

Study on the techniques of wallpaper (“Biaohu”) in the Palace Museum: Case on Lodge of Bamboo Fragrance (Zhuxiang guan)

Ma Yue (✉ mayue_cc@hotmail.com)

Palace Museum

Congshan Zhao

Palace Museum

Yong Lei

Palace Museum

Research Article

Keywords: The Palace Museum, wallpaper, UPLC

Posted Date: March 9th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-724159/v2>

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Abstract

"*Biao Hu*" was one of the eight famous traditional crafts in the late Qing dynasty. It included decorating the interior of ancient buildings and making burial objects, including ceilings, walls and windows. It was popular in the structures of northern China in the early Qing dynasty. There was white and patterned wallpaper in the Forbidden City. The latter included traditional and rare patterns. Taking the wallpaper in Lodge of Bamboo Fragrance (*Zhuxiang Guan*) as an example, in this article, its structure and composition have been studied by morphological observation and spectroscopic analysis. The pigments and dye were analyzed by Raman spectroscopy and UPLC. Combined with an analysis of the patterned wallpaper in other buildings of the Forbidden City, traditional technology has been investigated.

1 Background

The traditional crafts in ancient China named "*Ying Zao*." "*Biao Hu*" was one of the eight crafts of the late Qing dynasty^[1]. They were composed of tile, wood, stone, scaffold, soil, oil painting, coloured painting and wallpaper. The use of paper and textile on the ceiling, wall and window was widespread in the buildings of northern China in the early Qing dynasty^[2]. They have been extensively documented in the historical archives of Ming and Qing dynasties, related to the climate and building type in northern China. Chinese wallpaper was also exported to Europe, mainly by Canton wallpaper painters. It has once been an essential element of European interior decoration^[3]. Some academics conducted research on Chinese wallpaper. Hand-painted wallpaper belonging to a private Portuguese collection was analyzed to identify the pigments used^[4]. The destruction of paper by green copper pigments on Chinese wallpaper was also investigated^[5]. The wallpaper helps prevent cold and dust, adjust the relative humidity, improve the luminosity, etc. Numerous kinds of wallpaper remain in the Forbidden City, containing multiple decorative patterns, most of which are green dragons with " " characters, as well as twigs and lotus, "prolonging life" patterns, etc. All of them are Buddhist symbols, which symbolizes happiness and longevity. On the second-floor roof in the south ear room of *Zhuxiang guan*, a rose flower decoration was found, which was not commonly seen in the Palace Museum.

Zhuxiang guan is located in the northwest corner of the fourth courtyard in the Qianlong Garden. It was built in the 37th year of the Qianlong Period in the Qing dynasty, imitating the *Bilin* Pavilion of the Palace of Established Happiness (*Jianfu* Palace)^[6]. It was divided across two floors, connected with *Juanqin Zhai* and *Yucui Xuan*. The patterned wallpaper was found on the second-floor ceiling during the conservation work; it has been entirely removed under conservation.

The wallpaper appeared to be yellowing, cracking, missing and suffering from other age-related issues. It can be divided into six layers, the pattern of the outermost layer was rose flowers, and the other layers were twigs.

In this work, three types of patterned wallpaper in the Palace Museum were analyzed. The structure of the wallpaper was visualized based on the cross-section observation by visible and UV light. Micro-XRF

imaging analysis was applied for elemental imaging. Pigments were observed by polarizing microscope. Dye was analyzed by HPLC-MS. The fiber morphology was observed by microscope. In the investigation of patterned wallpapers in *Zhuxiang Guan* and *Yangxin Dian*, it was found that some of the outermost layers used modern synthetic dyes or pigments, and the paper was also made of wood pulp. It may be related to the links between China and the West.

2 Scientific Analysis

The sample was taken from the edge of the wallpaper. It is embedded with Technovite 2000LC resin (Henraeus Kulzer Co.), polished after curing under ultraviolet light for 30 minutes^[7]. Observed under visible and ultraviolet light (Leica 4000M), it can be divided into at least five layers, and each layer was pasted by an adhesive made of flour^[8].

The structure of pigment and fiber were observed under a microscope. For instance, the surface of the fifth layer (the outermost layer) and the second layer, the colour of red pigment and paper fiber, seemed different, requiring further component analysis.

Micro-XRF imaging analysis was conducted on the surface of the patterned wallpaper. From the distribution of elements, it was found that the red vein lines of flowers mainly contain barium, the yellowish-brown leaves mainly contain chromium, and the white part of the flower was rich in calcium. The distribution of iron reflects the red pattern on the surface of layers 1 to 4—the specific components of each part of the material required further analysis.

The distribution of elements of the fourth layer was analyzed. Iron was mainly present in the red pigment, which also contained Ocher.

The red and brown samples from the fifth layer were observed by a polarizing microscope (Leica,4500P)^[9]. Organic dyes may have been used in the red vein. A small red sample was taken by ultra-high-performance liquid chromatography-time-of-flight mass spectrometry (Waters UPLC H-class) and Waters G2-XS QTOF MS. After 10 min, was extracted by ultrasound at 70 °C with 0.1 mL DMSO, centrifuged, the clear liquid was discarded and set aside, the residue in 0.1mL MeOH/H₂O/HCl (1: 1, V ≤ V) at 70 °C. was extracted by ultrasonic at 70 °C for 10 min, and then concentrated and re-dissolved with clear liquid of the first step, which was measured.

Table 1
Compound analysis

Sample	R. T. (min)	[M + H] ⁺ (<i>m/z</i>)	Possible compound
Red line of the flower	7.37	646.703	Eosin

According to the analysis by Ultra-High-Performance Liquid Chromatography-Mass Spectrometry, the red vein may contain a synthetic dye—eosin, which was relatively rare on the wallpaper of the Palace Museum, which might have been the result of the later communication or renovation between China and the West. Eosin is a bright red synthetic dye produced by the action of bromine on fluorescein and stains basic proteins due to its acidic nature. It was discovered in 1874 by Heinrich Caro^[10]. Eosin has been used in a selection of Japanese prints of the Meiji era^[11]. The fading of eosin in Van Gogh's *Iris*es and *Roses* was studied^[12]. Eosin has also been found in other buildings in the Forbidden City, such as the Hall of Mental Cultivation in the late Qing dynasty.

The main component of the white part of the flower is the kaolinite group mineral and lime^[13], 1429 cm^{-1} is the peak of CO_3^{2-} , 1114 cm^{-1} , 1060 cm^{-1} and 1036 cm^{-1} are attributed to $\text{Si}_2\text{O}_3^{2-}$.

The paper fiber of the fifth layer was observed under a polarized and transmission microscope. The shape of the sawdust under polarized light, the hole and the wood ray structure under transmission light all proved it to be wood fiber^[14]

Paper has been made from wood pulp only since the mid-1800s^[15]. This layer was pasted later from the 1–4 layers. It was maybe used after the reign of Emperor Daoguang in the late Qing dynasty.

The decoration on the 1–4 layers is a traditional type in the Qing dynasty. From the analysis of the red pigment and microstructure of paper fibre, the red pigment could have been iron red, the white base contained talc, and the paper was made of bamboo fiber. It was similar to other buildings in the Qianlong Garden studied by the author^[16]. They all show that traditional materials and techniques were used in layers 1–4. Because the surface of the third layer underwent severe wear, and the pigments on layers 1–3 were more orange, it was speculated that layers 1–3 were pasted together, and the fourth layer was pasted later. So, layers 1–6 of the wallpaper have been pasted at least thrice.

3 Wallpaper In The Hall Of Mental Cultivation (Yangxin Dian)

During the investigation of the wallpaper in *Yangxin Dian*, numerous types of patterned wallpaper were found. The following are examples compared with them in *Zhuxiang guan*, two samples of traditional and synthetic pigment were discussed.

3.1 Wallpaper with dragon and “☯” patterned decoration

The residue of patterned wallpaper was found on the backing wall in the Hall of Following the Practice (*Tishun tang*). It was decorated with traditional dragons and “☯”. The Raman spectrum collected from the green pigment showed strong Raman peaks at 3356 cm^{-1} and 3437 cm^{-1} . These Raman peaks fit well with atacamite^[17]. FTIR spectrum shows that the green pigment is composed of atacamite, lime and clay. 3445 cm^{-1} and 3335 cm^{-1} are attributed stretching vibrations of -OH of atacamite^[18], 1417 cm^{-1} is stretching vibrations of CO_3^{2-} in lime, 1022 cm^{-1} and 1080 cm^{-1} are attributed to SiO_3^{2-} in clay.

Combined with Raman and FTIR analysis above, the distribution of Cu by XRF mapping shows a typical dragon decoration of wallpaper in The Palace Museum.

3.2 Patterned wallpaper on the wall surrounding the bed(*Kang*) in the western buildings of *Yangxin Dian*

The wallpaper surrounding the bed (*Kang*) differs significantly from others; the pigment and technique were subsequently analyzed. According to the mapping of lead, barium and titanium of the white pigments, titanium white and barium white may have been used. It also proves that this wallpaper was pasted later than the others, thereby requiring dye analysis.

