-GC/MS	O		O	
EPR			O	

Table 04 – Overview of scientific methods applied to four lacquerwares collections from Museo d'Arte Orientale

The main objectives of this study were: 1) to characterize the pigments and the chemical composition of the urushi lacquers; 2) to assess possibly their provenance based on historical-iconographic and scientific analysis.

In order to understand the pigments and chemical composition of the four lacquerware samples, we employed various techniques. Non-invasive techniques, like FORS and ER-IR were applied to get an overview in situ of the pigments and organic components (lacquer, additives) used in the manufacturing of the artifacts. For the fan shaped box, just FORS analysis was carried out. FORS showed that the red areas were probably realized mainly with cinnabar, or cinnabar-ochre mixtures, and maybe with some amount of minium.. In the polychrome plate, FORS indicated a rich palette of colours, with a different choice of pigments for the different type of reds. The border was realized with a mixture of ochres, whereas the red areas in the drawing were realized with cinnabar or maybe a mixture of cinnabar and minium. Yellow areas were probably realized with a complex mixture of pale yellow ochre (maybe a Sienna-type pigment) to give a yellow tone, combined with minium (orange) and cinnabar (red). Finally, the green areas showed a complex pattern, likely attributable to a mixture of indigo and a yellow pigment like orpiment or a yellow ochre. ER-IR analysis allowed us to characterize the organic component (additives and lacquers), identifying the presence of siccative oil together with main peaks related polymerized cathecols.

The presence of a small fragment from the Brush holder allowed us to cross the data from non-invasive (ER-IR, FORS) and micro-invasive techniques (micro-ATR, py-GC-MS) applied on the Brush holder, which allowed us to evaluate the reliability of non-invasive techniques in the identification of the main pigments and organic components. According to FORS, brown areas were likely produced as a combination of orpiment and minium, while the red parts were realized with cinnabar. No other information was available on the pigments, since SEM and Raman investigations were not carried out on the Brush holder fragment. However, cross-referencing the data of ER-FTIR, Micro-ATR, and Py-GC/MS provided key insights in the organic components. In ER-FTIR spectra of the Brush holder, the strong absorption signals from the lipid, likely related to a siccative oil, dominate the ER-IR spectra and overshadowing any signals from polymerized catechol. The micro-ATR spectra on the Brush holder fragment showed clear polymerized catechol, along with the signals of drying oil and proteins after chloroform treatment. Therefore, non-invasive ER-IR provided a positive identification of an additive (drying oil), although it was unable to spot a protein component. Also, a synthetic varnish was detected both with ER-IR and py-GC-MS in the black fragment of the Brush holder, again suggesting that ER-IR can spot also materials from restoration intervention on the lacquerwares. Also, microATR combined with chloroform extraction was able to detect all the components observed with py-GC-MS.

For the Box with drawers, the most complete analytical scheme was applied.

We cross-referenced the FORS, SEM, and Raman data to identify its pigments. FORS identified primarily cinnabar with traces of ochre, which was confirmed by SEM and Raman as cinnabar (HgS) in the surface layer. SEM further reveals that layer 2 contains a mix of clay particles, iron compounds, and cinnabar, suggesting the ochre signature may arise from the presence of iron compounds. This is a quite good indication that FORS, in spite of its simplicity, can give a good insight in the chemical composition of red pigments in lacquers. Cross-referencing the data of ER-FTIR, micro-Raman, and py-GC/MS we got a consistent picture, again confirming that non-invasive ER-IR can provide good indications about the organic parts: both ER-IR and py-GC-MS detected the presence of the drying oil, together with signals related to cathecol derivatives, although py-GC-MS detected also the presence of a gelatin glue. Micro-Raman was able to spot signals related to cathecol-derivatives.

The different components found in the examined objects are consistent with the compounds traditionally used in the manufacturing of the lacquerwares.

E.g., the detection of siccative oil is in agreement with the ancient literature from both Japan and China, which stated that several types of oils were used during lacquerware production, including linseed oil, tung oil, and perilla oil. Notably, in Chinese carved lacquer, the ratio of siccative oil to lacquer could be as high as 1:1. The use of oil served to improve workability and to slow down the lacquer polymerization process, providing artisans with more time to carve the lacquer.

