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Analysis and characterization of materials used in heritage theatrical figurines

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Abstract

The precious collections of the Qing Dynasty paper-made theatrical figurines known as Shage xiren (纱阁戏人) represent a unique type of Chinese traditional folk art. The name, "Shage xiren" can be explained as the theatrical figurines that display in gauze curtains covered showcases. There were originally 36 showcases of Shage xiren of which 34 are preserved with 28 showcases exhibited at Qingxu Taoist Temple of Pingyao and the other damaged 6 are kept in the storeroom. It is rare that ancient paper-made figurines can be retained; therefore Shage xiren became a valuable source for understanding the traditional folk art as well as exploring rarely inherited crafts. Due to the material specificity and the poor preservation conditions, most of the figurines are found with various damages. It appears necessary to carry out appropriate conservative and restorative actions. To date, very few works have been reported on investigating the materials and crafts of making Shage xiren, resulting in a lack of basis for restoration. In this research, the samples collected from the damaged figurines, including wooden stick, plant fibers, paper pieces, clay fragments and textile fibers were studied. Polarized light microscope, X-ray diffraction, granulometry, Raman spectrum, digital microscopy and Fourier transform infrared spectrum analyses were employed to characterize the materials used in producing the cultural relics. The results indicated that not only paper, but also various materials were utilized in making the figurines. To form well-shaped bodies, the figurines have moso bamboo sticks applied as supporting structures, then covered with wheat straw and filled with natural cotton. The paper costumes and decorations were made from coniferous wood pulp and bamboo fibers respectively, and the textile belts were made from silk. The heads, feet and fingers of the figurines were shaped with fine local clay mixed with natural fibers to prevent cracking. The heads were further applied with lime to improve the surface smoothness and brightness. The pigments of red lead, basic lead carbonate, indigo and artificial ultramarine were used in painting and dyeing the clay heads and feet, and paper decorations. Although the figurines were made from accessible materials, the ingenious design and the sophisticated skills combining sculpturing, paper folding and elaborate ornamenting made it one of the unique artefacts. This research further provided reliable evidence in guiding the conservation and restoration work.

Keywords: Theatrical figurines, Shage xiren, PLM, XRD, Granulometry, Micro-Raman, ATR-FTIR

Introduction

Paper-made figurines which integrate the crafts of binding, pasting, molding, paper cutting and painting represent a unique form of traditional Chinese folk art. This type of artefact is made mainly for the purpose of religious sacrifice, funeral ceremony and festival decorations [1]. During the Ming and Qing Dynasties, merchants of Shanxi were passionate with competing their wealth in funerals by presenting plenty of fine paper-made sacrificial figurines. Upon the prevalence of Jin opera (the local traditional opera of Shanxi province), the figurines were made in various forms to simulate the characters which were not only used in funerals but also widely used in festival decorations. Owing to the blossom of this folk art, lots of craftsmen sprung up

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with their sophisticated works. Among them was Liting Xu (许立廷), a well-known craftsman of the Qing Dynasty who ran a shop of paper-made artwork products in Pingyao county, Shanxi. His famous works, the 36 showcases of figurines named "Shage xiren" were completed in 1906. Owing to his sophisticated skills, the figurines were endowed with expressive faces, animated postures and elegant garments. Each showcase was priced at 2000 coins (approximately the price of 300 catties of rice) which made a hit for the time. The artefacts were designed with the inspiration of classic Jin opera including historic dramas and fairy tales. The archetypes of the figurines were the iconic characters from Jin opera, such as General Yue Fei, the First Emperor of Qin, Emperor Taizu of Song and generals of the Yang family. Some of the operas are nowadays extinct which made Shage xiren the vivid single copies that record the lost opera culture [2]. Although it is called paper-made figurines, they were made of not only paper, but also various auxiliary materials. The showcase was made from wood and was measured at 77 cm*83 cm*44 cm, with 3 or 4 figurines displayed in each case (as shown in Fig. 1a, b). The interior of the showcase was decorated with calligraphies and paintings to form the scenery (as shown in Fig. 1c). The figurine itself is made of wooden sticks, natural fibers, straws, paper and so forth. Several wooden sticks were firstly cut into appropriate sizes and positioned to support the whole body while shaping the posture. Straws were applied to cover the wooden sticks and roped to form the body curve. The body was then filled up with natural fibers and dressed in paper-made costumes. The paper-made costumes consist of basically undergarment and outerwear. The undergarment was made of unpainted raw paper and was used to wrap the body. According to the characters, various outerwears including dresses, coats and skirts were fabricated with sophisticated handicrafts. They were prepared by first tailoring colored paper into appropriate sizes and forms, then drawing or pasting detailed patterns onto the paper. After completion, the outerwears were dressed on top of the figurine's undergarment. Subsequently, the heads, hands and shoes of the figurines were made separately by using clay and further respectively drawn and painted with countenance, skin color and patterns. These parts were then installed to the body. Some of the figurines were further decorated with delicate ornaments, such as textile belts, metal earrings, coronets and weapons. As a final step, the finished figurines were placed into the wooden showcases and covered with sheer curtains to simulate theatrics [3]. Since these sets of Shage xiren present the most exquisite paper-made figurines, they were exhibited in the gate towers of Pingyao during important traditional festivals.