4 Discussion

According to the painting techniques and materials of the wallpaper, it may be related to the links between China and the West.

The exchanges between China and the West can be traced back to the prehistoric period. In the Neolithic Age, China's Lingnan region has begun primitive sailing activities. Through the ceramic trade, the culture has indirectly influenced the coasts of the South Pacific and Indian Oceans and islands. During the Western Han Dynasty, Minister Zhang Qian led the envoys to the Western Regions. He opened up the 'Silk Road', and it developed into a comprehensive trade road in the Ming Dynasty.

The development of 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 under European Christianity continued to send missionaries to China to spread religion. From the end of the 17th century to the 18th century, during the three dynasties of Kangxi, Yongzheng and Qianlong in the Qing Dynasty, along with missionary activities, western science and art also began to spread in China. After several European missionary painters came to China, they worked in the court and became court painters. They taught the painting techniques of European fine arts to the Chinese court. In addition to the paintings of the missionaries themselves, they also taught European painting techniques to Chinese court painters.

Art types such as oil paintings, copperplate prints, and sculptures were introduced to China by missionaries. One of them is "Zenith Painting". Ceiling painting is a common type of painting in European churches. It is painted on the ceiling of buildings and belongs to murals. In this article, the wallpaper which was pasted on the ceiling of the second floor of *Zhuxiang guan*, its outermost layer was painted with flower patterns. The rose was three-dimensional, and the surrounding branches and leaves were very vivid. It is lifelike to look up at the ceiling from various angles. Although there is no signature of the painter on the printed paper, but according to the drawing patterns and techniques of the ceiling paper of other buildings in the Forbidden City, it can be speculated that the wallpaper of the *Zhuxiang guan* may have been painted by missionaries or court painters who were taught by missionaries. In the Qianlong Garden, *Juanqin zhai*, located on the northeast side of the Bamboo Fragrance Pavilion, has

paintings pasted on the top of its inner eaves and walls. The ceiling part is painted with purple vines on a bamboo frame, through which the blue sky can be seen. According to research, the ceiling painting of *Juanqin zhai* was made by Wang Youshi, a student of Lang Shining, according to Lang Shining's pattern^[16]. From the above, it can be seen that western art has been spread in the Qing Dynasty court.

The study of wallpapers in the Palace Museum includes numerous kinds of patterned ones. However, the most common during the Qing dynasty were traditional decorations, such as green dragons, twigs and lotuses, and curly grass. However, in the investigation of several patterned wallpapers in *Zhuxiang Guan* and *Yangxin Dian*, it was found that some of the outermost layers used modern synthetic dyes or pigments, and the paper was also made of wood pulp. The surface of these wallpapers was richly decorated, differing from the traditional style of the Qing Dynasty.

This paper studies the different types of printing paper in *Zhuxiang uan*, *Juanqin zhai* and *Yangxin dian*, analyzes its materials, and then studies its production process. It will provide a scientific basis for the reproduction of different kinds of wallpaper.

Declarations

Acknowledgements: I express my gratitude to Duan Pei-Quan for helping me perform tests with XRF. He substantially contributed to this study.

Authors' contributions: YM performed most of the analytical work and was a major contributor in drafting the manuscript. CSZ provided us with the sample. YL introduced crafts of the wallpaper. All authors read and approved the final manuscript.

Funding: This research was supported by the National Key R&D Program of China, No. 2019YFC1520300.

Availability of data and materials: The datasets used and analyzed during the current study are available from the corresponding author upon request.

Declaration of competing interests: The authors declare that they have no competing interests.