Linseed oil was widely used due to its excellent binding and film-forming properties. However, it is prone to oxidation and may undergo chemical changes due to photo-oxidation, leading to the formation of oxidation compounds such as carboxylic acids. These compounds were also detected in our IR spectra, where they were spotted by the C=O stretching vibration. Tung oil was commonly used in lacquerware production for its durable coating properties, while perilla oil was employed to enhance the flexibility and gloss of the lacquer.

The presence of protein signals on the translucent fragment of Brush holder (micro-ATR after chloroform treatment and py-GC-MS) and the Box with drawers' fragment (py-GC-MS) is noteworthy. According to historical recipes, the protein additive could be either animal glue or egg whites. However, the remaining translucent fragment after chloroform treatment is more characteristic of animal glue, as egg whites are brittle and less likely to leave such residues.

Ancient texts like "Exploitation of the Works of Nature" *《天工開物》* (Tiāngōng Kāiwù) by Sòng Yìngxīng (宋應星) document the use of animal glue and other natural adhesives to enhance the structural integrity and decorative effects of lacquer objects. Animal glue, typically derived from animal skin, bones, or connective tissue, was used as an adhesive, while egg whites were applied to improve the smoothness and gloss of the lacquer surface. This combination of materials underscores the sophisticated techniques employed in lacquer production and highlights the balance between aesthetic and functional considerations in traditional craftsmanship.

The stratigraphical investigation of the Box with drawers fragment with SEM and Micro-Raman highlights further details on the production technique of this object: a first, thin layer (Layer 1) showed the presence of cinnabar, according to SEM. A second red layer (layer 2) was a mix of cinnabar, iron oxide, and clay particles in a lacquer matrix, according to the consistent SEM and micro-Raman results. The bottom layer 3, a black layer was a mix of carbon black pigment and powdered clays in a lacquer matrix, well matching the ancient receipt of making base coat in China or the foundation layer in Japan. In China, the base coat is called 灰漆"huī qī" (Lacquer plaster): Lacquer plaster is a mixture of lacquer and sieved powdered horn, clay, or shell. In Japan, lacquer foundation is called"漆下地 urushi shitaji", which uses raw urushi mixed with one or both of two types of powdered clays: "地の粉 jinoko" and "砥の粉 tonoko". "地の粉 jinoko", also referred to as "地粉 Chiko", is made from natural minerals such as clay, gypsum, tile ash, or other similar materials, which are crushed and sieved to form a uniform fine powder. "砥の粉 tonoko", also known as "砥粉 Toiko", is primarily composed of natural minerals like quartz, shale, and diatomaceous earth.

A CW-EPR spectrum at room temperature of the "Box with drawers" fragment was acquired. The spectrum showed a weak signal whose position could be assigned with precision to catechol-type radicals, which are typically expected in the radical-initiated polymerization of urushiol. A complete and reliable simulation of the signal could not be carried out, due to the weakness of the signal, and the significant line broadening, but further investigations at lower temperature (80 K) should allow a better signal to be obtained. Even so, starting from EPR parameters typical for catechol-type radicals, a first simulation was in good agreement with the experimental spectrum. The successful acquisition of a CW-EPR spectrum for a catechol radical in an urushi lacquer fragment from a true artifact paves the way for further EPR investigations on similar lacquer debris. EPR characterization could be useful both for an evaluation of the radical pattern, related to urushi polymerization and degradation, and for a possible tracing of lacquer origin.

This comprehensive scientific approach allowed us to understand the capabilities and limitations of different scientific instruments when applied to lacquerware analysis. Crossing data provided us a whole picture of the material usage in lacquerware. The result of the pigments and organic materials correlate with traditional recipes for high-quality lacquerware craftsmanship. The results demonstrate that cinnabar was used as a main pigment. Additionally, the foundational layer, made of clay powder mixed with urushi, provided a highly durable base.

The second aim of this thesis was to determine the provenance based on historical-iconographic and scientific analysis.

