

Techniques of Wallpaper (*Biao Hu*) in the Palace Museum: A Case Study of the Lodge of Bamboo Fragrance (*Zhuxiang Guan*)

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Abstract: *Biao Hu* was one of the eight famous traditional crafts in the late Qing dynasty. This skill involved decorating the interiors of ancient buildings such as ceilings, walls, and windows and creating burial objects. It was primarily used for wooden buildings in northern China during the early Qing dynasty. For example, there is white-patterned wallpaper in the Forbidden City utilizing both traditional and nontraditional patterns. Moreover, there was wallpaper with a special pattern in the Lodge of the Bamboo Fragrance (*Zhuxiang Guan*). Its structure and composition were studied via morphological observations and spectral analyses, the pigments and dyes were analyzed by Raman spectroscopy and ultra-high performance liquid chromatography-mass spectrum (UPLC-MS). Traditional technology and exchanges between China and the West were discussed by the study of patterned wallpapers in other buildings of the Forbidden City.

Keywords: the Palace Museum; wallpaper; wooden structure

Received: 31 May 2023; accepted: 26 June 2023; DOI: 10.26599/PBM.2023.9260015



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1 Introduction

The traditional crafts in ancient China are named *Ying Zao*; notably, *Biao Hu* was one of the eight crafts in the late Qing dynasty ^[1], which composed of tiles, wood, stone, scaffolding (building frameworks for ancient buildings), soil, oil paintings, colored paintings, and wallpaper. *Biao Hu* refers to the pasting of papers or textiles onto ceilings,

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walls, and windows, and is used to decorate buildings. In particular, *Biao Hu* was widespread in wooden buildings in northern China during the early Qing dynasty^[2]. This has been extensively documented in the historical archives of the Ming (1368–1644) and Qing (1636–1912) dynasties. As northern China often experiences wind, wallpaper can block sand and dust. It can also help prevent the spread of cold from the plaster on the wall and improve luminosity. Given this, numerous kinds of wallpapers have remained in the Forbidden City, including multiple decorative patterns, most of which were green dragons with “卍” characters, twigs, lotuses, and “prolonging life” patterns. All of these are Buddhist symbols of happiness and longevity.

Chinese wallpaper, once an essential part of interior decoration in Europe^[3], was also exported to Europe for commerce purposes, mainly by Canton wallpaper painters. A few scholars have conducted studies on Chinese wallpaper. For example, hand-painted wallpaper belonging to a private Portuguese collection was analyzed^[4] and the destruction of paper by green copper pigments in Chinese wallpapers has also been investigated^[5].

Zhuxiang Guan is located in the northwest corner of the fourth courtyard of Qianlong Garden (Fig. 1). It was built in the 37th year of the Qianlong period (1772) during the Qing dynasty, imitating the *Bilin Pavilion* of the Palace of Established Happiness (*Jianfu Gong*)^[6]. It is divided into two floors and connected to *Juanqin Zhai* and *Yucui Xuan*. On the ceiling of the second floor in the southern cubicle of *Zhuxiang Guan*, the wallpaper was decorated with roses, which were rare in the Palace Museum (Fig. 2). This was entirely removed during conservation. Therefore, a patterned wallpaper was

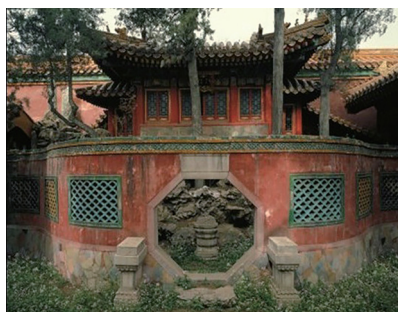


Fig. 1 Exterior of *Zhuxiang Guan*



Fig. 2 Patterned wallpaper in *Zhuxiang Guan*

investigated in this study.

During the investigation of the Palace Museum wallpaper, such as *Yangxin Dian*, numerous types of patterns were found. Two samples of traditional and synthetic pigments from *Yangxin Dian* were discussed and compared with the wallpaper from *Zhuxiang Guan*.

2 Materials and methods

The wallpaper is fragile and yellow in color. Cracks and losses are observed in Fig. 3. It can be divided into five layers; the pattern of the outermost layer being roses and the others presenting the images of twigs.