Author Details

1 Department of Conservation Science and Technology, The Palace Museum, 4 Jingshan Qianjie, Beijing 100009, China.

2 Key Laboratory of Calligraphy and Paintings Conservation, Ministry of Culture and Tourism, Beijing, China

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Figures



Figure 1

Exterior of *Zhuxiang guan*



Figure 2

patterned wallpaper in *Zhuxiang guan*



Figure 3

Sample of patterned wallpaper in *Zhuxiang guan*

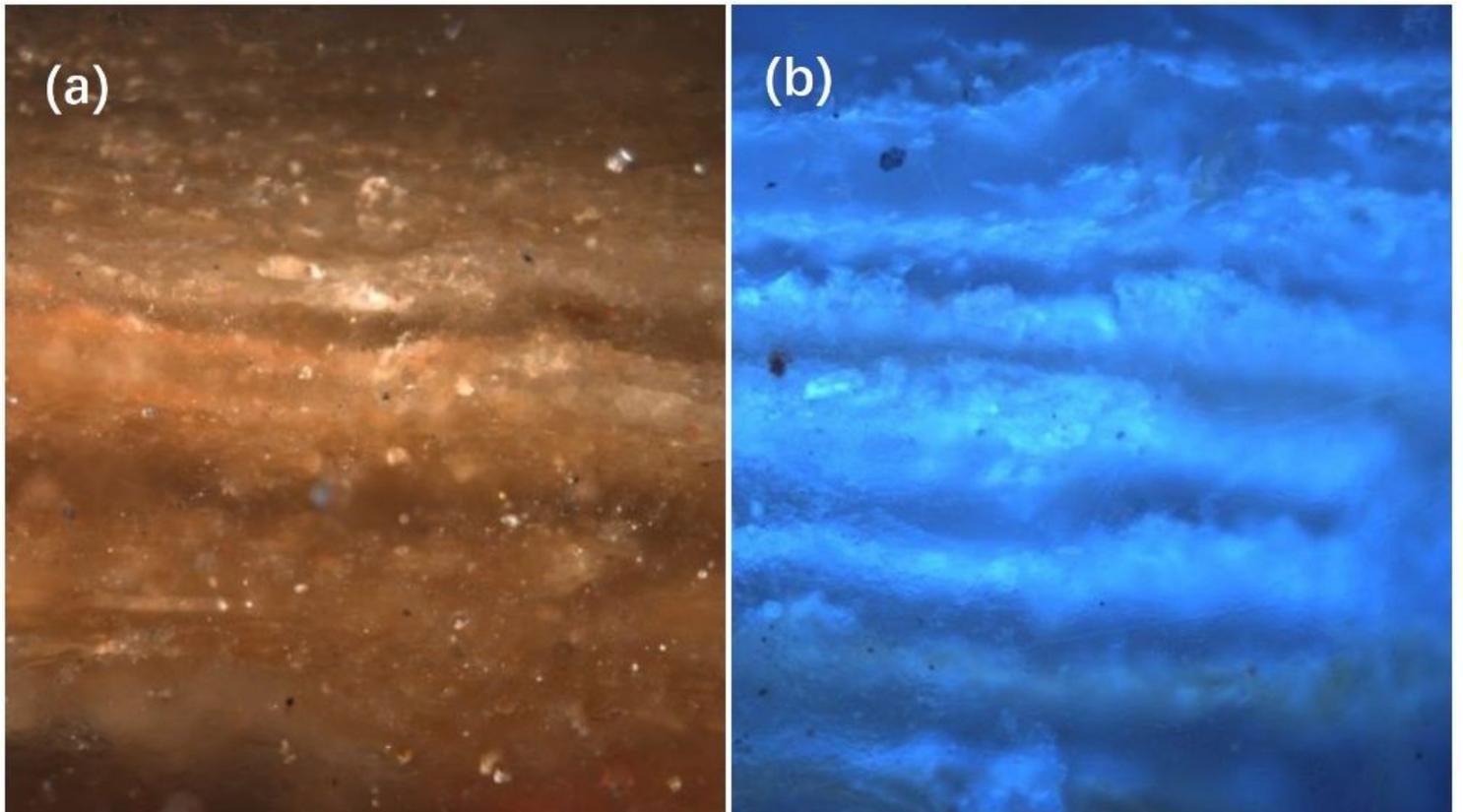


Figure 4

Microstructure of crosssection. (a)Vis,100X (b)UV,100X

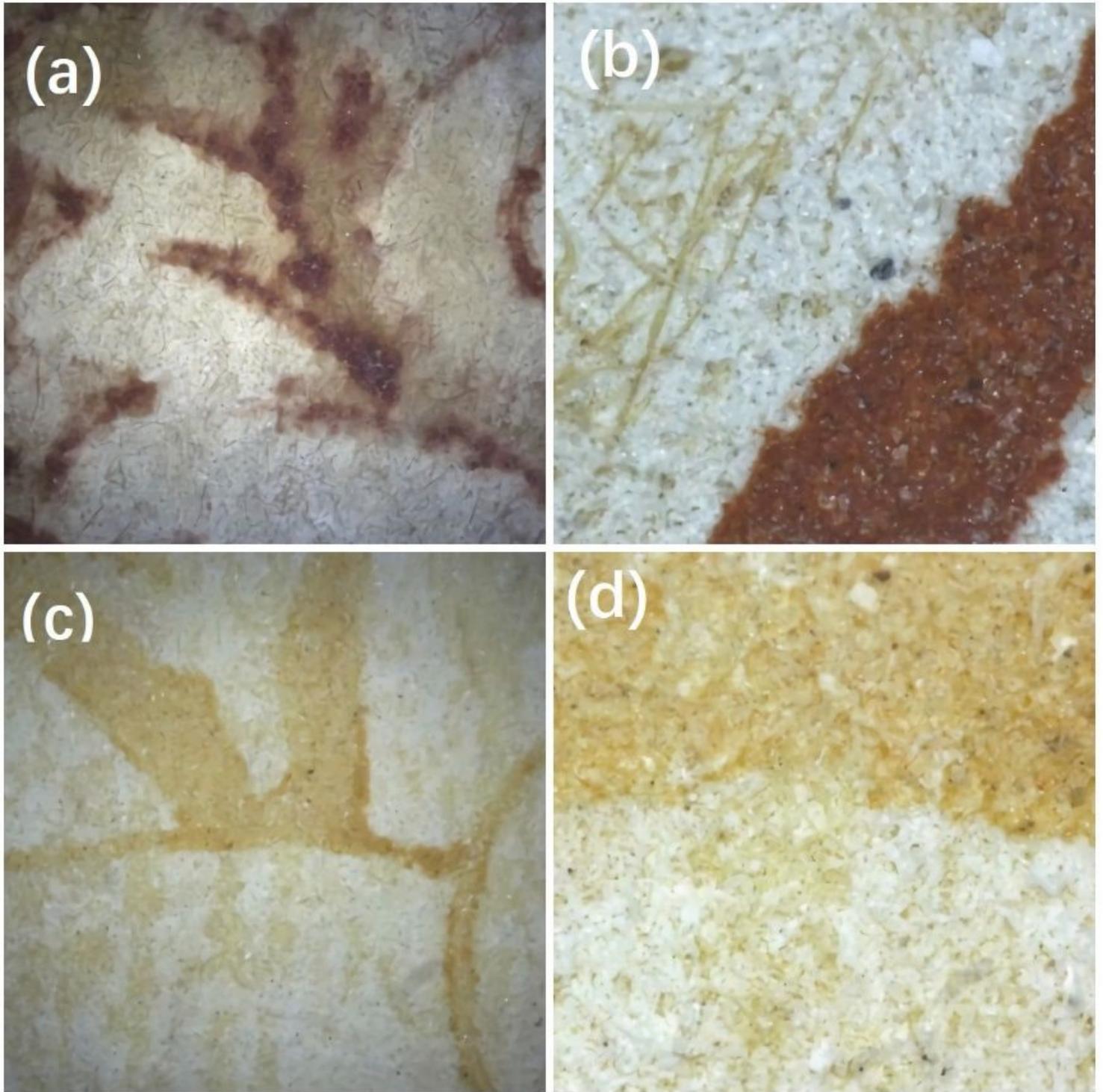


Figure 5

Microscopic morphology of the wallpaper

(a) the 5th layer,20X (b) the 5th layer,150X (c) the 2nd layer,20X (d) the 2nd layer,150X

