# Analytical Investigation Into Feather Decoration Technique of 17th-18th Century Chinese Royal Hanging Screen

**An Gu** ( gu.an@outlook.com )
The Palace Museum https://orcid.org/0000-0002-3194-9177
**Na Wang**
The Palace Museum
**Yan-ju Kong**
The Palace Museum
**Jia-yu Hou**
The Palace Museum
**Gen Li**
The Palace Museum
**Yong Lei**
The Palace Museum

**Research article**

**Keywords:** Feather Decoration, Featherworks, Feather Art, Diancui, China, Royal, Qing Dynasty

**Posted Date:** March 19th, 2021

**DOI:** https://doi.org/10.21203/rs.3.rs-299638/v1



**Version of Record:** A version of this preprint was published at Heritage Science on July 9th, 2021. See the published version at https://doi.org/10.1186/s40494-021-00555-8.

# Abstract

Decoration with feather was a universal phenomenon in human history. Objects decorated with feathers were regarded as fine artworks and hence were enormously prized. In ancient China, dotting a surface with kingfisher-feather blue was the most famous, complex and delicate feather decoration technique, called diancui. Although various ancient diancui artworks appear in many museums around the world and some researches have achieved significant results on the history, technique and conservation of diancui, but some key historical details are still not clear. In this research, by the opportunity of restoration, an important collection of the Palace Museum - the "Feather Decoration Hanging Screen with Birds and Flowers Pattern" was rounded analyzed by various scientific technologies. This object is a Chinese royal artwork of Qing dynasty (17th-18th century), decorated with kingfisher and several other bird's feathers, and present the highest level of this period. As a typical and valuable case, the result provides important clues for solving unclear questions for related academic field.

# 1 Introduction

Decoration with feather was a universal phenomenon in human history. It was widely used in textiles, jewelry and painting in ancient America, Europe and China. At that time, objects decorated with feathers were regarded as fine art works and hence were enormously prized. [1–4] In ancient China, kingfisher feather, with bright, mellow and constant blue or violet color, was considered as the best and most widely used material for luxury decoration among various bird feathers. Dotting a surface with kingfisher-feather blue was call diancui (tian-tsui or □□) which was the most representative feather decoration technique of China. This technique could be traced back to the Warring States Period (475-221 BCE)[5] and became very popular in Tang and Song dynasty (618-1279). The development of diancui reached its top in Ming and Qing dynasty (1368-1912).

The diancui technique was complex and delicate. Craftsman pasted micron-sized feather fibers on support and adjusted the microscopic structure and materials by subtle skills to get various texture and color effect. It demonstrated a high level of artistic achievement. Together with the rarity of kingfisher feather, objects with diancui has always been a kind of the most deluxe artworks in ancient China and appear in many museum and private collections around the world now [6–9].

Although featherwork has recently been the subject of academic attention, the research on the important Chinese tradition is comparatively weak. Even some researches have achieved significant results on the history, technique and conservation of diancui [4, 5, 7, 10]. Some key historical details are still not clear, especially details of the complex technique. For example: (1) Although only two kinds of kingfisher feathers (bule and violet) were used in diancui, but obviously the ancient craftsman could slightly adjust color and texture of the finishing surface to reach a rich and vivid decorative effect. What skills did the they used? (2) What materials and technique were used in the support and adhesive parts of diancui objects which are under the feather layer and hard to be directly observed? (3) On some ornately decorated objects, both diancui and other kinds of feathers with different colors were used in different

areas to rich the colors and patterns. What other feathers were used? Was the technique same with kingfisher feather?

Analytical investigation on typical ancient diancui objects could be the most effective way to answer these questions. But normally, existing diancui objects are rare and precious because they are fragile and hard to preserve. Lack of sample limited research in this field. The Palace Museum China contains abundant diancui artworks of Ming and Qing dynasty. In this research, by the opportunity of restoration, an important collection of the Palace Museum - “Feather Decoration Hanging Screen with Birds and Flowers Pattern” was rounded analyzed by various scientific technologies. This object is a royal artwork of Qing dynasty (17th-18th century), decorated with kingfisher and several other kinds of bird’s feathers, and present the highest technique level of this period. As a typical and valuable case, the result provides important clues for solving unclear questions mentioned above.

# 2 Materials And Experiments

2.1 The Hanging Screen

The hanging screen investigated in this study is a collection of the Palace Museum China, named as “Feather Decoration Hanging Screen with Birds and Flowers Pattern”. It is considered that the hanging screen was made for the emperor in Qing Dynasty (17th-18th century). But the exact production date is unknown.

Normally, diancui technique was used to make small objects (for example jewelry) because of the rarity of the material and the difficulty of the process. But this hanging screen is not only big (width 795mm and high 1130mm) but also have ingenious design and exquisite craft. As it reached the highest level of the royal diancui artworks in ancient China.

As shown in Fig. 1, the pattern of the screen is that two birds are standing on two stones with background of trees, flowers and ground. There are 4 kinds of feathers used in the screen: the bird’s body, leaves and flowers were made of light blue feather; the stones and some parts of the birds were made of violet feather; the tree trunk was made of brown feather; the ground was made of dark irisated feather and eaten by insects seriously.

2.2 Samples

The most parts of the screen were in good condition. And only nondestructive analysis without sampling were acceptable. But a small leaf part dropped from the screen (Fig. 2) could be used for micro sampling before restored and pasted back. In addition, a small fragment from the ground area could be used for cross section analysis. Modern kingfisher feather was also used for comparing with the feather from the screen.

2.3 Experiments

Variety of microscopes were used for observing micromorphology: video microscope (LEICA DVM5000) with a cross cantilever for observing in situ; metallographic microscope (LEICA) with a spectrograph for observing the cross section and collecting the visible spectrum of the micro area of feather; biological microscope (Olympus) for analysis the paper base fibers dyed by Herzberg reagent; SEM (FEI Quanta600) with EDS (EDAX Genesis) for elements imaging of cross section; FESEM (Tescan mira3) for observing the Nano coloration structure of kingfisher feather.

Variety of spectroscopy technology were used for materials analysis: FTIR-Microscope (Thermo Scientific Nicolet iN10), fitted with a mercury–cadmium–telluride detector cooled by liquid nitrogen was used for FTIR spectroscopy analysis in the range 4000–675 $cm^{-1}$, at a spectral resolution of 4 $cm^{-1}$; Raman (RENISHAW Invia) spectroscopy, 50X lens (Olympus), 633nm wave length laser, 5mW energy, 10s exposure time, integral for 1 time; m-XRF (Bruker M4 Tornado) spectrometer with an Rh X-ray source operated at 50 kV and 200μA, beam size 20μm, test time 120s; XRD (Rigaku 2550/PC), 40kV, 150mA, scanning speed=5degree/min, step=0.02degree, DS=SS=1degree, RS=0.3mm.

# 3 Results And Discussion

3.1 The Light Blue Area

The light blue feather was the most common used in diancui. Fortunately, the dropped leaf part from the screen is light blue, and could be overall analyzed. According to the damaged part (Fig. 3 (a) and (c)) and flank side (Fig. 3 (b)), there are 6 layers in this part as shown in Fig. 3 (d). The analytical investigation result of every layer was shown in Table 1.

According to the investigating on modern diancui craftsmen, a rough process of diancui is as follow. First, put feather back side up on a panel. Then brush glue on the back side of the feather. At last, separate the feather from the panel by knife as a feather sheet when the glue dried. This process can protect the feather fibers to scatter and make it easier to cut to required shape. Then the feather sheets are glued on a support body. The analytical results of this screen fit the rough process well, but more details were found. The following is the detailed analytical result and discuss:

**Layer 1:** Layer 1 is the surface feather layer. It is obvious that this layer was spliced by small pieces of feather because the seams could be found through microscope (Fig. 3 (c)). There is a golden line decoration on Layer 1, which was proved by XRF. In order to identify whether the feather is from kingfisher, several methods were used to compare with the modern kingfisher feather. And the result showed that they matched well.