Fig. 3 Sample of patterned wallpaper in *Zhuxiang Guan*

In this study, two patterned wallpaper types in the Palace Museum were analyzed: one in *Zhuxiang Guan* and the other in *Yangxin Dian*. The structure of the wallpaper was examined based on cross-sectional observations under visible (Vis) and ultraviolet (UV) light. Microbeam X-ray fluorescence spectroscopy

(Micro-XRF) imaging was used for elemental imaging; the pigments were observed under a polarizing microscope; and the dye was analyzed by ultra-high performance liquid chromatography-mass spectrum (HPLC-MS). The fiber morphology was observed under a microscope. In an investigation of patterned wallpaper in *Zhuxiang Guan* and *Yangxin Dian*, it was found that some of the outermost layers used synthetic dyes and the paper was made of wood pulp. As such, this may be related to the communication between China and the West.

3 Scientific analysis

3.1 Optical observation

The samples were collected from the edge of the wallpaper and were then embedded in Technovit® 2000LC ultraviolet curing resin (Kulzer Technik) and polished after UV curing for 30 min [7]. Observed under visible and UV light by Leica 4000M, it could be divided into at least five layers (Fig. 4).

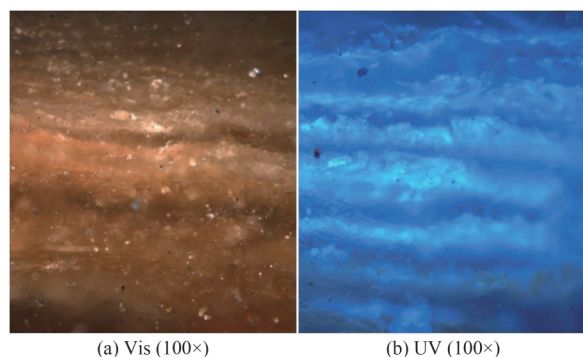


Fig. 4 Microstructure of cross section

The pigment and fiber structures were observed under a microscope. For instance, the colors of the red pigment and paper fiber appeared different in the fifth layer (outermost layer), and the second layer requires a more intensive study (Fig. 5).

3.2 Composition and materials

3.2.1 Analysis of the fifth layer

The distribution of the elements on the surface of the patterned wallpaper was analyzed using Micro-XRF imaging. The red vein lines of the flowers contained barium (Ba), the light brown leaves mainly contained chromium (Cr), and the white part of the flower was

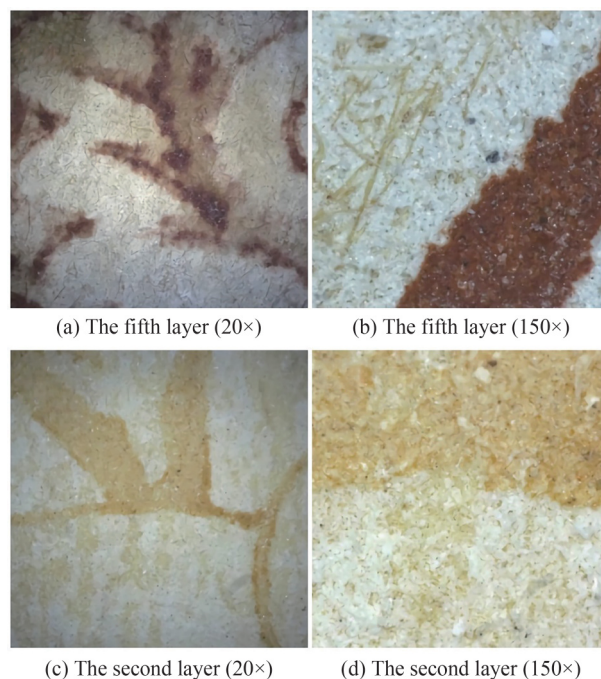


Fig. 5 Microscopic morphology of the wallpaper

rich in calcium (Ca). The distribution of iron (Fe) corresponded to the red decoration under the surface layer, as shown in Fig. 6. A white pigment containing Ba may be mixed with red dye to draw a red vein. Chrome yellow may be used in light-brown leaves, and the distribution of Fe in each layer was analyzed.