Japanese and Chinese carved lacquerware have been both produced from ancient times to the present, with their techniques and appearances exhibiting significant similarities. Typically, determining whether a piece is of Chinese or Japanese origin relies on analyzing its function or decorative elements. This is due to the extensive historical exchanges and trade between the two countries, which have led to highly similar crafting techniques. The comparison of the aesthetic styles in Japanese Edo period and Chinese Qing-dynasty craftsmanship of lacquerware is as follows:

Chinese lacquerware from the Ming and Qing dynasties is renowned for its lavish and intricate decorations, reflecting the grandeur of court art and the high standards of mass production. Carved lacquer, a highlight strongly advocated by early Qing emperors, features multiple layers of lacquer, creating rich textures and vivid colors. Common decorative themes include classic literary stories such as “Dream of the Red Chamber” *《紅樓夢》*, “Journey to the West” *《西遊記》*, and “The Seven Sages of the Bamboo Grove” *《竹林七賢》*, as well as auspicious motifs of flowers, dragons, phoenixes, and landscapes. These works emphasize symmetry and precision, embodying the court's pursuit of luxury, order, and authority, closely aligned with the political and cultural context of the time. Lacquerware was primarily produced in royal workshops, used mainly for court ceremonies and imperial life as symbols of status, and rarely integrated into everyday life among the general populace.

In contrast, the decorative styles of Japan’s Edo period can be broadly divided into two schools. The mainstream aesthetic favored opulence and flamboyance, as seen in ukiyo-e prints, kabuki, and luxurious lacquerware, epitomizing the dazzling "Edo taste" 江戸好み(Edo-gonomi). This style reflected the era's flourishing consumerism and hedonism. On the other hand, wabi-sabi, a Zen-influenced aesthetic, emphasized imperfection, simplicity, and the beauty of nature. During the Edo period, wabi-sabi permeated tea ceremonies, literature, art, and garden design, providing a sense of simplicity and tranquility in contrast to the era's extravagance, helping individuals reconnect with their inner selves and nature. It became a widely embraced lifestyle and aesthetic (GRAHAM P. 2014).

Lacquerware from the Edo period reflects these dual influences of Japanese aesthetics. The "Edo taste" emphasized lavish decoration and refined craftsmanship, with common themes including characters from ukiyo-e stories or intricate floral patterns, showcasing the prosperity of material culture. Meanwhile, under the influence of wabi-sabi, decorative themes often featured natural elements like cherry blossoms, bamboo, and maple leaves, emphasizing abstraction and negative space, embodying harmony and nature. Techniques like maki-e (gold lacquer) and mother-of-pearl inlay were particularly prominent. Compared to Chinese carved lacquer, Edo-period carved lacquer was often thinner and more restrained in color, typically applied to smaller items such as inro (medicine cases), incense boxes, and tea utensils. These pieces were widely used across all social classes, combining practicality with artistic value, and enjoyed broader popularity compared to Chinese lacquerware.

According to the contents of Chapter 2, which based on iconographic analysis, stylistic analysis, and comparisons with other existing artworks, the four carved lacquerware pieces studied in this thesis are more likely to have been produced in China, because their decorative motifs align more closely with the traditional craftsmanship of Ming and Qing Dynasty lacquerware. However, this conclusion requires further validation through scientific analysis. The following section discusses the cross-comparison of data derived from scientific methodologies.

Although Chinese and Japanese lacquerware traditionally use urushi, but if a mixture of different types of oriental lacquers is found, the origin can be inferred based on the composition. According to the description above, if the samples reveal a mixture of urushi and laccol, it can be concluded that the lacquerware was more likely produced in China. Conversely, if the samples reveal a mixture of urushi and thitsi, it can be concluded that the lacquerware was more likely produced in Japan. (HEGINBOTHAM A., SCHILLING M. R. 2009) (SCHILLING M. R., CHANG J., KHANJIAN H., HEGINBOTHAM A., et al. 2014) (INSTITUTE OF HISTORY AND PHILOLOGY. 1962) Due to this reason and also due to the micro-sized samples from natural degradation, we opted for Py-GC/MS, which complements IR data and distinguishes between different types of lacquer trees. However, according to the result of Py-GC/MS, three samples from the Brush Holder and Box with

Drawers were found to be made purely of urushi, without any laccol or thitsi mixed. This indicates the highest quality craftsmanship but does not definitively confirm whether the lacquerware originated from China or Japan. As the provenance still not proved by Py-GC/MS, future studies to determine provenance between China and Japan could be 87Sr/86Sr Isotope. Due to the micro-sized samples from natural degradation, we could not perform Sr isotope analysis. (LU R., HONDA T., 2023) (NAKAGAWA R., NAKAI S., 2023).