First, they were compared by stereoscopic microscope. As shown in Fig. 4, the color and size of these two feathers was consisitent. Both of the colors appears dense and varying shades of blue spots. The screen feather (40~50μm) is a litte smaller than the modern one (60~70μm). This difference may be caused by individual differences of kingfishers or growing in deifferent location of kingfisher body.

Second, the color of kingfisher feather is a kind of structural color which formed by interference, diffraction and scattering of light by Nano structural of feather [11]. This is why the color of diancui is constant. Infiltration by liquid with high refractive index is a simple method of verification structural color [12]. As shown in Fig. 5 (a) and (b), some parts of the screen feather changed to transparent brown color and the visible spectrum redshifted (Fig.5 (c)) after infiltrated by isoamylol (refractive index = 1.4). When the isoamylol volatilized, the color was back to blue. This phenomenon showed that the feather has structural color, but not dyed. The result of FESEM supported this conclusion: the medulla of the feather form the screen Fig. 6 (a) has the similar Nano net structure with the modern feather Fig. 6 (b).

**Layer 2:** Normally, this layer was kind of glue that was painted on the back side of feathers to bond the feather fibers to a feather sheet. So that cutting and pasting would be much easier. So normally this layer is called “back side glue layer”. Micro-sample of this layer was tested by microscopic FTIR. The result shows that the glue material is protein and maybe animal gelatin, according to the bands of 1650 cm-1 (C=O stretching band), 1550 cm-1 (C-N-H bending band), 1450 cm-1 (CH bending band) and 3350 cm-1 (N-H stretching band) in the spectrum of Fig. 7 (a) [13].

According the Fig. 3, this layer is not only glue but also added black pigment. The black color can be seen through the gaps between feather fibers. So, another function of this layer was that making the sensorial color of the diancui surface darker and the texture of feather fibers clearer. The bands of 1350cm-1 and 1590cm-1 in the Raman spectrum (Fig. 8) are the D-band and G-band of carbon[14]. This shows that the black pigment of this layer is carbon black.

**Layer 3 and Layer 6:** The function of Layer 3 was bonding the feather sheet (layer1 + layer2) and support body (Layer4+Layer5+Layer6) together. The function of Layer 6 was bonding the diancui component on the screen. The FTIR spectrum (Fig. 7 (b)) of layer 3 and layer 6 is consistent. The bands of 3310 cm-1、1647 cm-1、1545 cm-1、1448 cm-1 shows that the materials is protein and maybe animal gelatin[13].

**Layer 4:** This is a red layer on the top of the support body. Normally, it was call called “back side color layer”. Its function was adjusting the sensorial effect of color and texture of the surface because the “back side glue layer” are often transparent and the color of this layer can be seen through the gaps between feather fibers. In this case, even Layer 2 is already black, this layer was still painted red. The purpose may make the color of diancui surface look a little warmer. The XRF test result shows that the main elements in this layer are Fe, Al and Si. So the red pigment may be ochre. The FTIR result (Fig. 7 (c)) also supports this inference. The bands of 3695 cm-1, 3620 cm-1, 1036 cm-1, 910 cm-1 is the characteristic of $Al_2O$ and $SiO_2$ from clay [13], which often accompany with ochre [15]. On the other hand, the bands of 3310 cm-1、1647 cm-1、1545 cm-1、1448 cm-1 shows that the materials could be gelatin [13].

**Layer 5:** Support body is the supporting structure of a diancui object and made by metal or paper. Silver and gold were soft and easy shaping. Therefore, commonly used for making metal support body. Paper support body was widely used in Qing dynasty for big jewels or furnishings, because it was much lighter than metal. The support body was rare studied before. In this research, the layer 5 is the main part of the

support body and made by several layers of paper. In the FTIR spectrum (Fig. 7 (d)), the bands of 3335 (OH str)、1430 ($CH_2$ def)、1370 (CH def)、1317 (OH def)、1160, 1105, 1054 (C-O str of COH/C-O-C)、898 (Ring semi-circle str) are consistent with cellulose of paper[16]. Fig. 9 is the microscope picture of paper fibers. Observing by a biological microscope, the color of fibers looks blue or brown after dyed by Herzberg reagent. The shape of the fibers is straight with cuspate end. The parenchymatous cells, sclereids and duct could be found. These show that the paper is made of bamboo [17]. A stick is sandwiched in the paper layers as a skeleton to make the support body stronger. The material of this stick is copper according to the result of XRF.

## 3.2 The Violet Area

On this screen, the stone, beak and wings of the birds were made by violet kingfisher feather. Different with the light blue area, Fig. 10 shows that the back glue layer of violet feather was transparent, and the back side color layer was red. This design made the sensorial color of diancui surface brighter. An interesting discovery was that the feathers of bird beaks (Fig. 10 (a)) was sparser than other parts (Fig. 10 (b)). So the color of beak areas looks redder and close to rosy. Obviously, it's not an accident. This discovery means that the ancient craftsmen can change the gaps between feather fibers to adjust the holistic color appearance. The XRF result shows that the main elements of the red layer are Fe, Al and Si, so the red pigment may be ochre. Further analysis did not carry out, because sampling was not allowed.

## 3.3 The Ground Area

The ground area had been damaged by pests. And layers under the feather can be seen in some cracked parts. As shown in Fig. 11, 4 layers could be found in the cracked area (a) and the cross-section image of a fragment sample (b).

Layer 1 was a kind of dark feather with irisation. The microstructure of the feather fiber (Fig. 12 (a)) was bamboo-like and similar with the peacock feather (Fig. 12 (b)). The difference was that the feather of the screen was flater than the modern feather. It means that the peakcock feather on the screen may be scraped.

Layer 2 may be the back glue layer and bonding layer together. It was transparent. So the back side color layer under this layer could be seen. The appearance and FTIR spectrum of this layer were same with the Layer 3 and 6 of the light blue area. The material could be gelatin.

Layer 3 was the back side color layer. The element Ag can be found in this layer from the SEM-EDS mapping (Fig. 13 (b)). So this layer should be a silver foil and for enhancing the shiny and irisated effect of the feather surface appearance. The feather was pasted on the silver foil by yellow transparant gelatin which made the foil look like gold. The technique may be a design to disguise as gold foil and save cost.

Layer 4 was used for stick the silver foil on support body. It is common that adding red pigments in the glue for bonding foils in China. SEM-EDS mapping (Fig. 13 (c-f)) shows that the main elements of this layer are Fe、Al、Si、O. The FTIR spectrum and elements result are almost same with the layer 6 of the light

blue area. So this layer could be a mixture of ochre and gelatin. Additional structure was found in the SEM picture (Fig. 13 (a)) under this layer. They might be the paper fiber from the support body.

3.4 The Tree Trunk Area

Fig. 14 (a) shows that the surface of the tree trunk area was made by a kind of brown down feather because the barbs are thin without hook and the barbules are thin and long. Further analysis for identification of species did not carry out, because sampling was not allowed.

Different from other areas, A white thick layer under the feather could be found at the damaged position (Fig. 14 (b)). The purpose of this layer was making a raised shape like real tree trunk. The white material was identified as $CaCO_3$, according to the characteristic bands of 1440 $cm^{-1}$ and 880 $cm^{-1}$ of the FTIR spectrum (Fig. 15) [13]. The high signal of Ca element in XRF result was also support it.

# 4. Conclusions

Decoration with feather was a universal phenomenon in human history. In this academic subject, Chinese tradition is an inescapable part. But some key historical details are still not clear. The hanging screen, investigated in this paper, is a typical royal feather decoration artwork of $17^{th}$-$18^{th}$ century China. The research results provided important clues for understanding the complex ancient diancui techniques better and solving following unclear questions.

(1) Even only two kinds of kingfisher feathers were used, how did the ancient craftsmen adjust the color and texture of the finishing surface to reach a rich and vivid decorative effect?