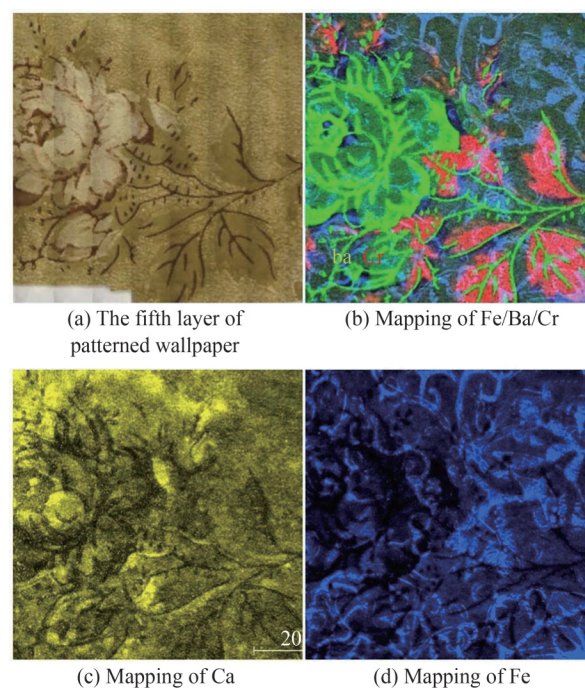


Fig. 6 Micro-XRF imaging analysis of the fifth layer of patterned wallpaper

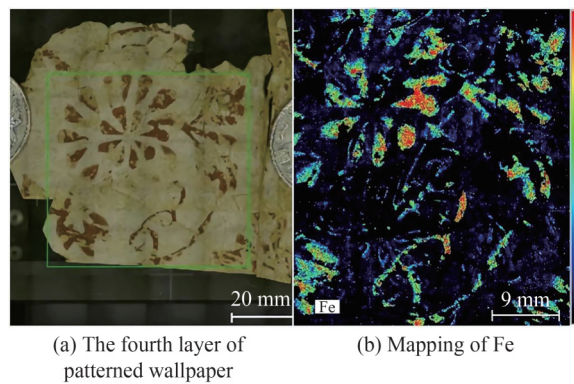


Fig. 7 Micro-XRF imaging analysis of the fourth layer of patterned wallpaper

Considering the fourth layer as an example, it was mainly present in the red pigment (Fig. 7).

Red and brown samples from the fifth layer were observed using a polarizing microscope (Leica 4500P) [8] (Fig. 8). Organic dyes may have been used for the red

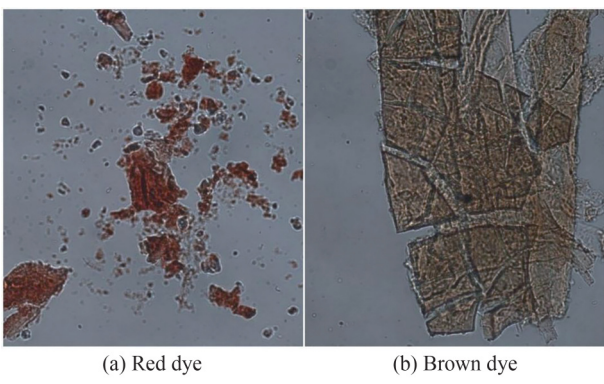


Fig. 8 Microscopic morphology of dye (single polarization)

veins. A small red sample was analyzed by UPLC-MS.

According to the analysis by UPLC-MS (Fig. 9, Fig. 10 and Table 1), the red vein contained eosin, which was

Table 1 Compound analysis

Sample	Retention time/min	m/z	Possible compound
Red line of the flower	7.37	646.703	Eosin