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Appendix

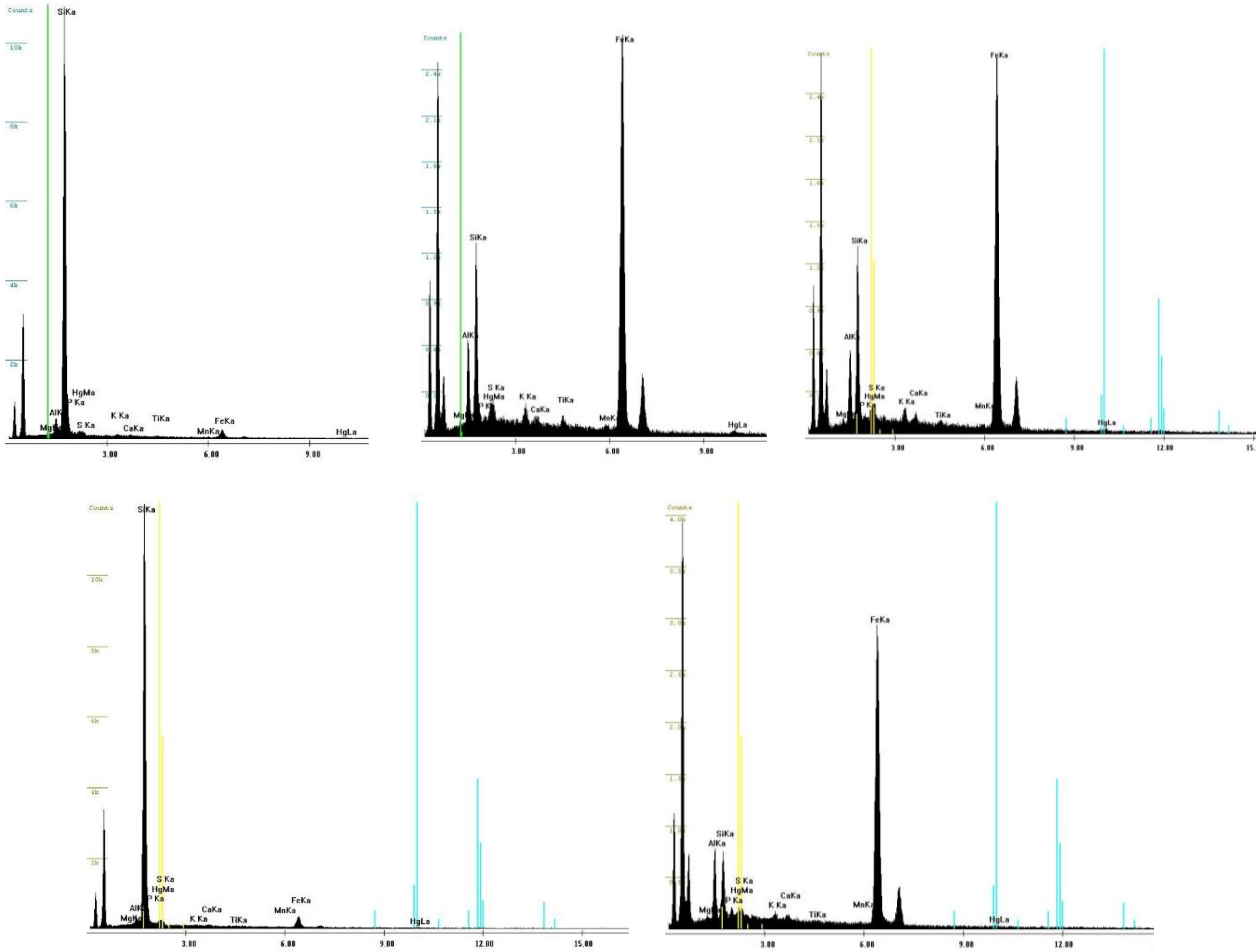

Figure 85 – Left to right: EDS of the particles at area C with labeled regions (a), (b), (c), (d), and (e).