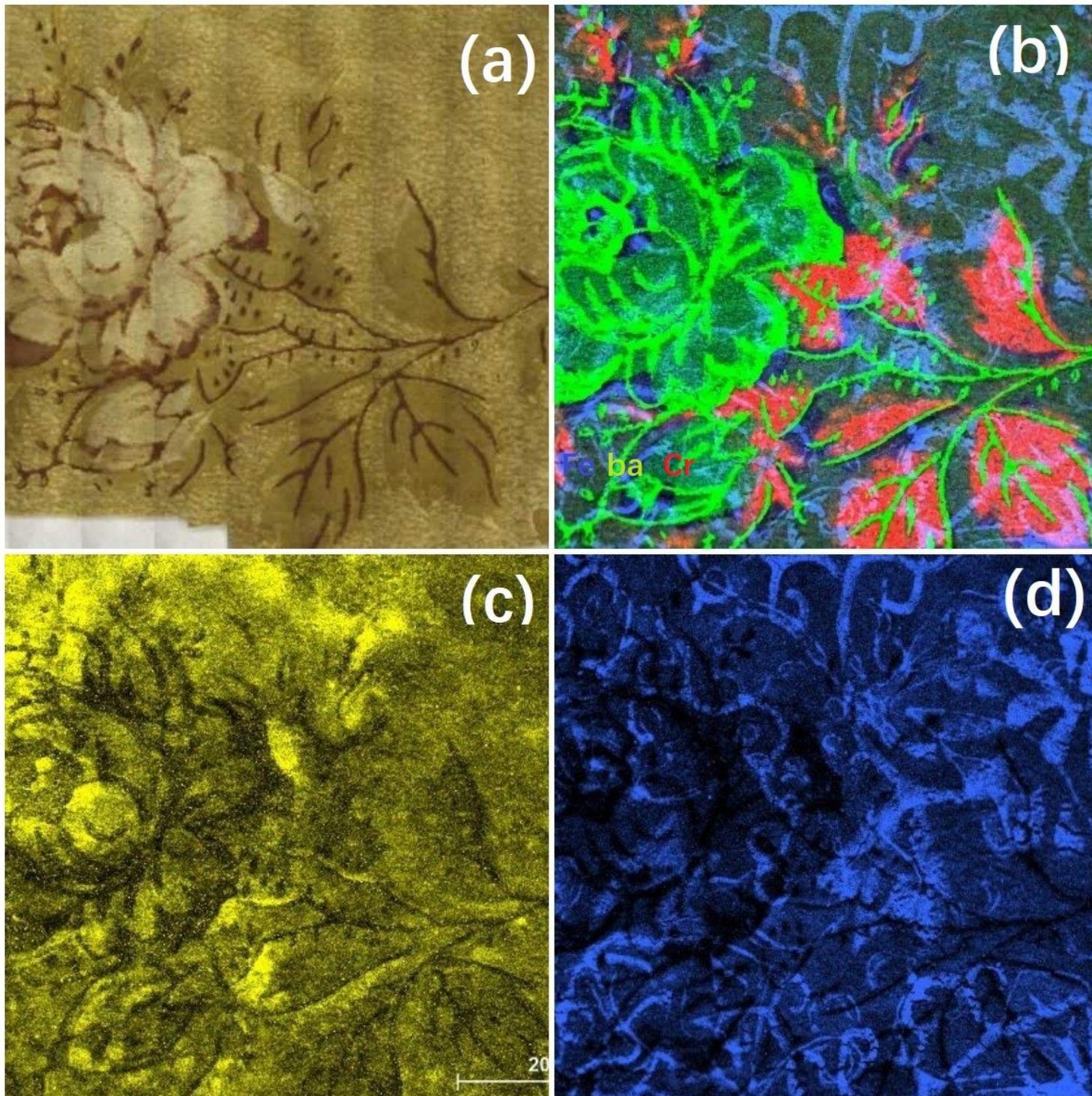


Figure 6

Micro-XRF imaging analysis of the 5th layer of patterned wallpaper

(a) the 5th layer of patterned wallpaper (b) Mapping of Fe/Ba/Cr

(c) Mapping of Ca (d) Mapping of Fe

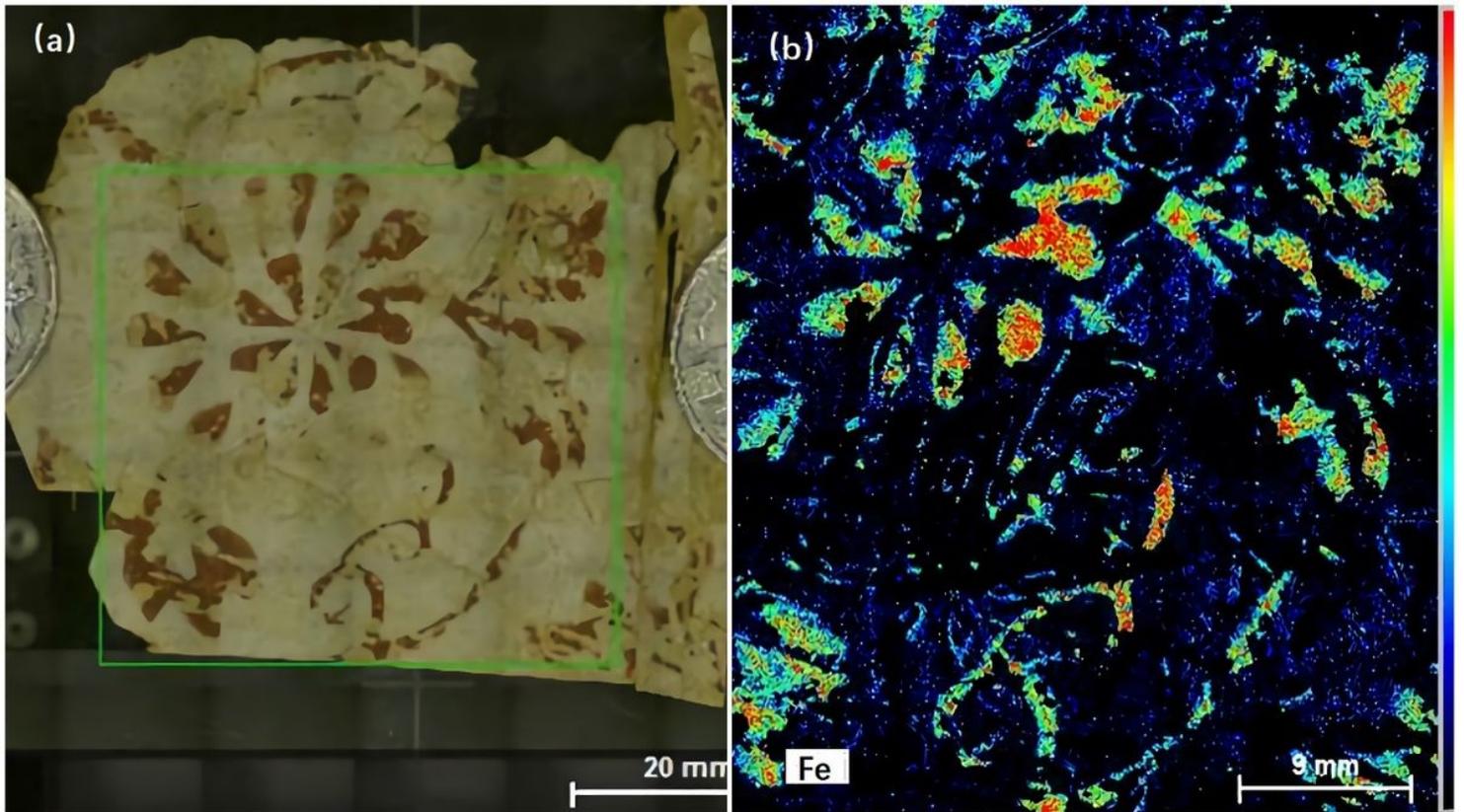


Figure 7

Micro-XRF imaging analysis of the 4th layer of patterned wallpaper

(a) the 4th layer of patterned wallpaper (b) mapping of Fe

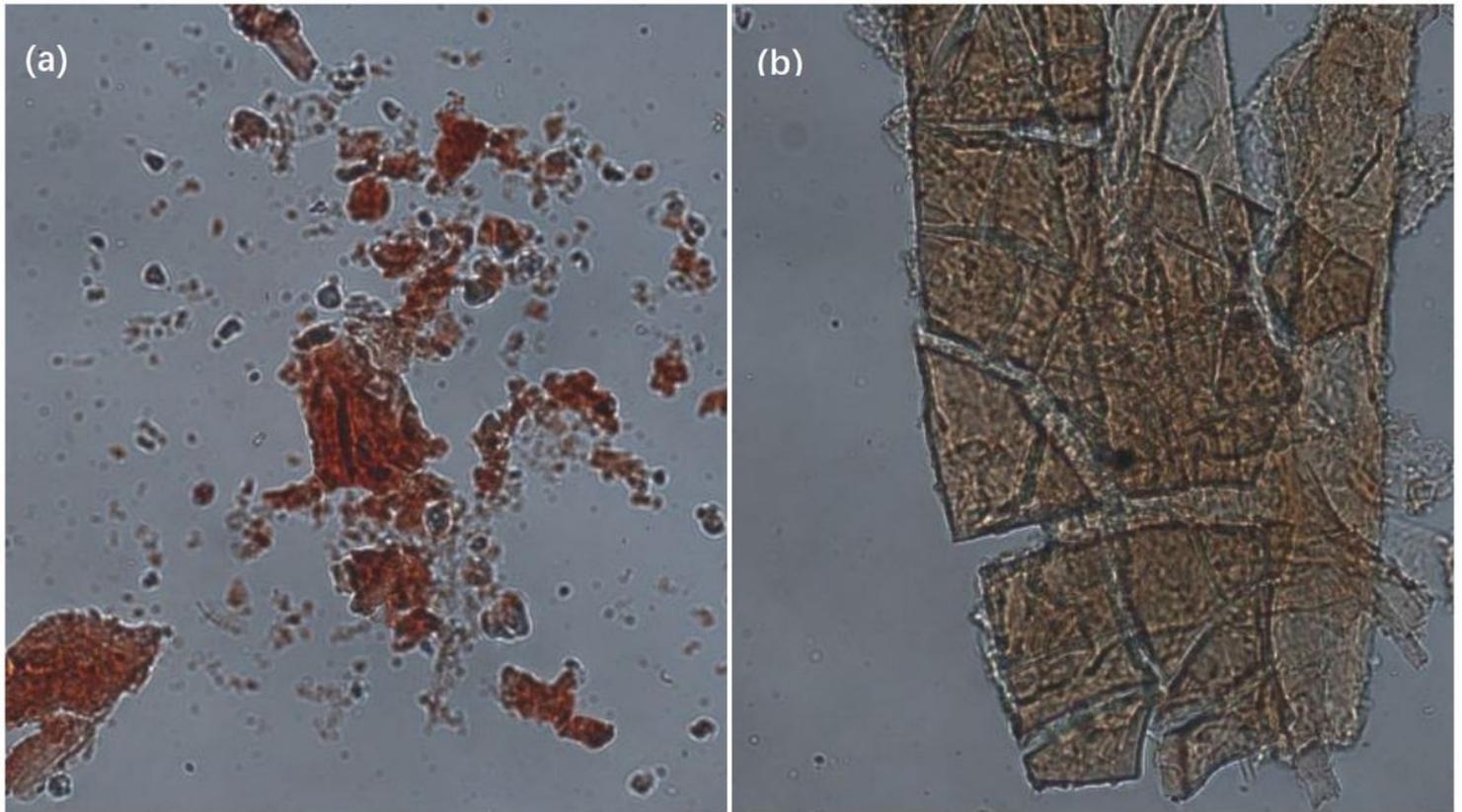


Figure 8

Microscopic morphology of dye(Single polarization)