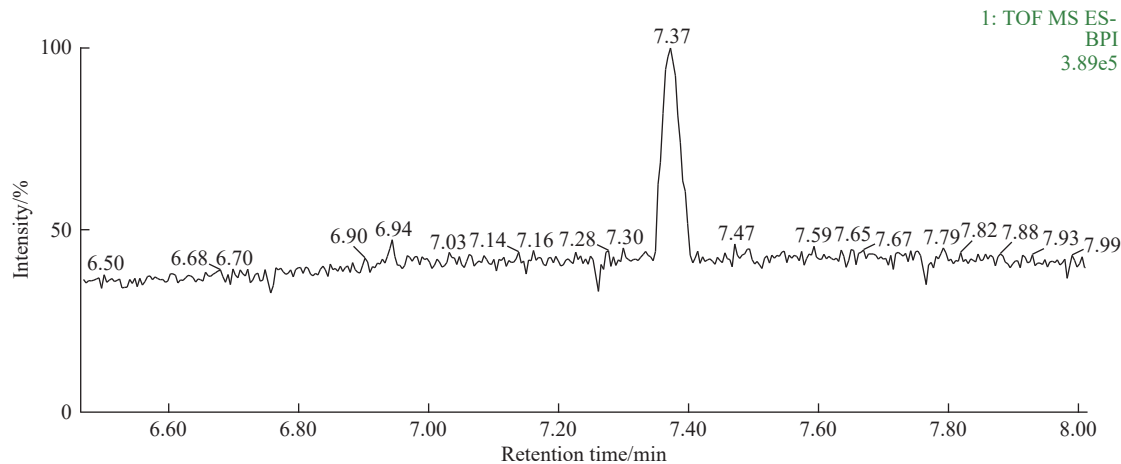


Fig. 9 Chromatogram of the red dye (UPLC-QTOF-MS ESI)

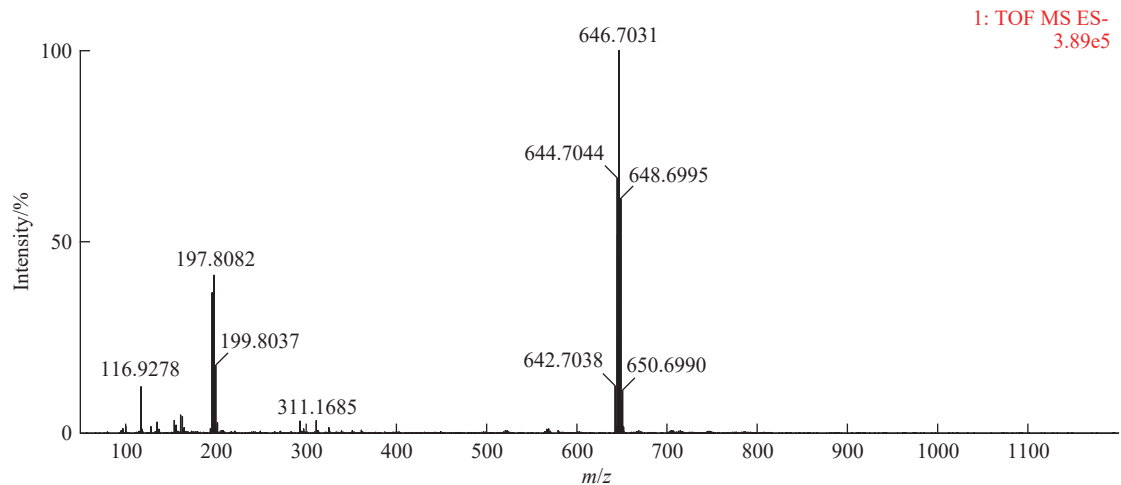


Fig. 10 MS spectrum

rarely used on the wallpaper of the Palace Museum. Therefore, this discovery might be the result of the communication between China and the West. Specifically, eosin is a bright red synthetic dye produced by the action of bromine on fluorescein and stains basic proteins because of its acidic nature. Discovered in 1874 by Heinrich Caro^[9], eosin has been used in a selection of Japanese prints of the Meiji era^[10]. The fading of eosin in Van Gogh's *Iris*es and *Roses* was also studied^[11]; moreover, eosin has also been found in other buildings in the Forbidden City, such as *Yangxin Dian* in the late Qing dynasty.

The white pigment was analyzed using Fourier transform infrared spectroscopy (FT-IR), as shown in Fig. 11. It is composed of kaolinite group minerals and lime^[12]. In particular, 1429 cm^{-1} is the peak of carbonates (CO_3^{2-}), and 1114 , 1060 and 1036 cm^{-1} are attributed to silicates ($\text{Si}_2\text{O}_3^{2-}$).