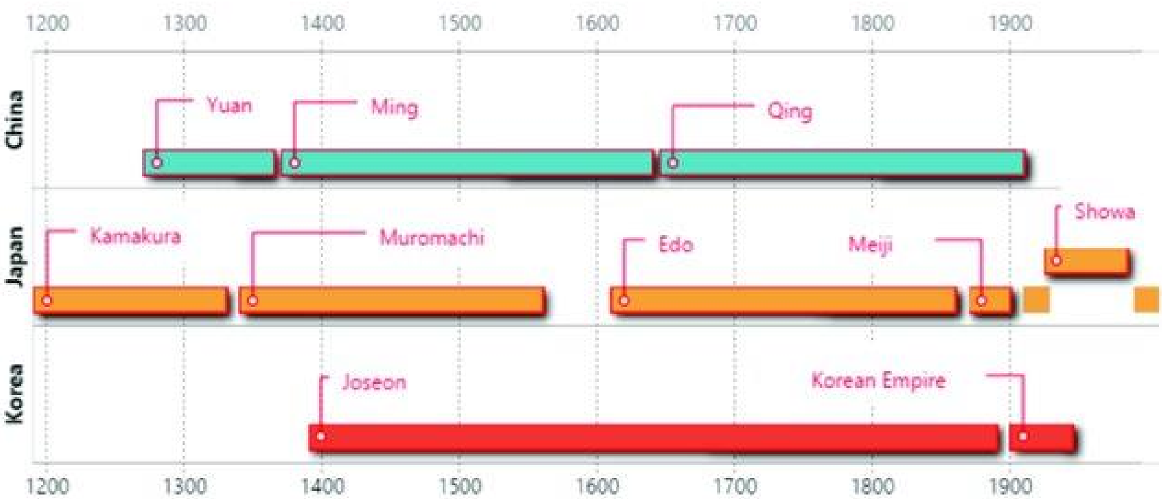

Figure 86 – Historical Period Comparison of China, Japan, and Korea. (by Xiaogang Ma)

Chinese lacquer history: (LIU L., FU J. 2023) (LI W. 2023)

夏 Xia Dynasty	2,146BC – 1,675BC	- Earliest Lacquerware found at the Neolithic Hemudu site, Zhejiang, 7,000 years ago: a wooden bowl with cinnabar lacquer. - Neolithic Era: Lacquerware, mainly wood and pottery, layered to oxidize black; cinnabar added for red, establishing these as key colors in ancient lacquer art. - Tribute Item: Lacquer was used for making items for the ruling class.
商 Shang Dynasty	1,675BC – 1,029BC	Here are the points translated and simplified in English: - Red lacquer as the base, with black lacquer painted in patterns. - Many lacquerwares show clear influences from bronze artifacts, with motifs and patterns inspired by bronze culture. - Techniques such as gilding, carving, and inlay were pioneered, laying the foundation for later Han and Tang "gold and silver relief" crafts. - Lacquered and carved wooden items also featured inlays of polished shells and jade.
西周 Western Zhou Dynasty	1,029BC – 771BC	- Book *"Record of Examination of Crafts"《考工記》 (Kǎo Gōng Jì)* record lacquer's anti-corrosion and moisture resistance, vehicle lacquer standards, and lacquer-specific tax laws. - Techniques: Base-making, carving, lacquering, painting, inlay (e.g., gilded and turquoise-inlaid lacquer). Added mineral pigments to make different colors. - Lacquerware complexity craftsmanship shows social status, often part of ritual sets with bronzeware and jade ware.
春秋 Spring and Autumn Period	770BC – 476BC	- Lacquerware replacing heavy, corrosion-prone bronze. - Lacquerware expanded and applied to stationery, instruments, weapons, tableware, furniture, burial items, and transportation. - Patterns evolved from traditional bronze motifs to include animals, clouds, and geometric designs. - Before Shang and Western Zhou, lacquerware was limited to Central Plains and mid-Yellow River regions; by the Spring