Using back side color was one of the main ways to adjust the sensorial color and texture of the diancui objects. In this hanging screen, double back side color layer (black and red) was used to make the light blue feather looks darker and warmer and the texture clearer. Red back side color layer was used to make the violate feather looks brighter. Adjusting gaps between feather fibers was another main way. The feather of bird beaks of the screen was sparser than other parts. So the color of beak looks redder and close to rosy.

(2) What materials and technique were used in the support and adhesive parts of diancui objects which are under the feather layer and hard to be directly observed?

According to the investigation on modern diancui craftsmen, there were normally two adhesive layers: back side glue layer and bonding layer. The function of the back side glue layer was bonding feather fibers together to a feather sheet. So that cutting and pasting small feathers would be much easier. The bonding layer was for bonding the feather sheet and support body together. The analyzing results of the screen supported this process well. Additionally, for the light blue feather, carbon black pigment was added in the back side glue layer and also used to adjust color and texture beside the back side color layer.

The support body of this screen was made of multi-layers of bamboo paper. Gelatin was used for bonding paper together. A copper stick was sandwiched in the paper layers to strengthen the body. The purpose of this design might be weight reduction for large diancui objects.

(3) What other feathers were used along with kingfisher feather? Were their techniques same with kingfisher feather?

Peacock feather was used in the ground area of the screen. The main structure of this area is similar with the diancui area. The difference is mainly on the back side color layer. The material of back side color layer is silver foil but not pigment, for enhancing the shiny and irisated effect of the feather surface appearance. Interestingly, the feather was pasted on the silver foil by yellow transparant gelatin which made the foil look like gold. This technique may be a design to disguise as gold foil for saving cost.

A kind of brown down feather was used in the trunk area of the screen. The layer under feather is different from other area. A raised shape was made by thick $CaCO_3$ in this layer to imitate the real tree trunk.

# Declarations

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

This research has been supported by the National Key R&D Program of China, No. 2019YFC1520300.

Authors' contributions

AG performed most analysis work, and was a major contributor in writing the manuscript.

NW observed micro-structure of various bird’s feather by optical microscope and found the characteristic.

YJK was the conservator of the hanging screen. She provided us the opportunity to study on it.

JYH performed the in-situ observation of the hanging screen by video microscope.

GL analysis and discuss the structural color of kingfisher feather.

YL introduced the information about the ancient diancui craft.

Acknowledgements

Thanks Liu Han-wen, Kang Bao-qiang, Li Yuan, Duan Pei-quan, Li Guang-hua. They help us for the testing of Raman, XRD, SEM, XRF and pigment analysis. This research cannot finish without their help.

# References

1. Russo A, Wolf G, Fane D, Kunsthistorisches Institut in Florenz (eds) (2015) Images take flight: feather art in Mexico and Europe 1400-1700. Hirmer, München
2. Doughty RW (1975) Feather fashions and bird preservation: a study in nature protection. University of California Press, Berkeley
3. Reina RE, Kensinger KM (eds) (1991) The gift of birds: featherwork of native South American peoples. The University Museum, Philadelphia, Pa
4. Milburn (2020) Featherwork in Early and Medieval China. Journal of the American Oriental Society 140:549
5. Zhu Z, Tan P, Yang J, Ge H, Liu L (2019) Mass Spectrometric Identification of Adhesive Utilized in a *Tian-tsui* Tiara of the mid-Qing Dynasty (1776–1839 CE) in the Collection of the Tang Clan Folk Museum. Studies in Conservation 64:187–192
6. Jackson B (2001) Kingfisher blue: treasures of an ancient Chinese art. Ten Speed Press, Berkeley, Calif.; Toronto
7. Paulson M (2018) Visible effects of adhesive and pressure on color in kingfisher feathers. UCLA
8. University of Oxford (2013) Chinese hairpins: “Rhapsody in Blue”. Rethinking Pitt-Rivers: analyzing the activities of a nineteenth-century collector. In: Pitt Rivers Museum. http://web.prm.ox.ac.uk/rpr/index.php/object-biography-index/1-prmcollection/290-chinese-hairpins/.
9. National Museums Scotland Kingfisher headdress. https://www.nms.ac.uk/explore-our-collections/stories/world-cultures/kingfisher-headdress/.
10. Chase ES, Maccarthy B (2002) Rhapsody in blue: kingfisher feather cloisonné in the Arthur M. Sackkler Gallery. AIC. Textile Specialty Group, pp 45–55
11. Stavenga DG, Tinbergen J, Leertouwer HL, Wilts BD (2011) Kingfisher feathers - colouration by pigments, spongy nanostructures and thin films. Journal of Experimental Biology 214:3960–3967
12. Zhang Q, Hao lv, Zhao Q, Wang X (2013) The Color Analysis of Peacock Feather. Spectroscopy and Spectral Analysis 33:632–635
13. Derrick MR, Stulik D, Landry JM (1999) Infrared spectroscopy in conservation science. Getty Conservation Institute, Los Angeles
14. Reich S, Thomsen C (2004) Raman spectroscopy of graphite. Philosophical Transactions of the Royal Society of London Series A: Mathematical, Physical and Engineering Sciences 362:2271–2288
15. Gettens RJ, Stout GL (1966) Painting materials: a short encyclopaedia. Dover Publications, New York

16. Larkin P (2011) Infrared and raman spectroscopy: principles and spectral interpretation. Elsevier, Amsterdam; Boston
17. Wang J (1999) Papermaking Raw Materials of China An Atlas of Micrographs and the Characteristics of Fibers. China Light Industry Press, Beijing

# Tables

Table 1. The analytical investigation result of every layer of the light blue area.

| Layer name | Color | Material | Function |
| --- | --- | --- | --- |
| Decoration Line | Golden | Gold | Delineate leaf veins |
| Layer 1: feather layer | Blue | Kingfisher feathers | The main decoration surfaces. |
| Layer 2: back side glue layer | Black | Gelatin and carbon black | The main function of this layer was bonding feather fibers together to a feather sheet. So that cutting and pasting small feathers would be much easier. In this case, this layer was not transparent but black. So it was not only for bonding but also another back side color layer besides Layer 4. |
| Layer 3: bonding layer | Transparent and yellow | Gelatin | Bonding the feather sheet and support body together. |
| Layer 4: back side color layer | Red | Gelatin and ochre | A red layer on the top of the support body. The color can be seen through the gaps between feather fibers. It was used to affect the sensorial color and texture of the surface together with the layer 2. |
| Layer 5: support body | Pale yellow | Bamboo paper | The main part of the support body. |
| Skeleton | Brown | Copper | Be sandwiched in the paper layers to make the support body stronger. |
| Layer 6: bonding layer | Transparent and yellow | Gelatin | Bonding this diancui component on the screen. |