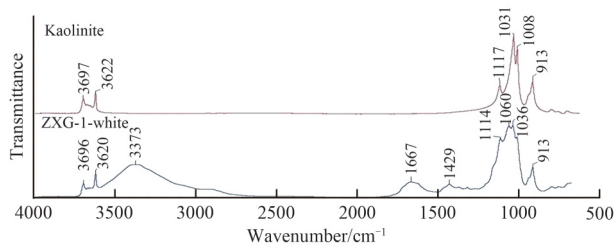


Fig. 11 FT-IR spectrum of white pigment on the fifth layer

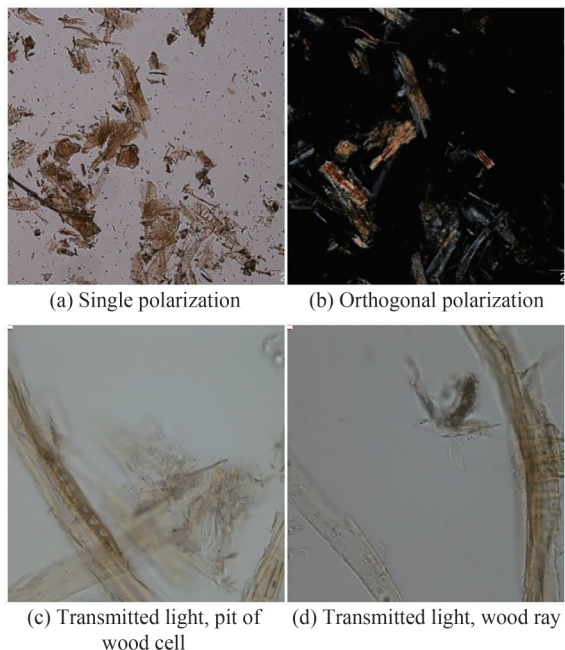


Fig. 12 Microscopic morphology of the fifth layer

The paper fibers in the fifth layer were observed under a polarized transmission microscope. The shape of the fiber under polarized light, the pattern of holes, and the wood ray structure under transmitted light proved that it was wood fiber^[13]. The earliest published example of paper made from wood pulp was the work of Dr. Jacob Christian Schäffer between 1765 and 1772. Large-scale paper production using wood pulp began in the 1840s with developments in mechanical pulping made by Friedrich Gottlob Keller in Germany^[14]. The fifth layer of wood pulp paper was pasted onto the first through fourth layers. It may have been used after the reign of Emperor Daoguang (1820–1850) during the late Qing dynasty.

3.2.2 Analysis of layers one through four

The decoration of layers one through four is a traditional Qing dynasty pattern (Fig. 13). According to the above research, the red pigment in layers one through four was iron oxide red (Fig. 14). Taking the fourth layer as an example, the white pigments were examined by FT-IR, which mainly contained talc (Fig. 15). Notably, 3675 cm^{-1} was the peak of $-\text{OH}$, 1021 cm^{-1} was ascribed to paper fibers, and 669 cm^{-1} was the peak of talc.