		and Autumn period, it spread to the lower Yellow and Yangtze River areas. - Wooden lacquerware includes carved wood and mortise-and-tenon joint pieces.
戰國 Warring States Period	475BC – 221BC	- Not relying only on wild lacquer trees, official lacquer gardens were established. - Seven main lacquer colors: red, black, yellow, blue, brown, gold, and silver. - Birth of the "戧金 qiangjin" and "戧銀 qiangyin" techniques: patterns were carved on lacquer, filled with lacquer, then inlaid with gold and silver powder.
秦 Qin Dynasty	221BC – 207BC	- The Qin Dynasty was China's first unified, centralized state, standardizing currency, measurements, and writing. It established strict standards for lacquerware, with artisans marking their names on pieces to ensure accountability.
西漢 Western Han Dynasties	206BC – 8AC	- The thick wooden base of lacquerware is becoming thinner. - Lacquerware and related industries hold high commercial value.
東漢 Eastern Han Dynasties	9AC – 23AC	- Cost-effective ceramics began to rise, leading to a gradual decline in lacquerware production.
三國魏晉南北朝 Three Kingdoms, Wei, Jin, The Northern and Southern Dynasties	220AC – 581AC	- Frequent wars and extreme social unrest led to very low lacquerware production and limited scale; few pieces from this period have survived. - Lacquer characteristics: "犀皮漆 xipi lacquer", "斑漆 mottled lacquer" and the "夾苧 jiā zhù" technique for making statues (popular in the Northern and Southern Dynasties, less used after early Tang, though many ancient Japanese Buddha statues are made with this method, In Japanese called "kan-shitsu").
隋唐五代 Sui and Tand Dynasty	581AC – 979AC	- The Tang Dynasty was powerful, with a thriving economy and culture, and engaged widely in international exchanges. Notable crafts included ceramics, silk, tea, and lacquerware, often featured in poetry and historical texts on tributes and taxes.

		- Lacquerware became luxurious, with techniques like gold and silver inlay, mother-of-pearl, and carved lacquer. Buddhist statues and musical instruments were popular lacquered items. - Gold and silver inlay was popular among elites but banned by two emperors, leading to its near disappearance by the Song Dynasty. - Mother-of-pearl and dry-lacquer techniques flourished but declined after two Buddhist bans, with dry-lacquer lost until the Qing Dynasty.
宋代 Song Dynasty	960AC – 1,279AC	- The national policy of "esteeming literature and restraining military power" led to the southward migration of skilled craftsmen, bringing handicraft production to a historic peak. - Song dynasty culture embodied an elegant, serene, and natural aesthetic, valuing simplicity and subtlety, contrasting sharply with the Tang dynasty's preference for richness and opulence.
元代 Yuan Dynasty	1,206AC – 1,368AC	- Yuan Dynasty lacquer art reached its peak in mother-of-pearl inlay, gold engraving, and carved lacquer, with some considering carved lacquer as its representative achievement. - The vibrant orange-red color is a typical hallmark of Yuan Dynasty lacquerware. - A new "soft mother-of-pearl" technique emerged in Yuan Dynasty lacquer art, favoring thinner and more transparent inlays. High-end lacquerware for wealthy families was often adorned with various colored gemstones in addition to mother-of-pearl.
明代 Ming Dynasty	1,368AC – 1,644AC	- Historical records show that the Ming dynasty emphasized the production of imperial lacquerware, with various government offices assigned to specific lacquer processes. After Emperor Yongle moved the capital to Beijing, he established the Orchard Factory, recruiting skilled artisans to produce lacquerware for the imperial court. The descendants of Zhang Cheng, a renowned Yuan dynasty lacquer artisan, were appointed to manage the Orchard Factory, specializing in carved and inlaid lacquer. The inner court also maintained the

		Dingzi Warehouse, stocked with raw materials like raw lacquer and tung oil. - Chinese carved red lacquer techniques were introduced to Japan. Emperor Yongle even sent lacquerware gifts to the Japanese king, including hundreds of carved red lacquer plates, measuring rulers, and incense boxes. - "Records of Lacquering" *《髹飾錄》 (Xiūshì Lù)"* written by 黃成 Huang Cheng
清代 Qing Dynasty	1,616AC – 1,911AC	- During the late Ming and early Qing periods, carved lacquer briefly disappeared but was successfully revived in the Qianlong era, becoming the pinnacle of Qing lacquer artistry. - In the 276-year Qing Dynasty, lacquerware from the Kangxi, Yongzheng, and Qianlong reigns was the most exquisite, reflecting the grandeur and characteristics of the "Kang-Qian Golden Age." - Ming Dynasty vs. Qing Dynasty Carved Lacquer: - Ming Dynasty: Dark red, wood base. - Qing Dynasty: Bright red, materials expanded from wood to ceramics, copper, etc., often combined with other techniques. Designs became intricate, with thicker lacquer layers, more depth, and a stronger sense of relief. Qing carved lacquer style was likely influenced by folk customs and the strict imperial examination system, emphasizing hierarchy and rules. This focus on technical intricacy gradually led to a decline in creative spirit.