(a)red dye (b)brown dye

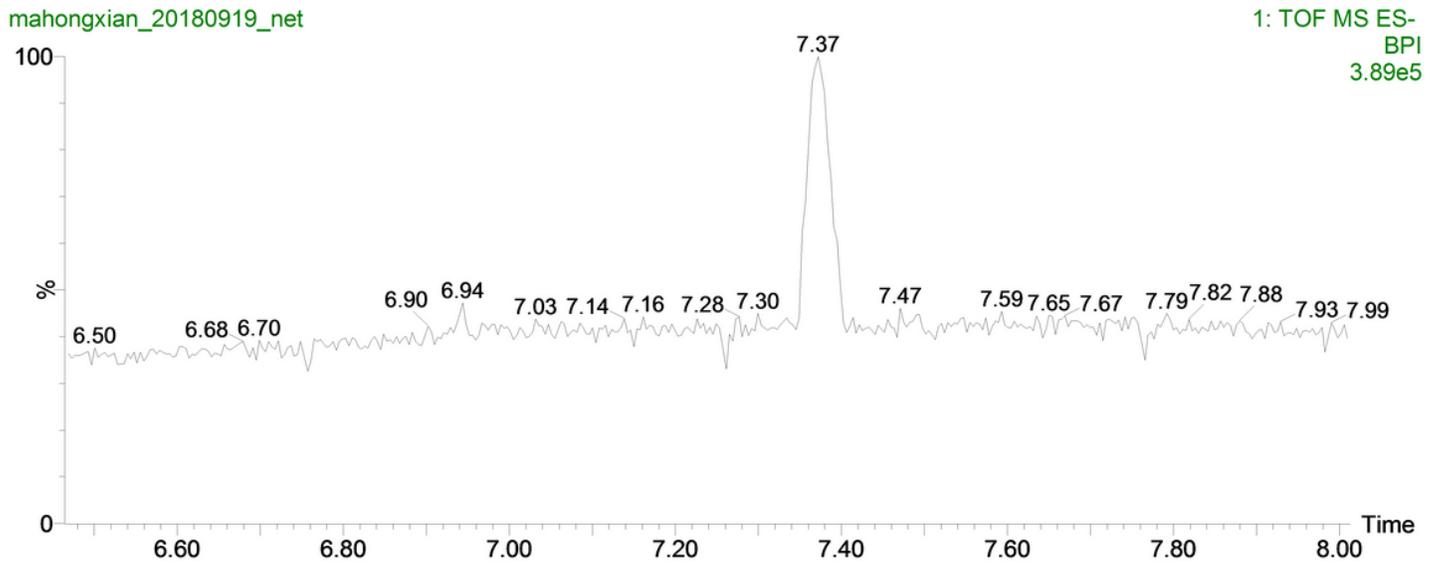


Figure 9

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

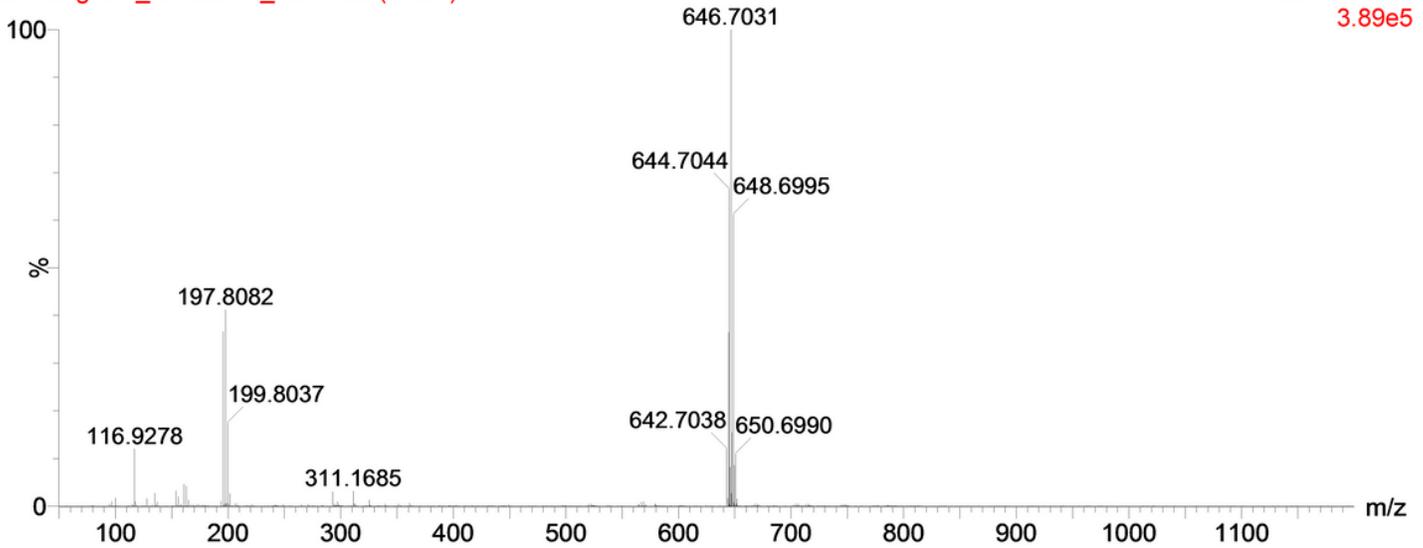


Figure 10

Mass spectrum at 37min

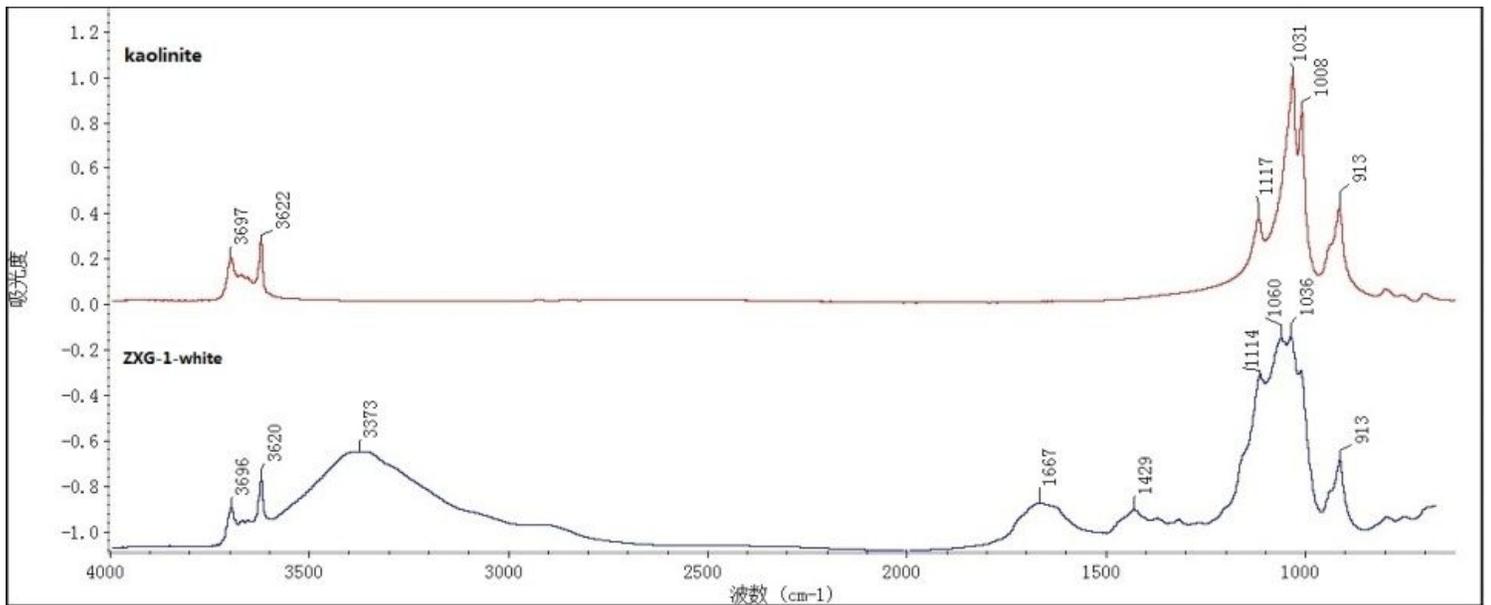


Figure 11

Micro-FTIR spectrum of white pigment the 5th layer

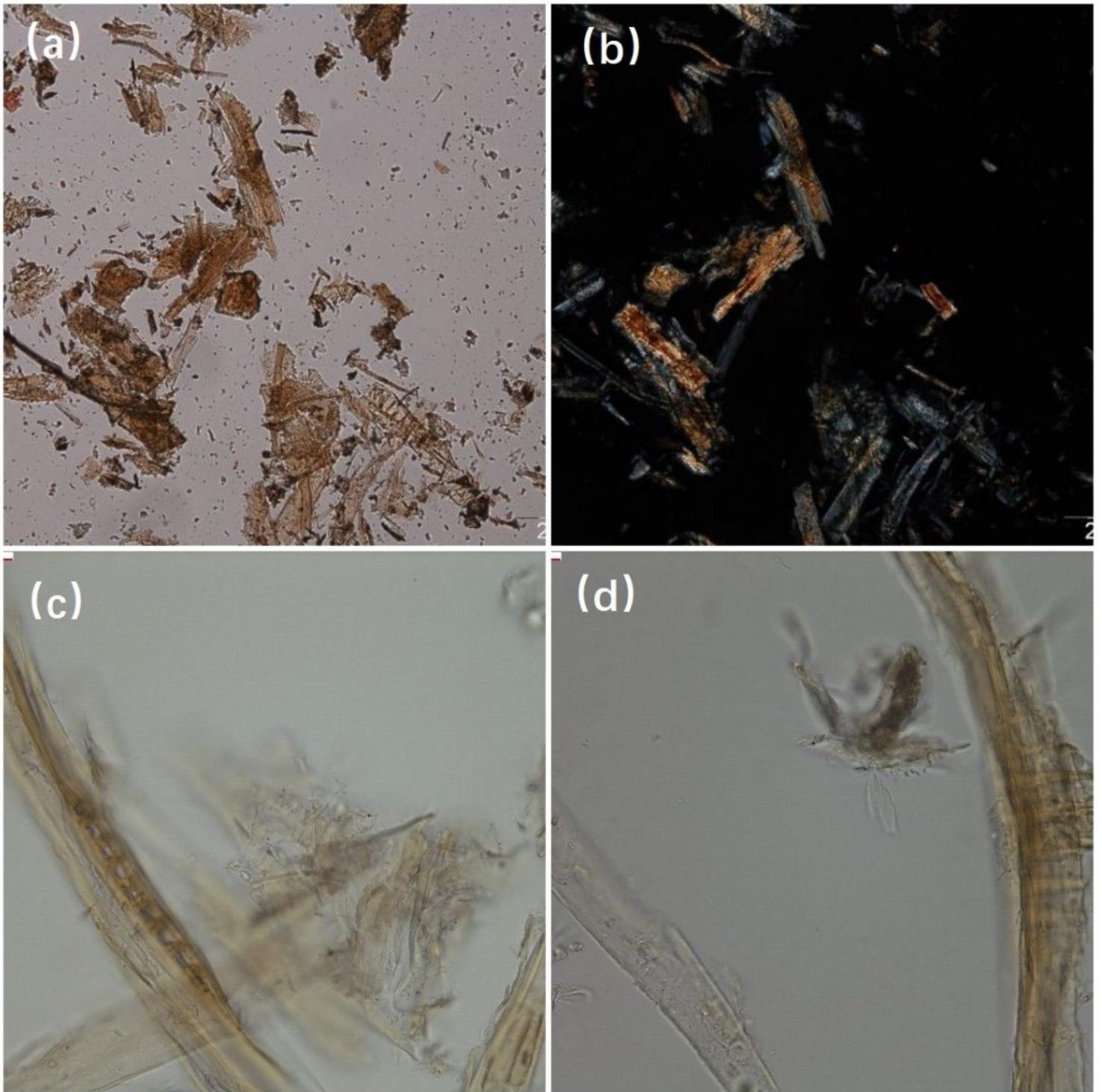


Figure 12

Microscopic morphology of the 5th layer

(a) Single polarization (b) Orthogonal polarization (c) transmitted light, pit of wood cell