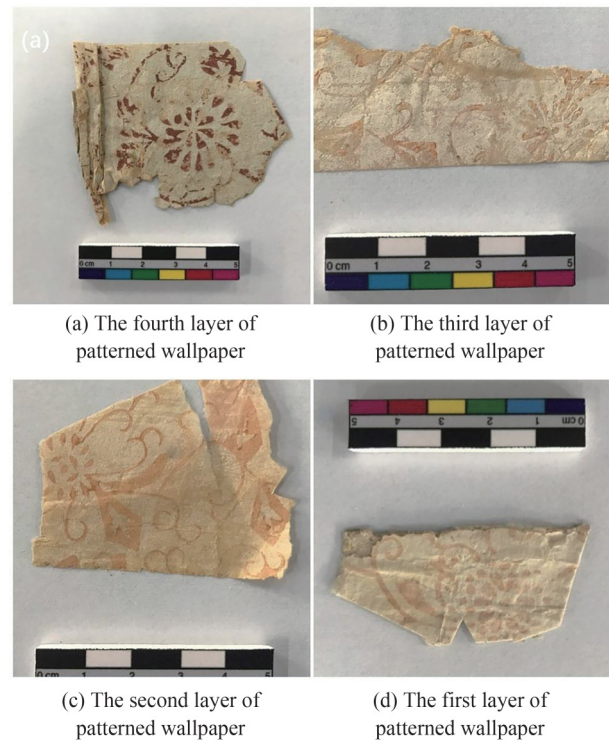


Fig. 13 Samples of the first four layers

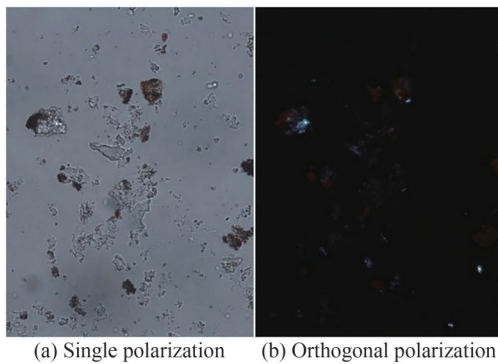


Fig. 14 Microscopic morphology of the red dye on the fourth layer

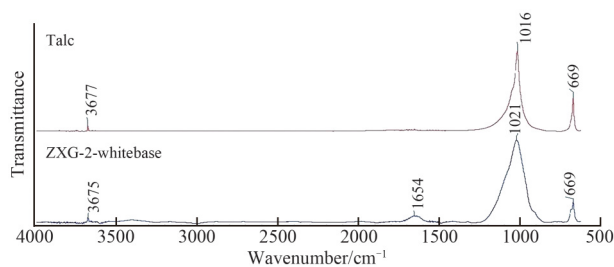


Fig. 15 FT-IR spectrum of white pigment on the fourth layer

The paper fibers were observed under a polarized transmission microscope after staining with Herzberg. Micrographs show the morphology of the straight bamboo fibers, and duct cells were found between the fibers (Fig. 16). The paper fibers of the second and third layers were the same as the fourth layer. The paper of the first layer was mulberry paper. In Fig. 17, the fibers are purplish-red, with transverse sections on the outer walls and a glial film on the surface.

This was similar to other buildings in the Qianlong Garden studied by the author ^[15]. This indicates that traditional materials and techniques were used in layers one through four of the wallpaper. In the palace of the Qing dynasty, the wallpaper was replaced when it was aged or when the building was under maintenance. As the surface of layer three demonstrated severe wear and fading, so layers four and five may have been pasted

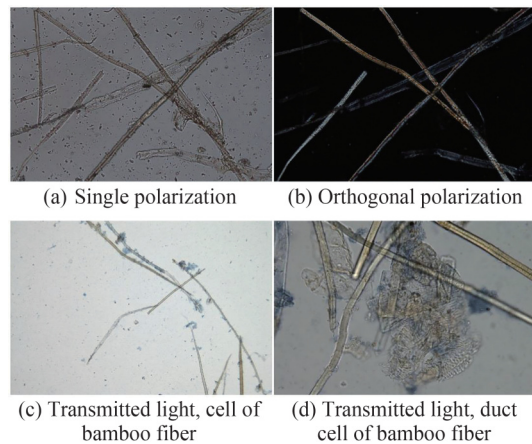


Fig. 16 Microscopic morphology of the fourth layer

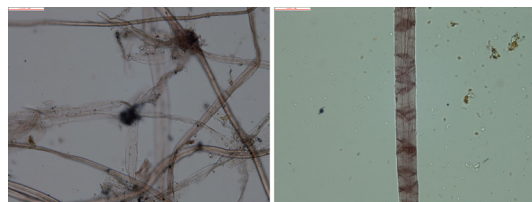


Fig. 17 Microscopic morphology of the first layer

over the other three layers at a later date. According to the pattern and fiber, layer five was different from layers one through four. Therefore, it can be concluded that layers one through five of the wallpaper were pasted at least three times (Table 2).

4 Wallpaper in *Yangxin Dian*

Numerous types of patterned wallpapers were found during the investigation of *Yangxin Dian*. The following examples are compared with those from *Zhuxiang Guan*; accordingly, two samples of traditional and synthetic pigments are discussed.

4.1 Wallpaper with a dragon and “ 卐 ” patterned decoration

Residue of the patterned wallpapers was found on the back wall of the Hall of Following Practice (*Tishun Tang*). It was decorated with traditional dragons and the

Table 2 Component of each layer

Layer	Red pigment	White pigment	Brown pigment	Paper fiber	Times of pasting
1	Iron oxide red	Lime, talc	—	Mulberry paper	
2	Iron oxide red	Lime, talc	—	Bamboo paper	
3	Iron oxide red	Lime, talc	—	Bamboo paper	1
4	Iron oxide red	Lime, talc	—	Bamboo paper	2
5	Eosin, Ba	Kaolinite, lime, soil	Cr	Wood pulp paper	3

symbol “卍” (Fig. 18). The Raman spectrum collected from the green pigment showed strong peaks at 3356 and 3437 cm^{-1} (Fig. 19). These Raman peaks fit well with atacamite^[16]. The FT-IR spectrum shows that the green pigment is composed of atacamite, lime, and clay (Fig. 20). Moreover, 3445 and 3335 cm^{-1} are attributed to the stretching vibrations of the —OH of atacamite^[17], 1417 cm^{-1} is the stretching vibration of CO_3^{2-} in lime, 1022 and 1090 cm^{-1} are ascribed to paper fibers. Combined with the above Raman and FT-IR analyses, the distribution of copper by Micro-XRF imaging shows the typical dragon decoration of the wallpaper at the Palace Museum (Fig. 21).