Fig. 1 The showcases of Shage xiren, **a** three figurines display in a showcase, **b** four figurines display in a showcase, **c** the decorations of calligraphies and paintings inside the showcase

Shage xiren is a type of folk art made with inexpensive materials. Due to the frail nature of the materials, ancient paper-made figurines are rarely retained. However, owing to the popularity of Shage xiren, 34 showcases are preserved to date with 28 showcases exhibited at Qingxu Taoist Temple of Pingyao. The other damaged 6 are kept in the storage. Since they are the most intact paper-made

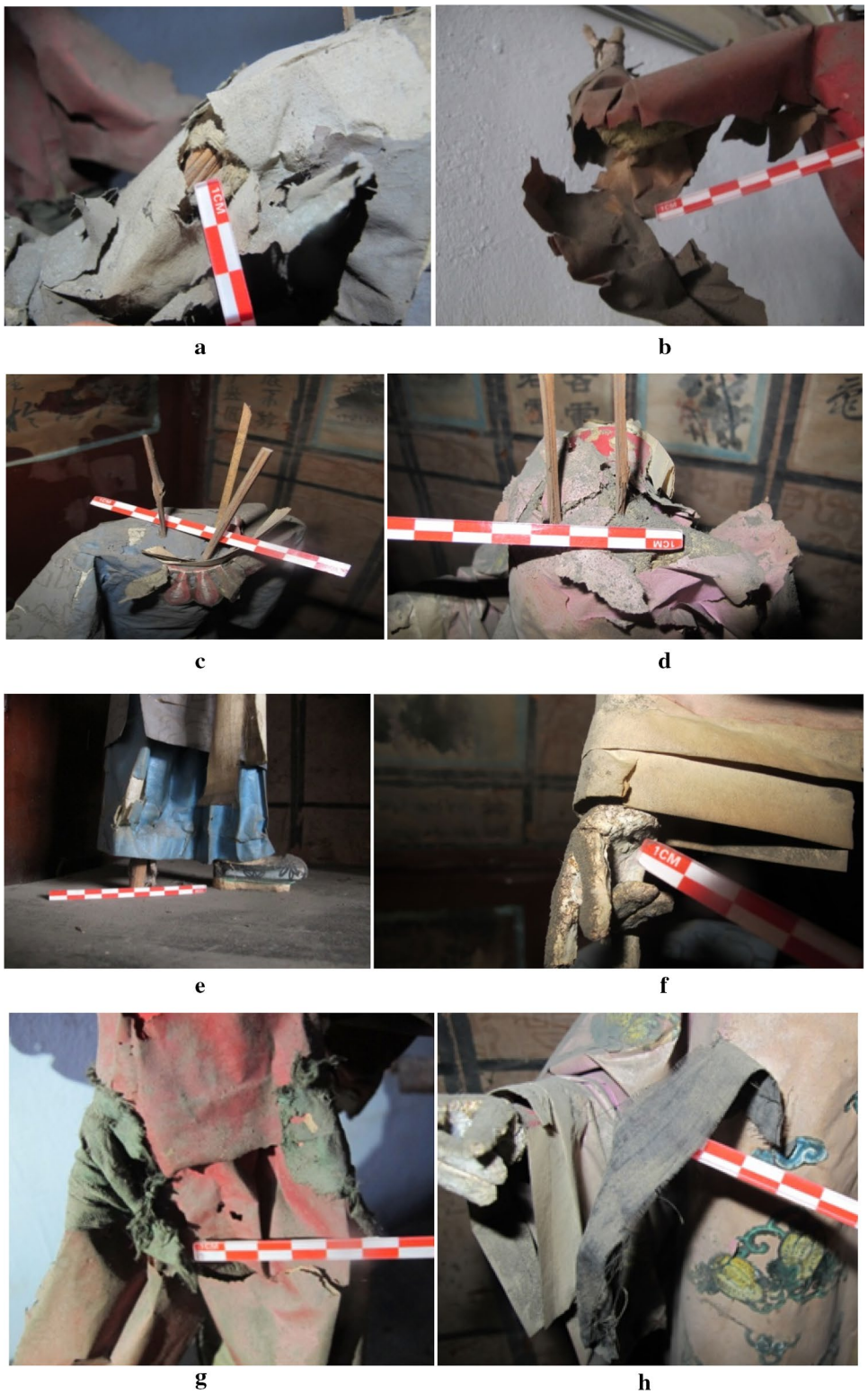