# Figures

## Figure 1

Feather Decoration Hanging Screen with Birds and Flowers Pattern

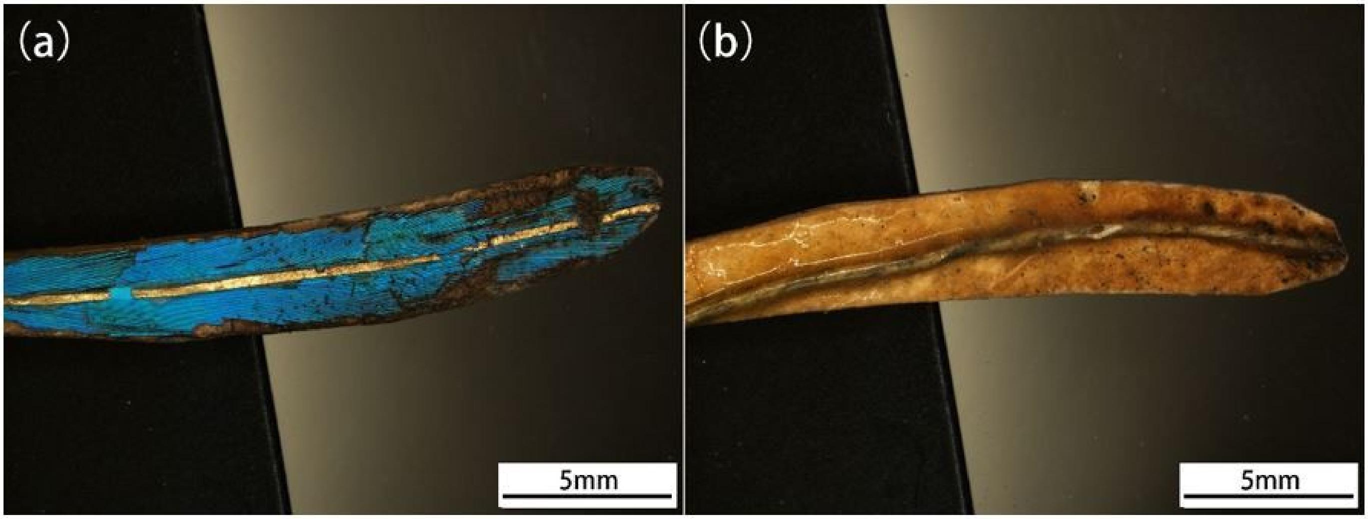



**Figure 2**

A small leaf part drop from the screen. (a) The frond side. (b) The back side.

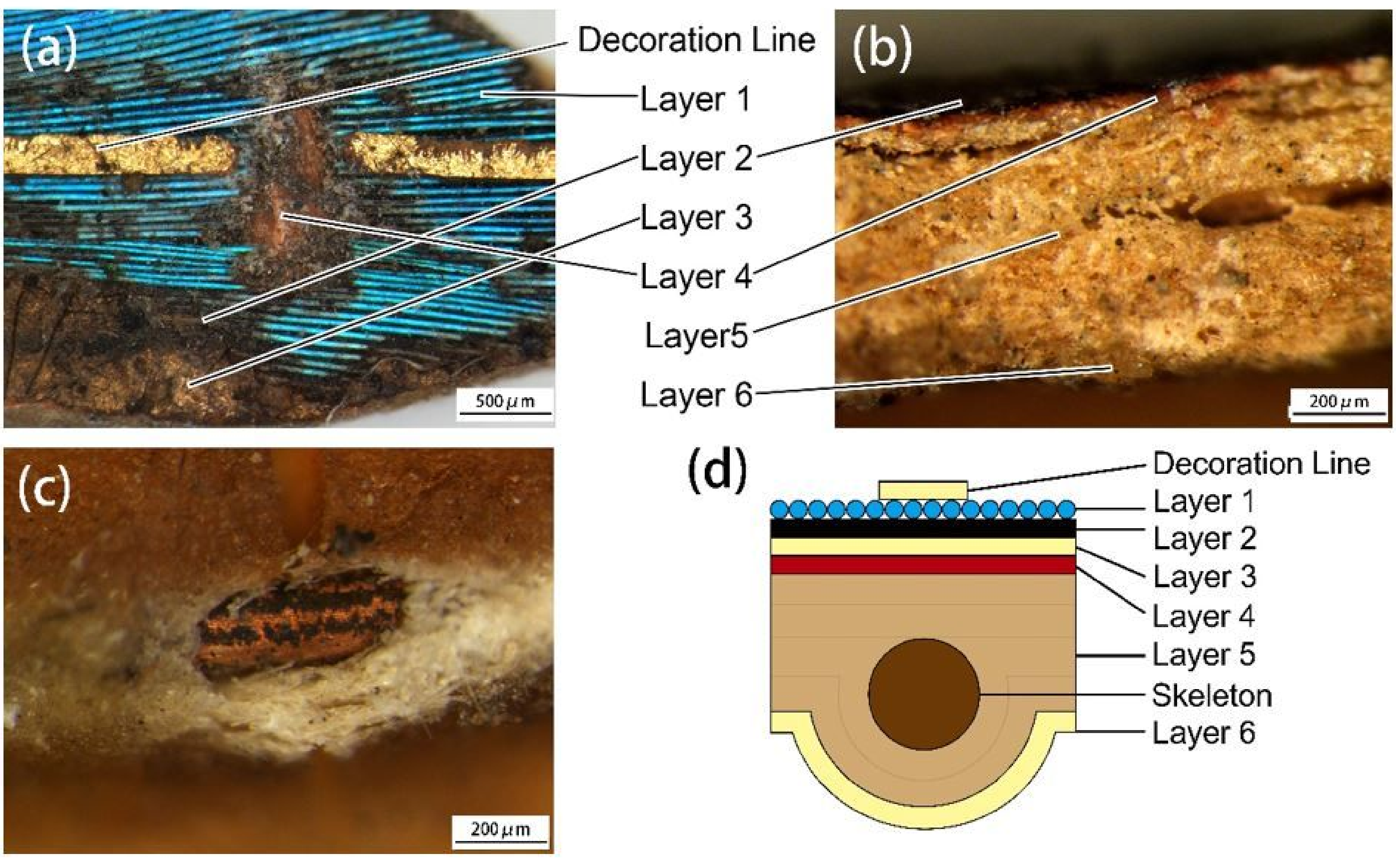



**Figure 3**

Layers structure of the small leaf part (a)The damaged part on the front side. (b) The flank side (c) The exposed the skeleton on the back side. (d) The layers structure sketches. The investigation result of every layer can be found in Table 1.

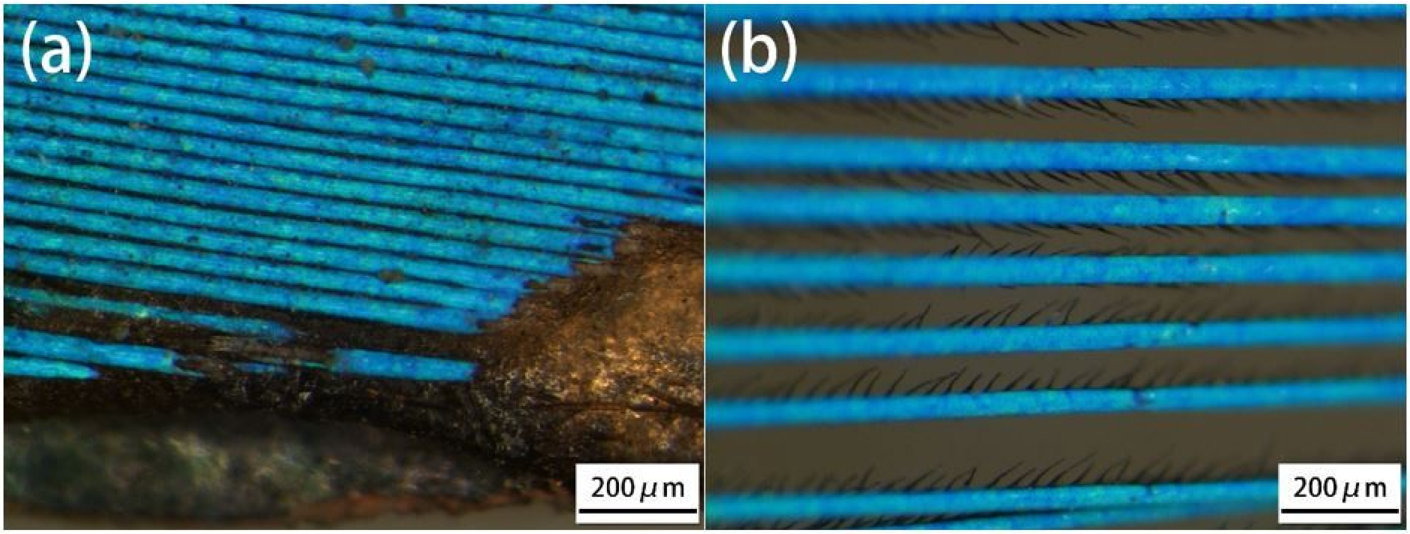



**Figure 4**

Comparing the feather from the screen (a) with the modern kingfisher feather (b).