4.2 Patterned wallpaper on the wall surrounding the bed in the western buildings of *Yangxin Dian*

The wallpaper surrounding the bed differed significantly



Fig. 18 Patterned wallpaper on the back wall of *Tishun Tang* in *Yangxin Dian*

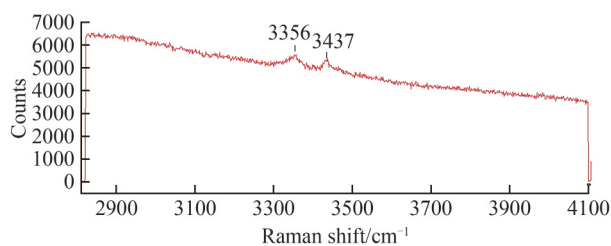


Fig. 19 Raman spectrum of green pigment

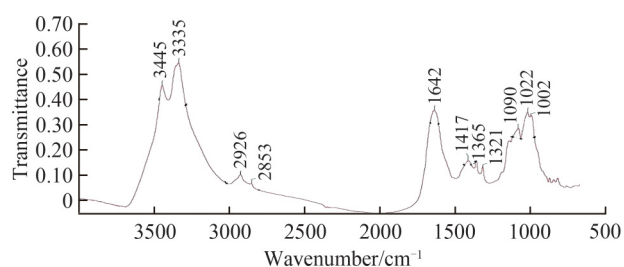


Fig. 20 FT-IR spectrum of green pigment

from the others (Fig. 22). Various pigments and techniques have also been investigated. Regarding the Micro-XRF imaging analyses of Ba, lead (Pb), and titanium (Ti) on the surface of the wallpaper, lead-white, titanium-white, and barium-white were used (Fig. 23). The use of titanium-white and barium-white occurred later than 1921^[18], so this wallpaper was pasted later than the others in *Yangxin Dian*.