(d) transmitted light, wood ray



Figure 13

Sample of the 1st ~4th layers

(a) the 4th layer of patterned wallpaper (b) the 3rd layer of patterned wallpaper

(c) the 2nd layer of patterned wallpaper (d) the 1st layer of patterned wallpaper

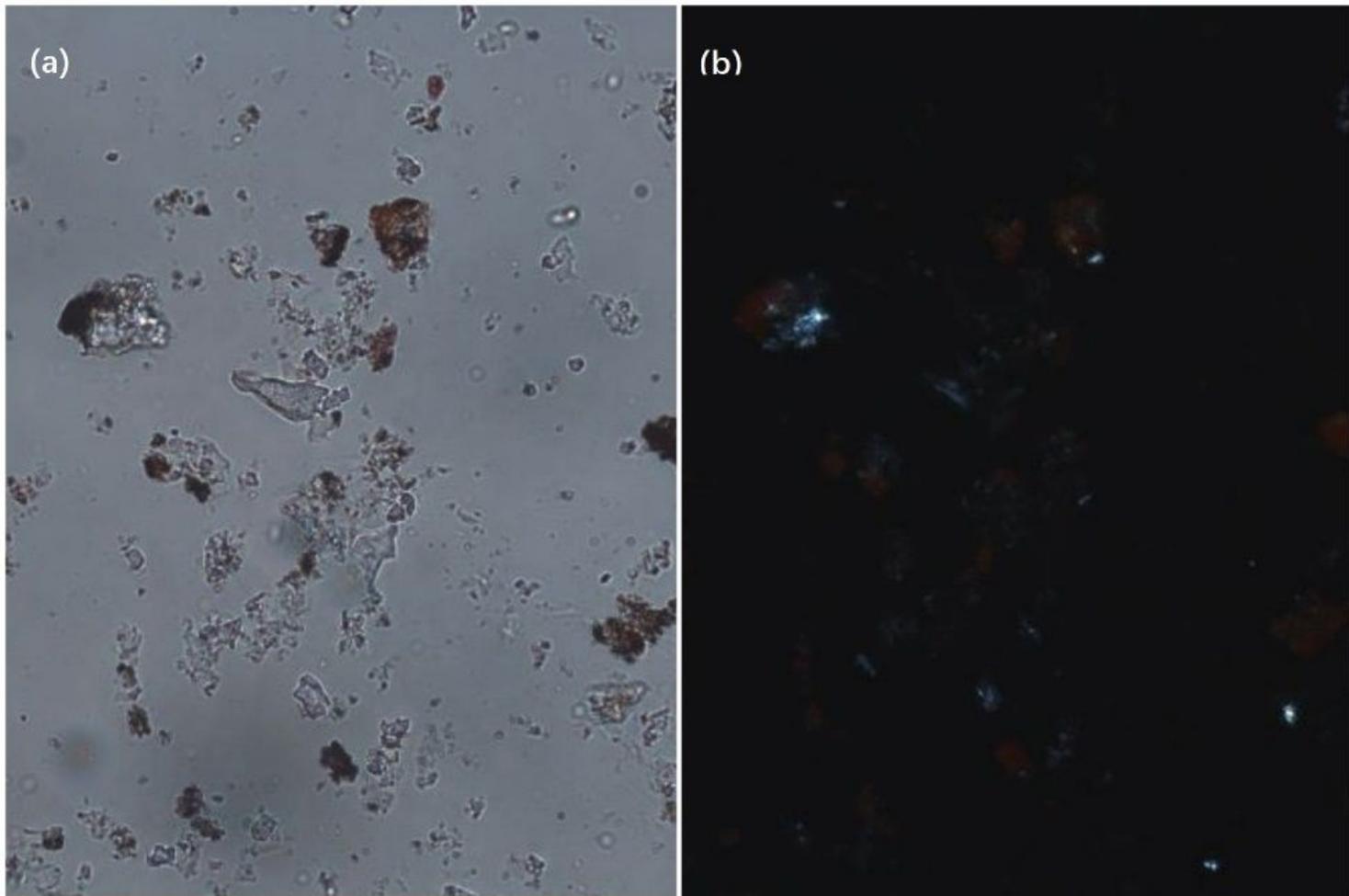


Figure 14

Microscopic morphology of the red dye on the 4th layer (a) Single polarization (b) Orthogonal polarization