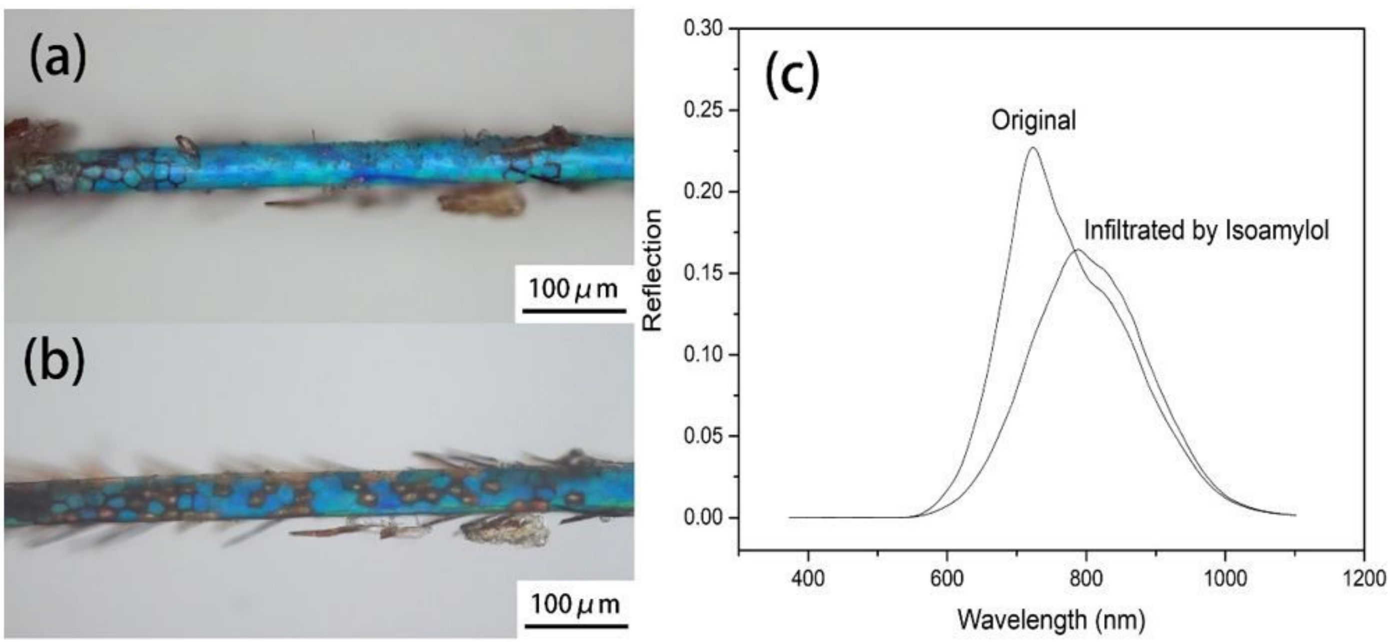
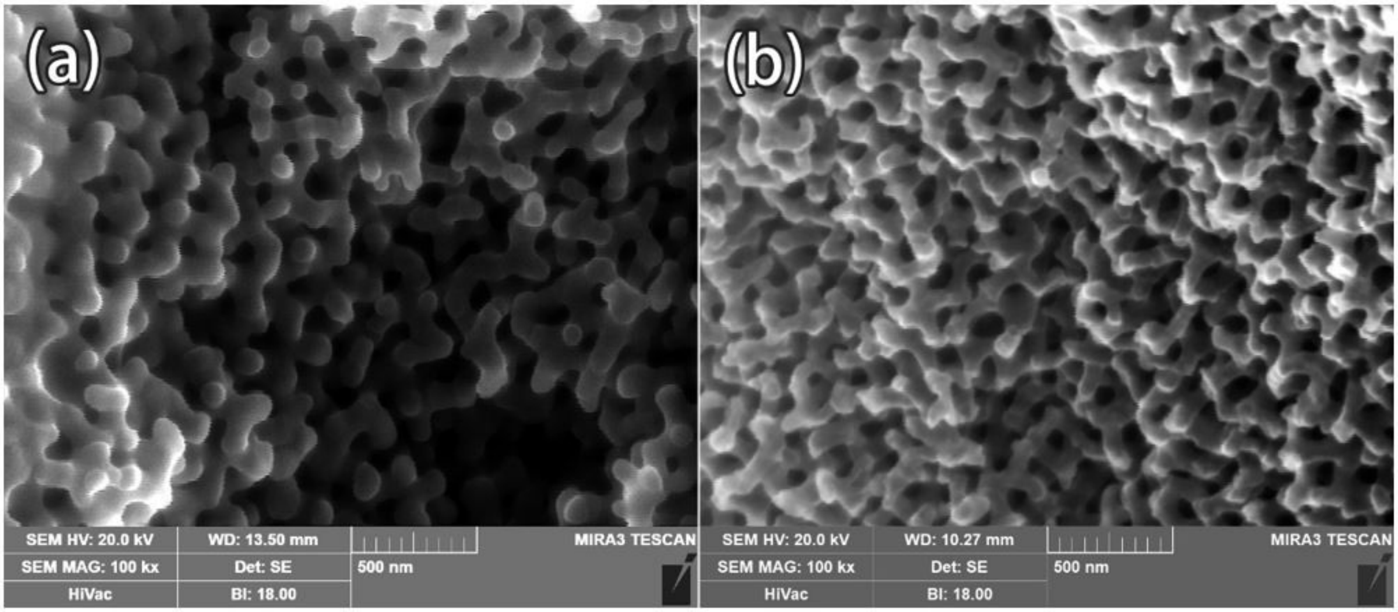