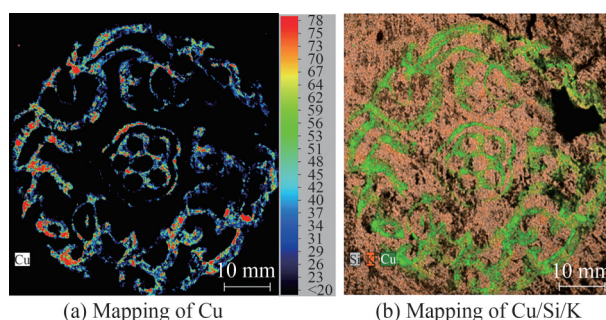


Fig. 21 Micro-XRF imaging analysis of the wallpaper

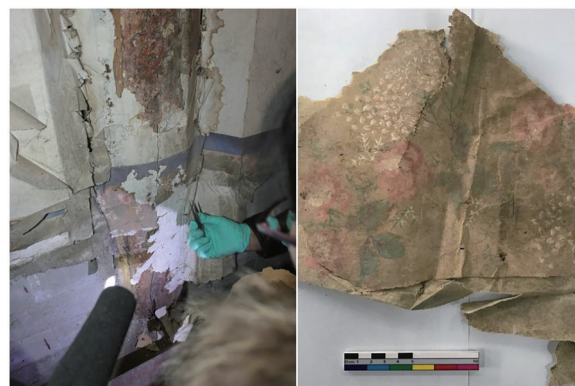


Fig. 22 Patterned wallpaper on surrounding of the bed in *Yangxin Dian*

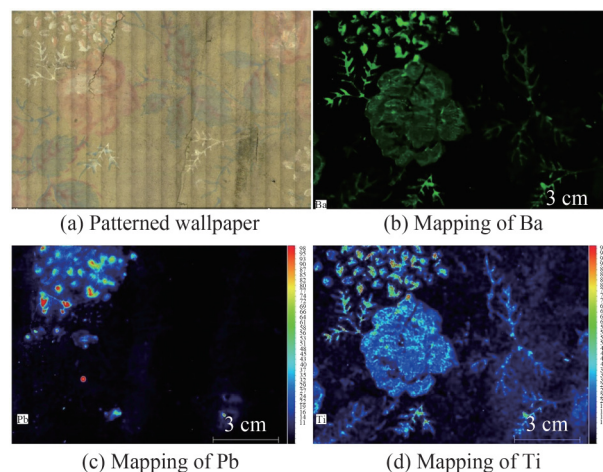


Fig. 23 Micro-XRF imaging analysis of the wallpaper

5 Discussion and conclusion

The above studies show the wallpaper in the Palace Museum consists of multiple layers. It was pasted several times—as in the Qing dynasty—and the wallpaper was replaced when it aged or when the building was under maintenance. Mulberry paper was used as the base layer owing to its high strength and toughness. Wood pulp paper and synthetic pigments were used in wallpapers of *Zhuxiang Guan*. Along with the missionaries' activities, exchanges between China and the West in the Qing dynasty became frequent. In fact, some materials were introduced to China from abroad. Based on the different painting techniques and wallpaper materials, it can be concluded that it is related to the links between China and the West.

Exchanges between China and the West can be traced back to the prehistoric period. Primitive sailing activities began in China's Lingnan region during the Neolithic Age. Through the ceramic trade, cultures have indirectly influenced the coasts of the South Pacific and Indian Oceans and islands. During the Western Han dynasty, Minister Zhang Qian led envoys to the western regions. He opened the "Silk Road" and developed it into a comprehensive trade route during the Ming dynasty.

Exchanges between China and the West in the Ming and Qing dynasties, especially the Qing court, originated from the activities of Western missionaries in China. At the end of the Ming dynasty, the Jesuits following European Christianity continued to send missionaries to China to spread their religion. During the Qing dynasty, under the Emperors Kangxi (1622–1722), Yongzheng (1723–1735) and Qianlong (1735–1796), along with missionary activities, Western science and art began to spread in China. After several European missionary painters arrived in China, they worked and became court painters; specifically, they taught the painting techniques of European fine arts to the Chinese court. In addition to the paintings of the missionaries, they taught European painting techniques to Chinese court painters.

Missionaries introduced examples of Western art techniques and designs into China, including oil paintings, copperplate prints, and sculptures. One such

artistic endeavor is the ceiling painting of buildings utilizing a mural technique. In this study, the wallpaper pasted on the ceiling of the second floor of *Zhuxiang Guan* had flower patterns on the outermost layer. The rose was three-dimensional and the surrounding branches and leaves were vivid. A life-like experience is presented when looking at the ceiling from various angles. As the patterns and techniques of the ceiling paper were different from those of other buildings in the Forbidden City, and no traces of printing were found, it can be speculated the flower pattern of the wallpaper may have been painted by missionaries or court painters who were taught by missionaries. In Qianlong Garden, *Juanqin Zhai*, located on the northeast side of the bamboo fragrance pavement, paintings are pasted on top of its inner eaves and walls. The ceiling is painted with a wisteria on a bamboo frame, through which the blue sky can be seen. According to research, the ceiling painting of *Juanqin Zhai* was done by Wang Youshi, a student of Lang Shining^[19] (also known as Giuseppe Castiglione (1688–1766)), a Jesuit missionary attached to the court of Emperor Qianlong. From the example abovementioned, it can be seen that Western art spread throughout the Qing dynasty court.

The wallpapers in the Palace Museum include examples of different patterns. The most common decorations during the Qing dynasty were traditional decorations such as green dragons, twigs, lotuses, and curly grass. However, an investigation of several samples of patterned wallpaper in *Zhuxiang Guan* and *Yangxin Dian* found some of the outermost layers used modern synthetic dyes or pigments and the paper was made of wood pulp. The surfaces were richly decorated, differing from the traditional style of the Qing dynasty.

This research studied the different types of wallpapers in *Zhuxiang Guan*, *Juanqin Zhai*, and *Yangxin Dian*, analyzed their materials and composition. It is hopefully that this research could provide a scientific basis for the reproduction of distinct types of wallpapers.

Acknowledgments

The author would like to express gratitude to Duan

Peiquan for helping perform the Micro-XRF tests and his substantial contribution to this study, Zhao Congshan for providing the sample, and Li Yue for introducing the wallpaper craft. The authors are grateful for the support from the National Key R&D Program of China (2019YFC1520300).

Availability of data and materials

The datasets used and analyzed in the current study are available from the corresponding author upon request.

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