Japanese Lacquer History: (TSUTOKI K., KUDO S., NISHIKAWA H. 2018**)**

繩文時代 じょうもんじだい Jomon Period	14,000BC - 300BC	- Late Paleolithic to Neolithic period in Japan. - In Hokkaidō, over 9,000 years ago, lacquer was used to coat garments and bamboo containers, as well as for decorations. - Flame patterns were common.

彌生時代 やよいじだい Yayoi Period 古墳時代 こふんじだい Kofun Period	300BC - 250AC 250AC - 538AC	- As rice cultivation developed, society became more stable. Lacquer was widely applied to agricultural tools, fishing tools, and daily necessities. - Lacquerware developed with carved wood and woodturning craftsmanship.
飛鳥時代 あすかじだい Asuka Period	592AC - 710AC	- Practicality combined with art. - Influenced by China (early Tang Dynasty), temple architecture, Buddhist instruments, and statues demanded large quantities of lacquer. Official lacquer art institutions were established to support production and taxation.
奈良時代 ならじだい Nara Period	710AC - 794AC	- Kanshitsu Technique (Dry Lacquer Technique) - 正倉院 Shōsōin Repository preserves artifacts from the Tōdaiji Temple, including records of lacquerware production techniques. - Attaching finely carved gold and silver foil patterns onto thin wooden panels using lacquer as adhesive.
平安時代 へいあんじだい Heian Period	794AC – 1,185AC	- Techniques such as 蒔繪 maki-e (sprinkling gold or silver powder) and mother-of-pearl inlay emerged. - Monks at Negoro Temple in Kii Province created their own lacquerware, known as 根来塗（ねごろぬり）Negoro lacquer. - In the late Heian period, temples used thin shells with maki-e decorations.
鎌倉時代 かまくらじだい **Kamakura Period** 室町時代 むろまちじだい Muromachi Period	1,185AC – 1,333AC 1,336AC – 1,573AC	- Influenced by Chinese artifacts, called as “唐物” karamono (can be translated as "Chinese goods" or "Chinese-style items"), such as carved lacquer, gold inlay technique and designs, which passed down from the Song, Yuan, and Ming dynasties of China.

安土桃山時代 あづちももやまじだい Azuchi-Momoyama period	1,568AC – 1,603AC	- Decorative techniques: flat maki-e raised maki-e and Nashiji technique became prominent. - 尾形光琳 Ogata Korin (1658-1716) - 本阿弥光悦 Honami Kōetsu (1558-1637) - Western European envoys visited, many lacquerware items suited to Western tastes, such as reading tables and Catholic/Christian cabinets, were exported.
江戶時代 えどじだい Edo Period	1,603AC – 1,868AC	- Japan's sakoku (closed country policy) led to a distinctive Japanese style that emphasized decoration. - Swords of the Samurai Spirit (Lacquer Used on Scabbards) Techniques and types: - 津軽塗 Tsugaru-nuri : layered lacquer - 輪島塗 Wajima-nuri: Local diatomaceous earth for strong durability - Kyoto: 蒔繪 Maki-e - Kanazawa: Gold powder, gold leaf - 若狭塗 Wakasa-nuri: Eggshell + silver leaf - 春慶塗 Shunkei-nuri: Highly transparent lacquer applied on cypress wood.
明治維新 めいじいしん Meiji Ishin	1,868AC – present	- Japanese lacquerware gained high praise abroad, Government stablish lacquer craft department, participating in world fairs. - 民芸運動 Mingei movement (folk art movement) (1,880 – 1,961) initiated by 柳宗悦 Soetsu Yanagi, also played a role in preserving the craft. - During World War II, lacquer became scarce, but the post-war period, lacquerware become a luxury item.