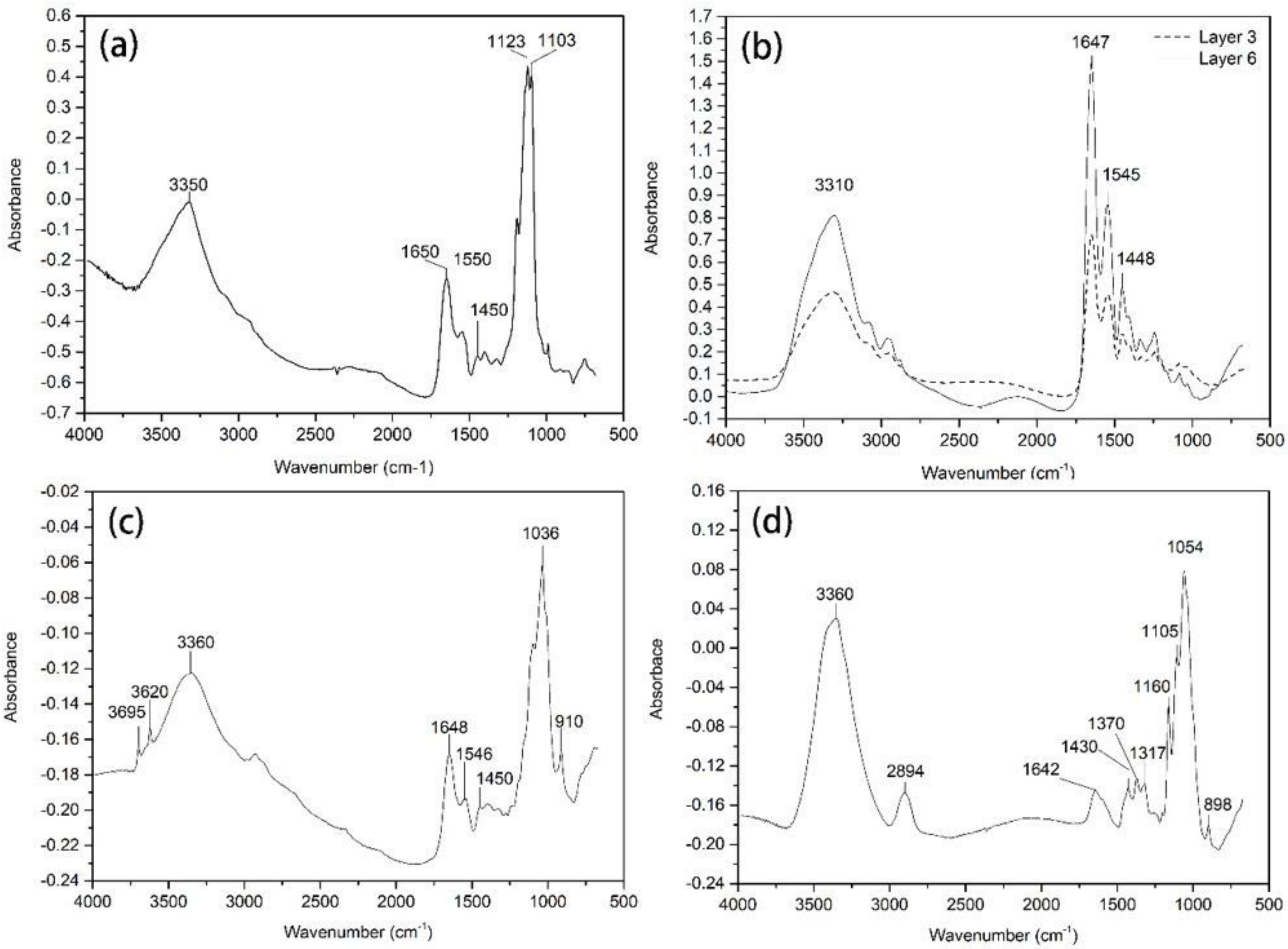

**Figure 5**

The color change of the feather before and after infiltrated by isoamylol. (a) before (b) after (c) the visible spectrum



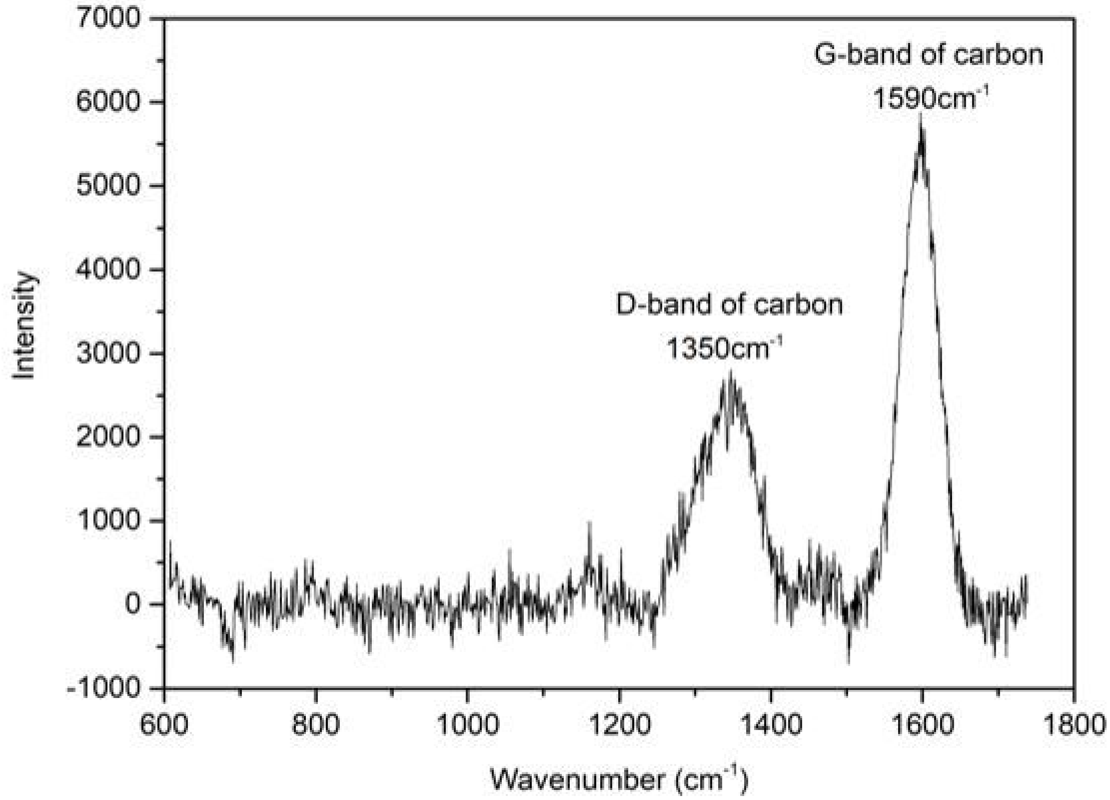

## Figure 6

The Nano structure of the ancient feather (a) and the modern kingfisher feather (b).



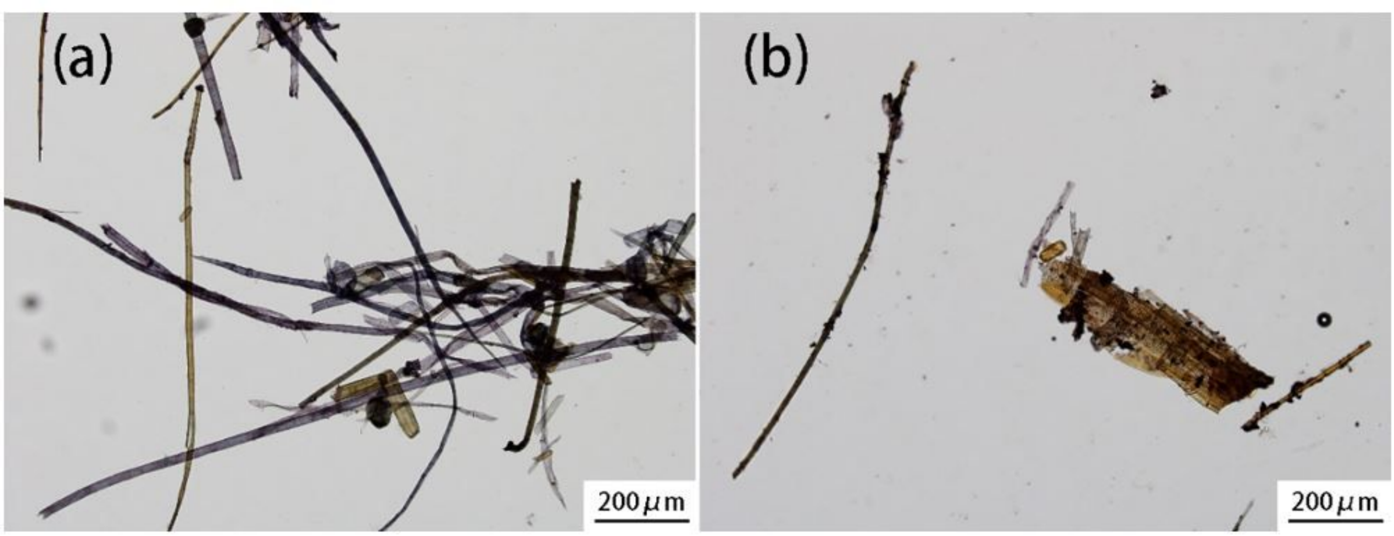
## Figure 7

The FTIR spectra of Layer2 (a), layer 3 and 6 (b), Layer4 (c), Layer 5 (d).




## Figure 8

The Raman spectrum of Layer 2.




## Figure 9

The biological microscope picture of paper materials in Layer 5. The fibers, parenchymatous cells, sclereids (a) and duct (b) could be found.