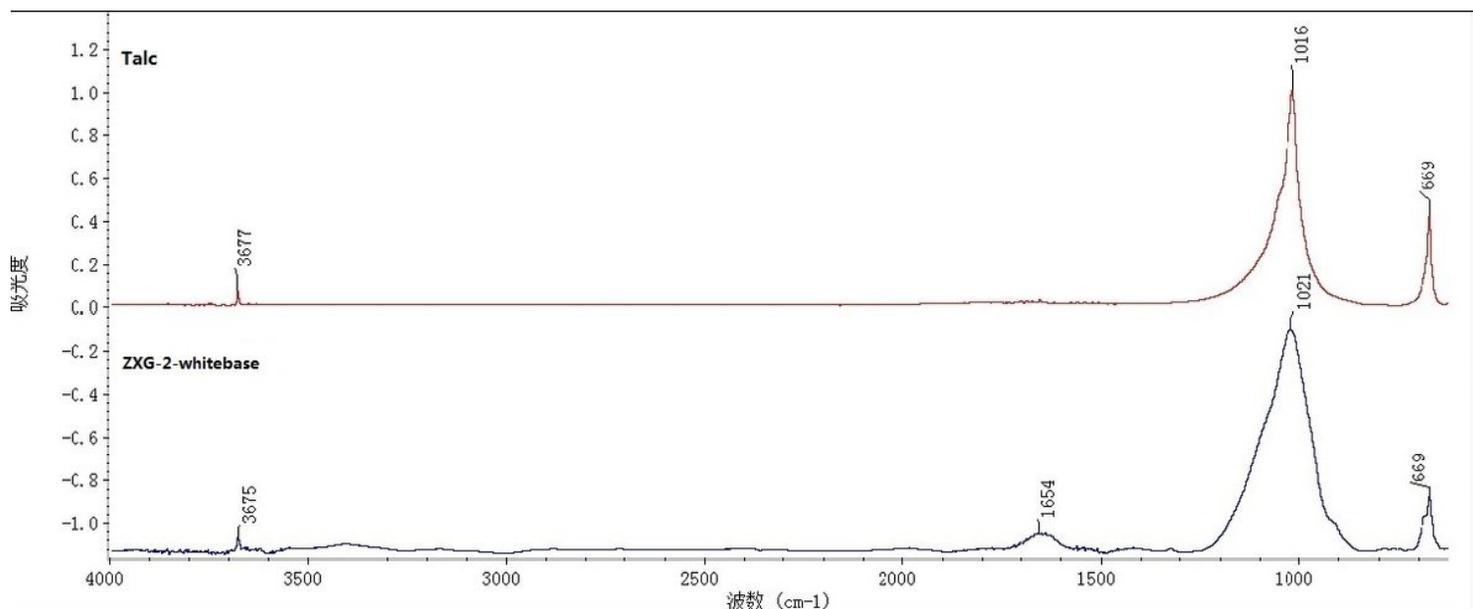


Figure 15

Micro-FTIR spectrum of white pigment the 4th layer

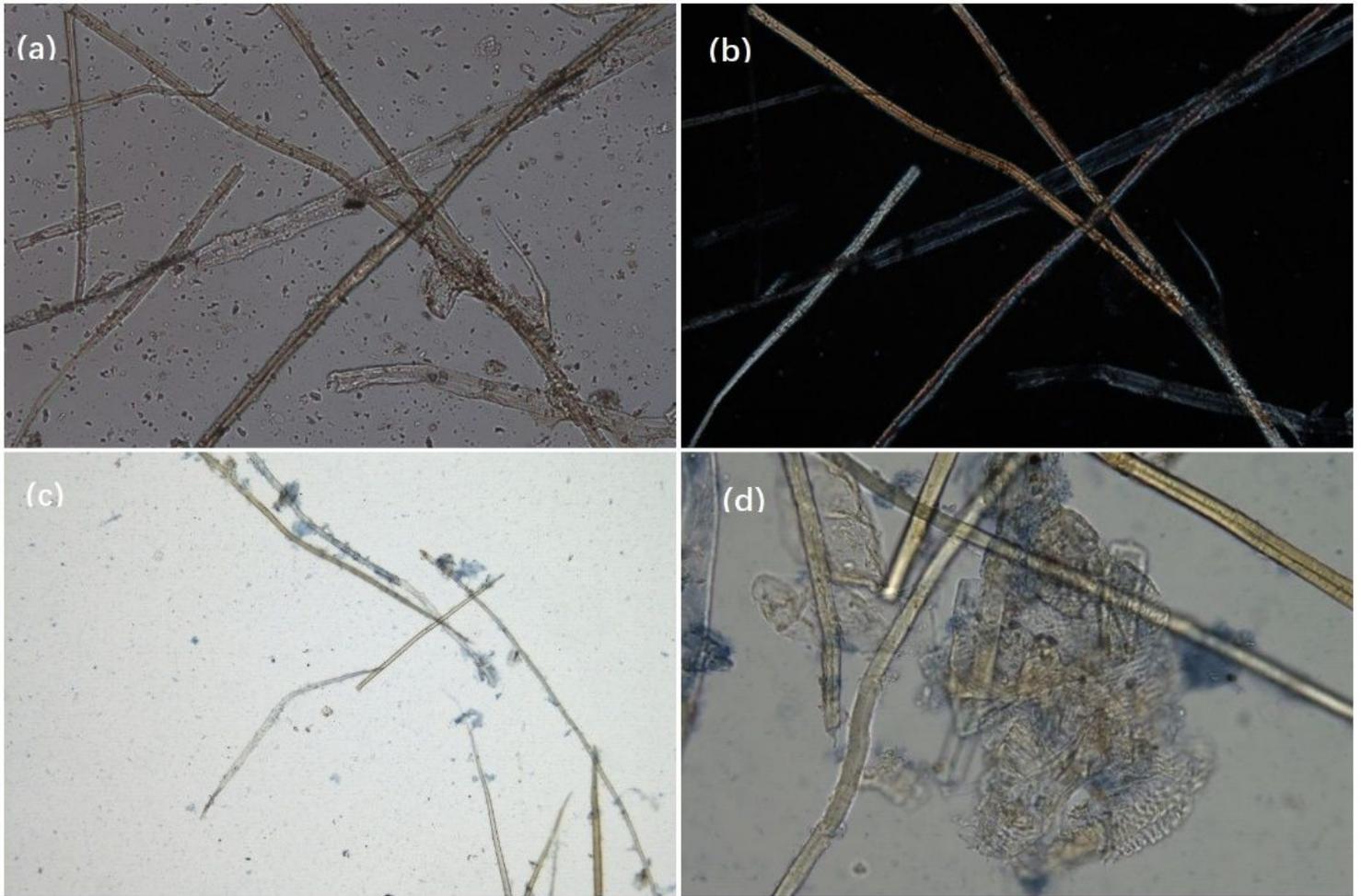


Figure 16

Microscopic morphology of the 4th layer

(a) Single polarization (b) Orthogonal polarization (c) (d) (transmitted light, pit of wood cell)



Figure 17

patterned wallpaper on the west room of *Ti shuntang* in Hall of Mental Cultivation (*Yangxin dian*)