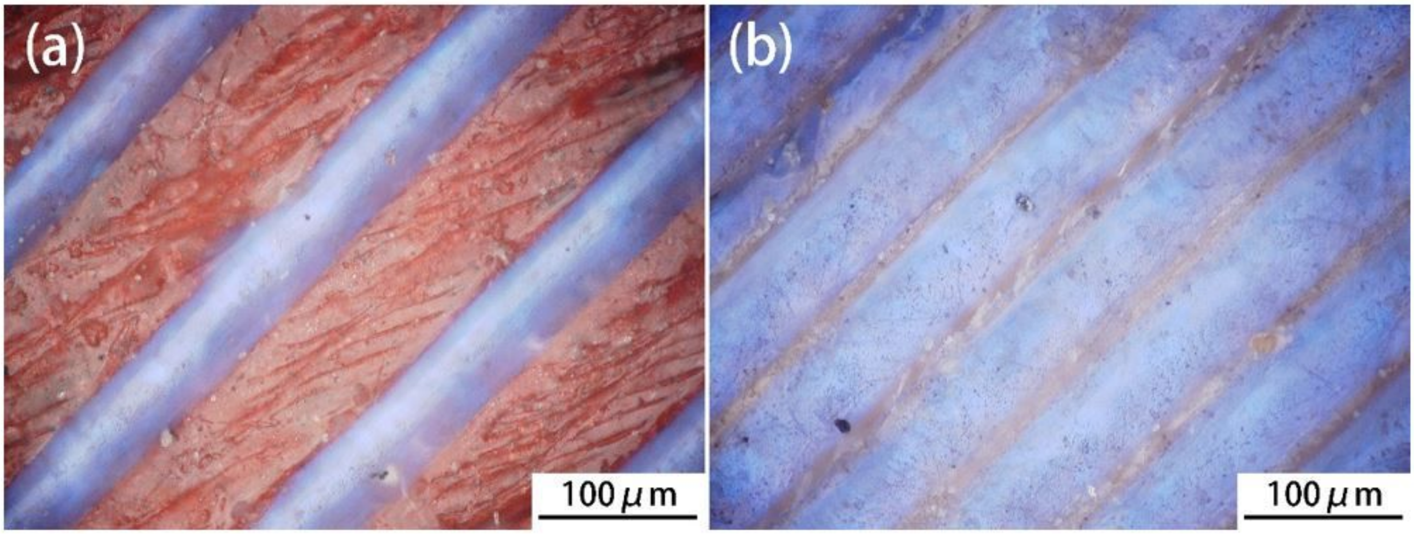



**Figure 10**

The microscopic image of the bird beak part (a) and other part (b).

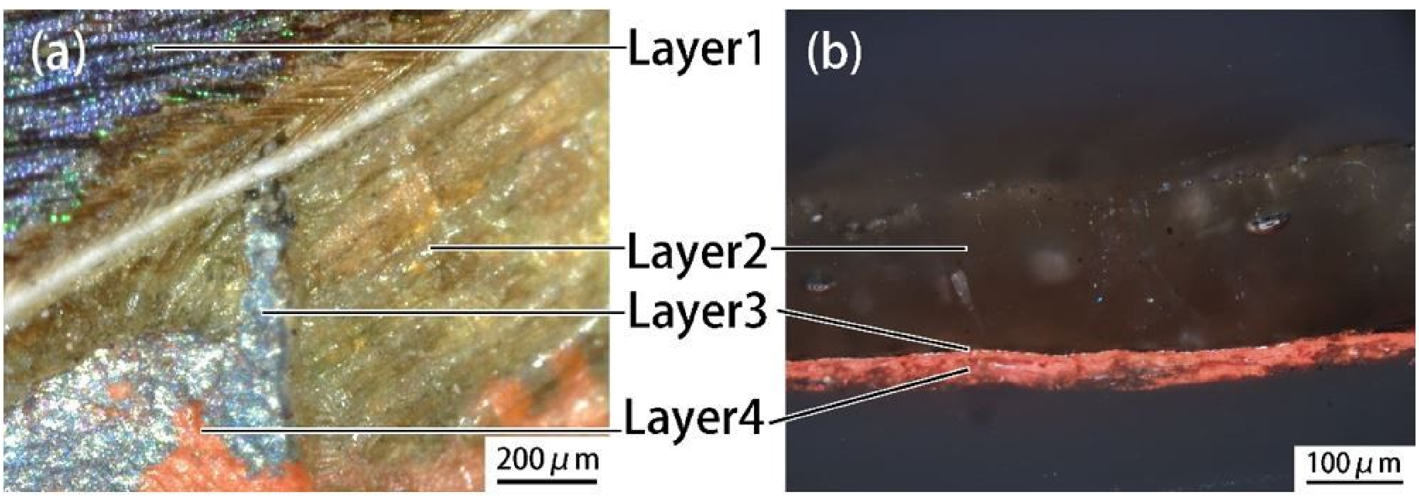
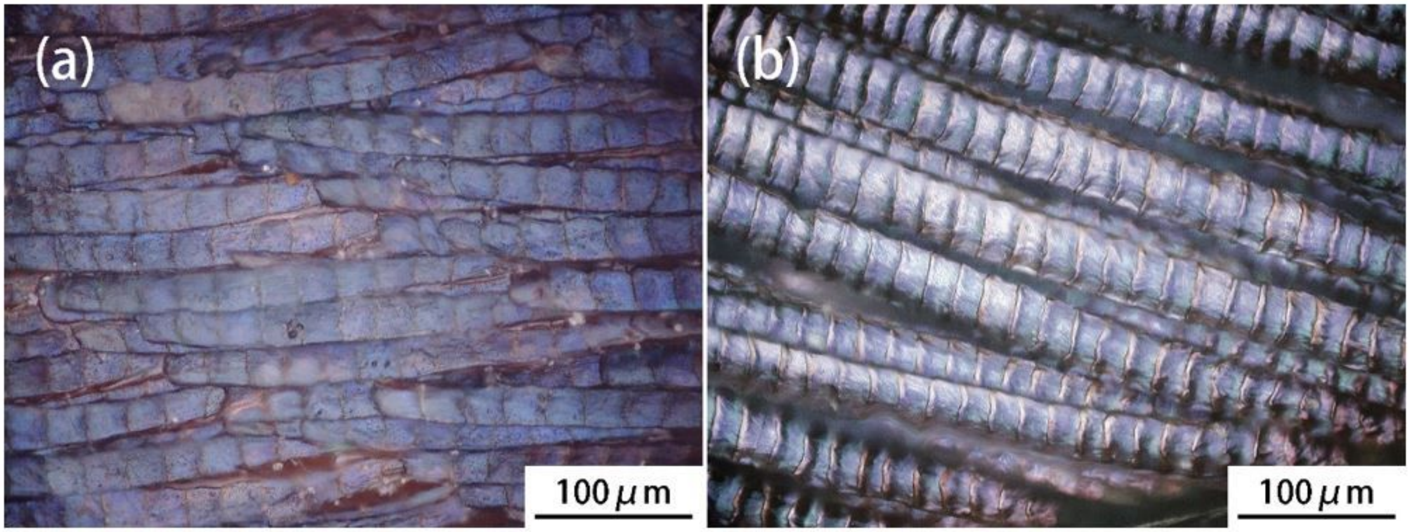


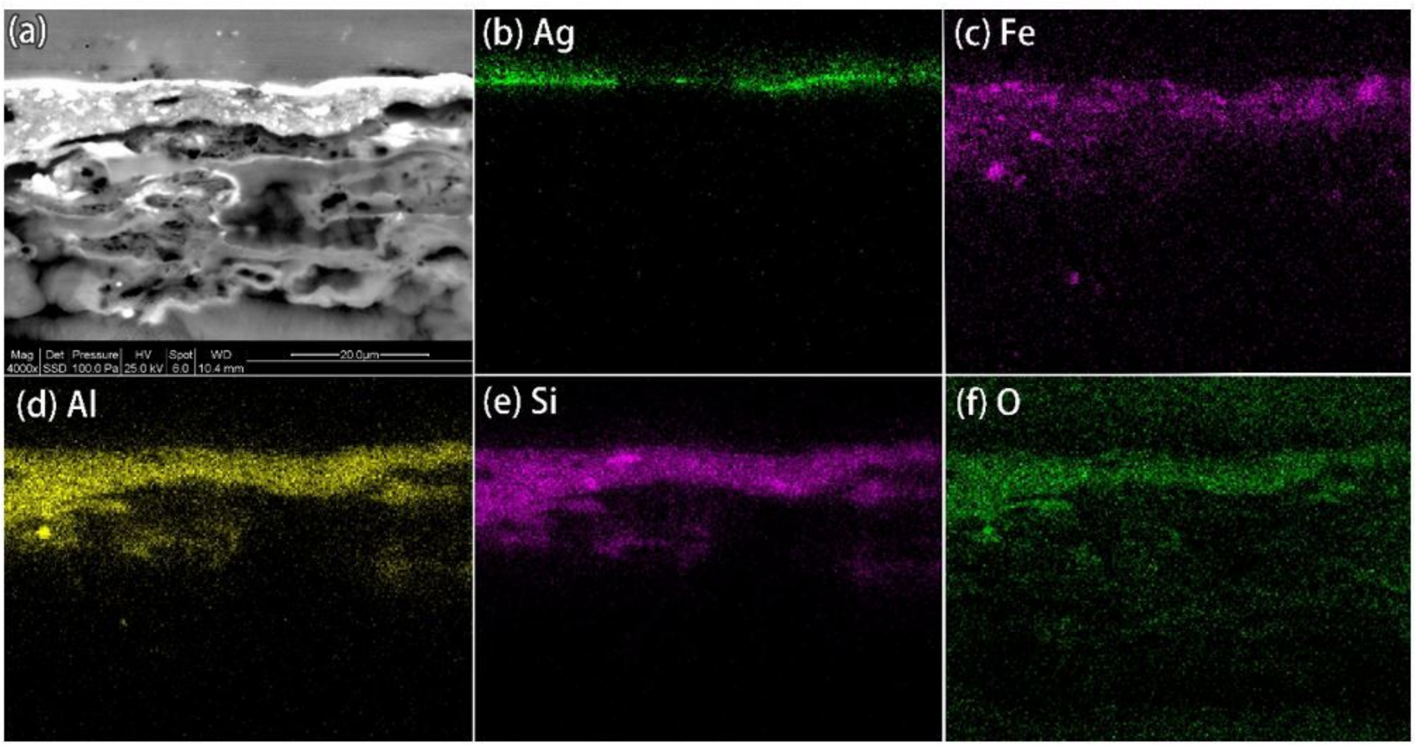

**Figure 11**

Four layers were found in cracked area (a) and cross section of a fragment (b)




## Figure 12

The microstructure of the feather of the ground area (a) and modern peacock(b).




## Figure 13

The SEM-EDS elements mapping of Layer3 and 4.

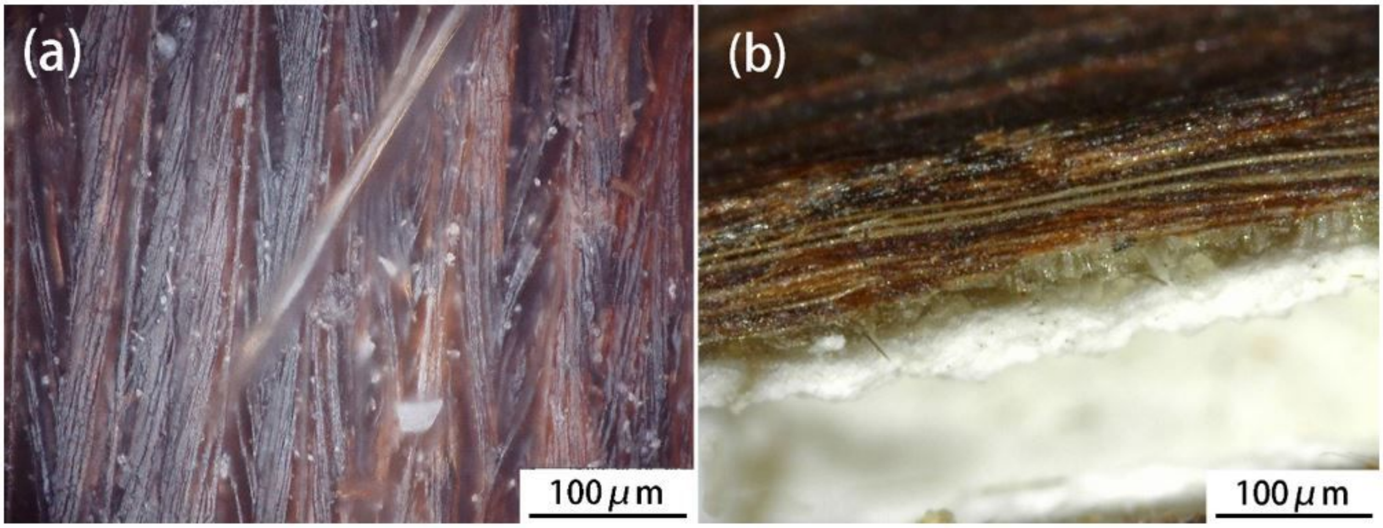



**Figure 14**

Brown down feather on the surface (a) and white thick layer under the feather (b)

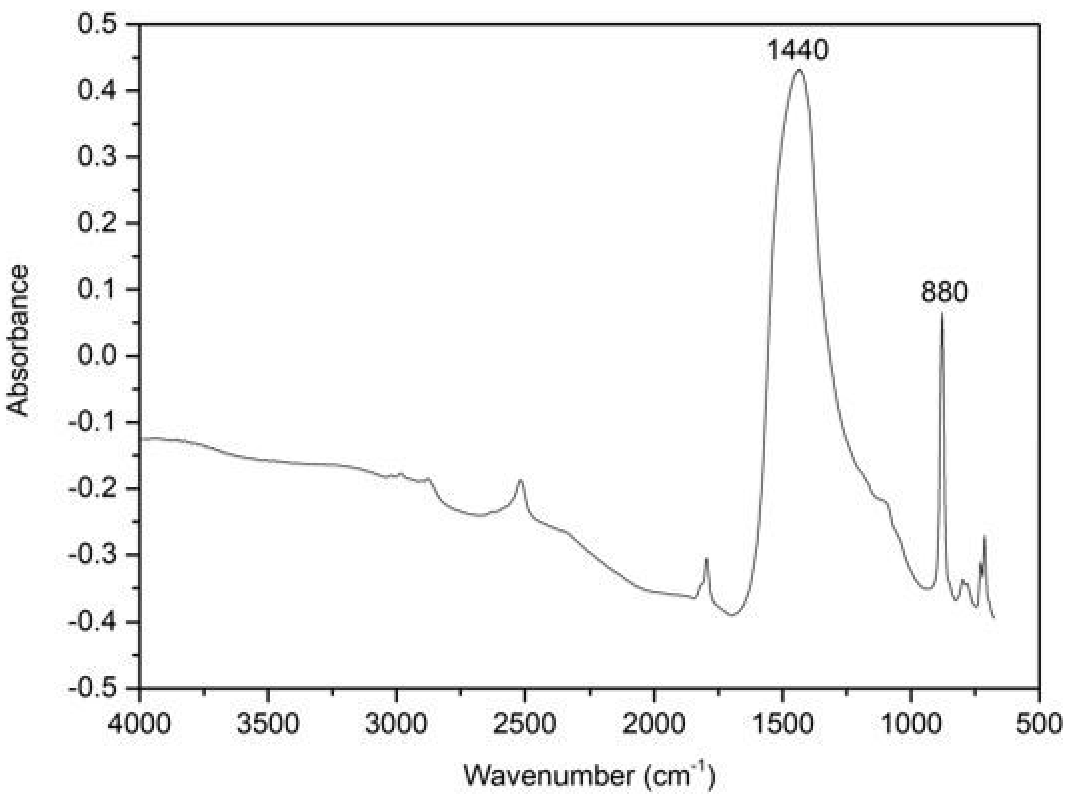



**Figure 15**

FTIR spectrum of the white layer.