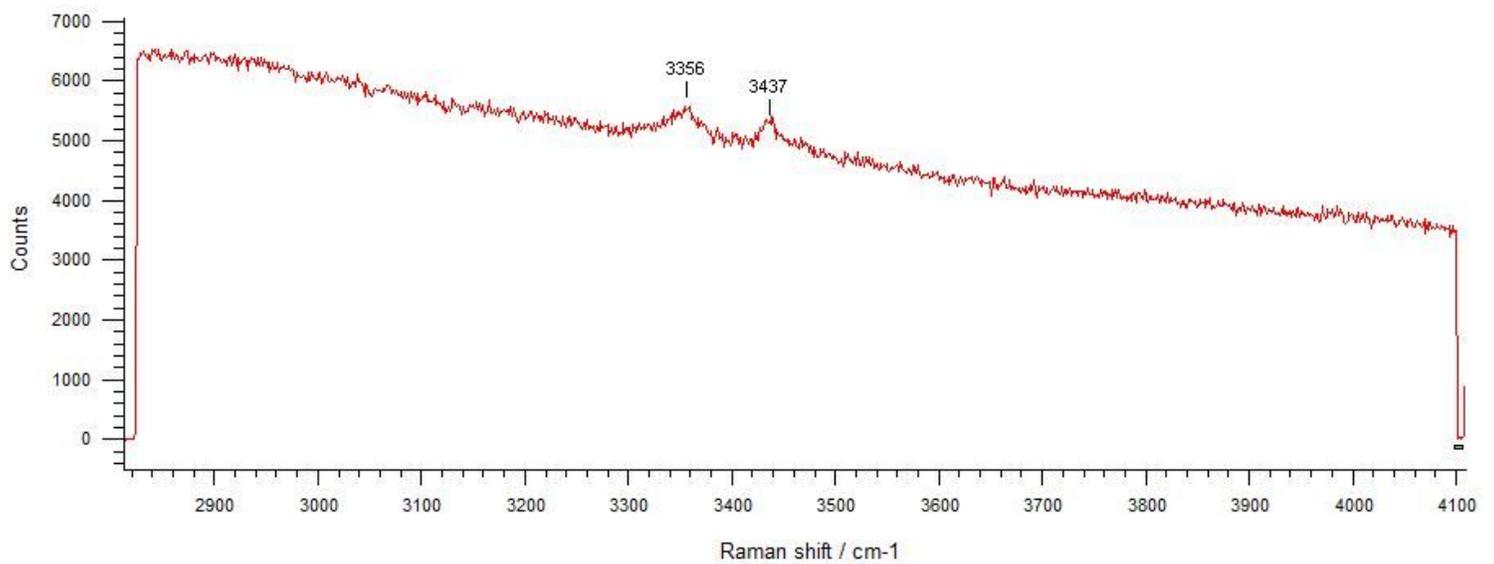


Figure 18

Raman spectrum of green pigment

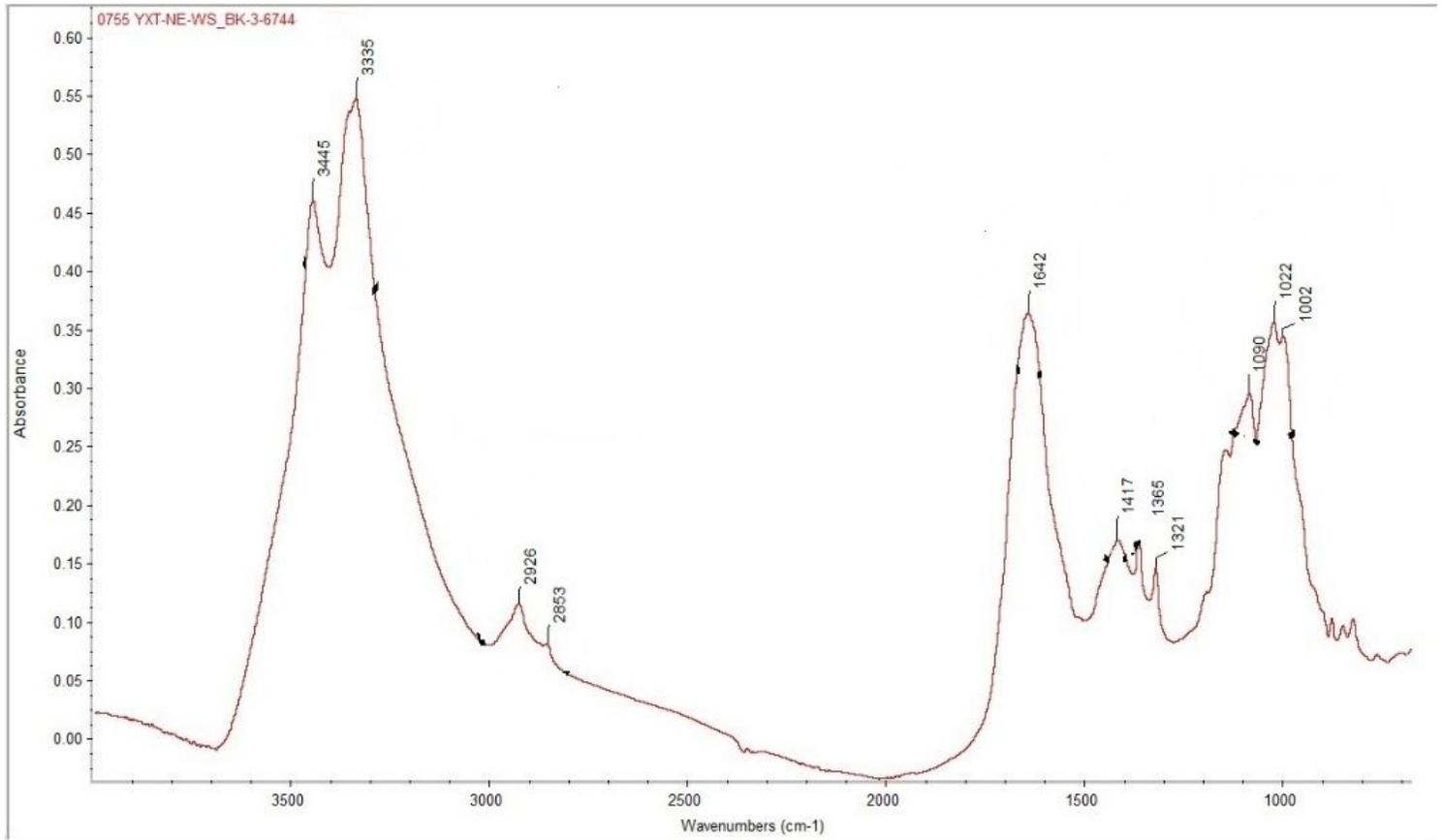


Figure 19

FTIR spectrum of green pigment

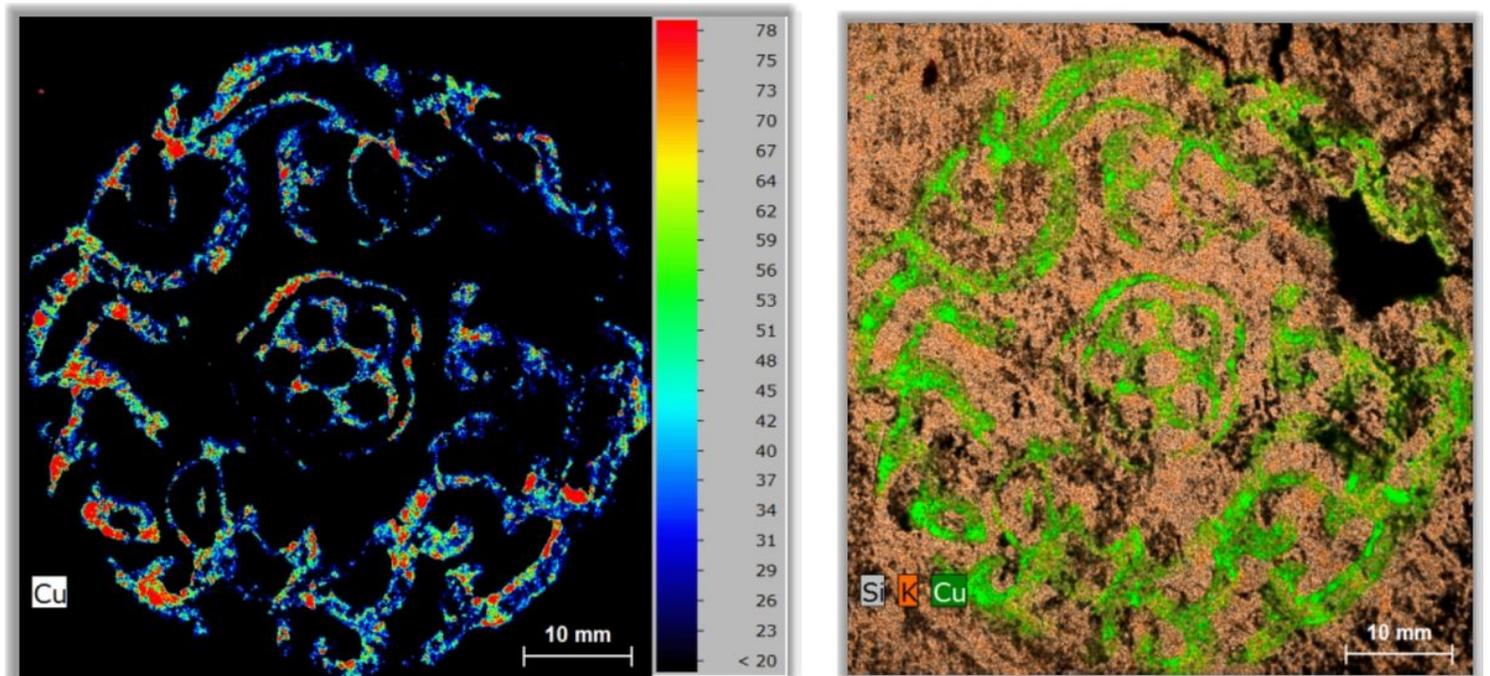


Figure 20

Micro-XRF imaging analysis of the wallpaper (a) Mapping of Cu (b) Mapping of Cu/Si/K



Figure 21

patterned wallpaper on surrounding of the bed in the Hall of Mental Cultivation (*Yangxin dian*)

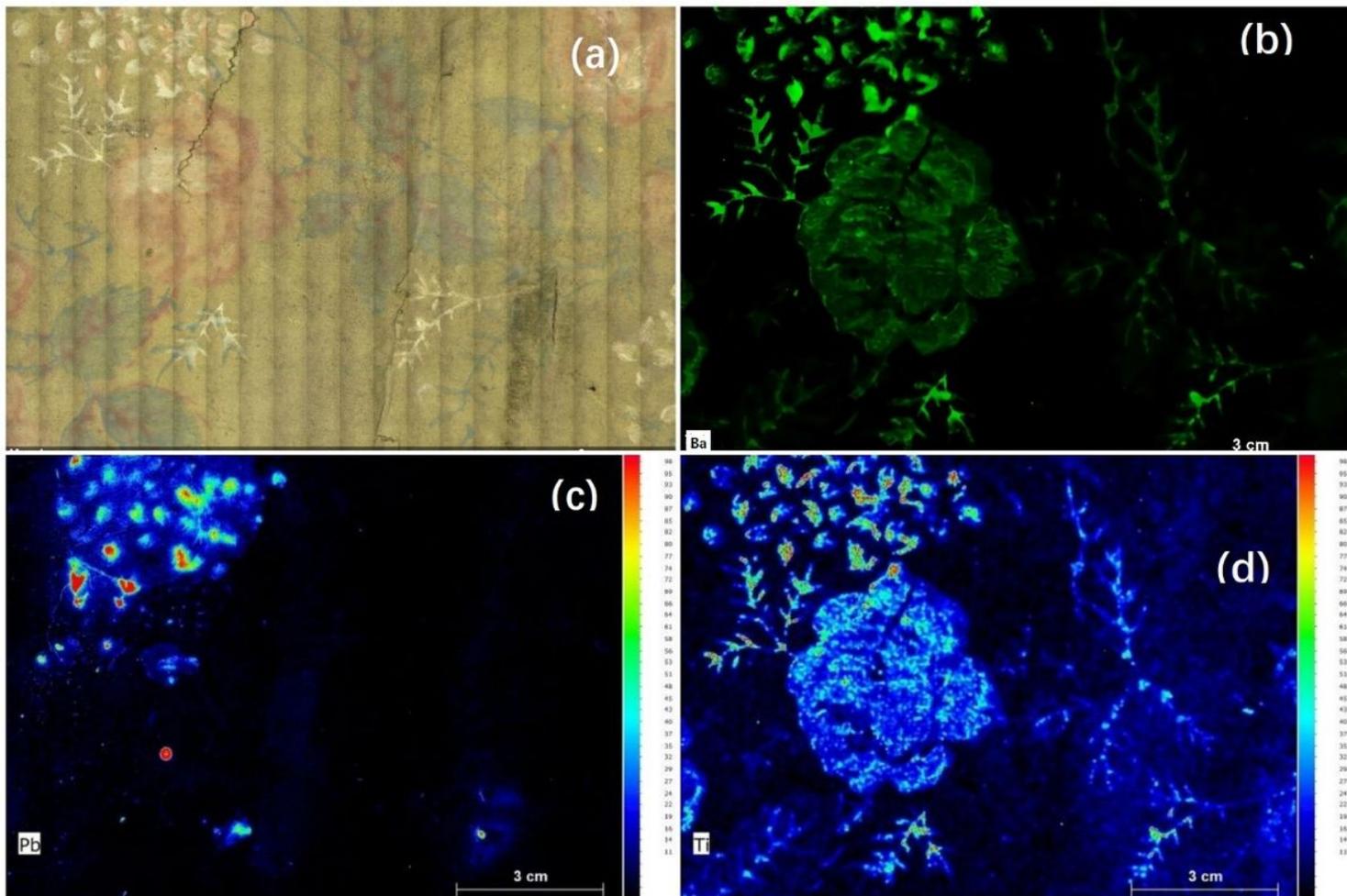


Figure 22

Micro-XRF imaging analysis of the wallpaper

(a)the patterned wallpaper (b) Mpping of Ba (c)Mpping of Pb (d)Mapping of Ti