Fig. 2 various damages found on the figurines, including broken paper costumes (**a**, **b**), head and skeleton missing (**c**, **d**), foot missing (**e**), broken fingers covered up with dust (**f**), broken belt (**g**) and textile decoration (**h**)

Table 1 Information of the samples

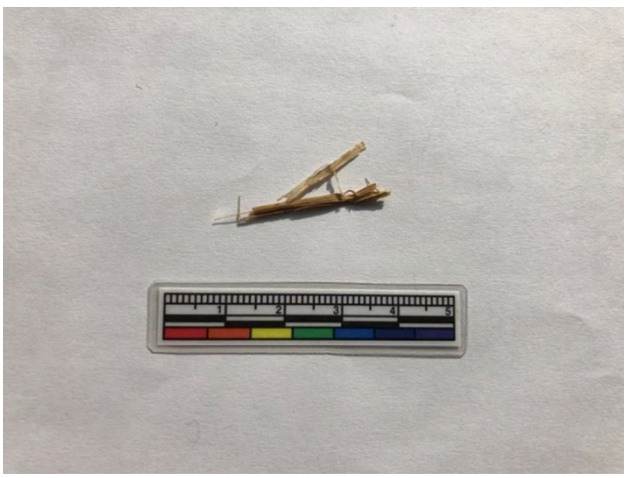
Sample no.	Image of the sample	Description
SHZ1		Clay fragment collected from the shoes
SHZ2		Clay fragment collected from the shoes
SHZ3		Straw pieces

Table 1 (continued)

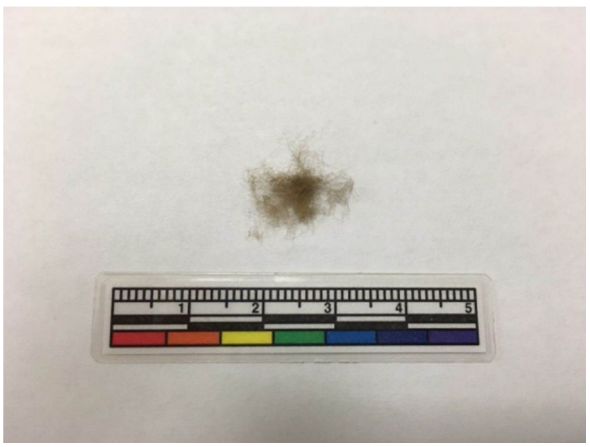
Sample no.	Image of the sample	Description
SHZ4		Wooden stick
JYG1		Textile fibers collected from the belt
JYG2		Filler fibers

Table 1 (continued)

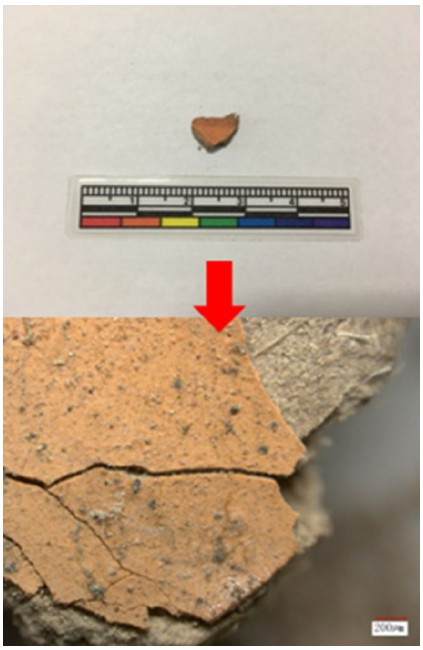
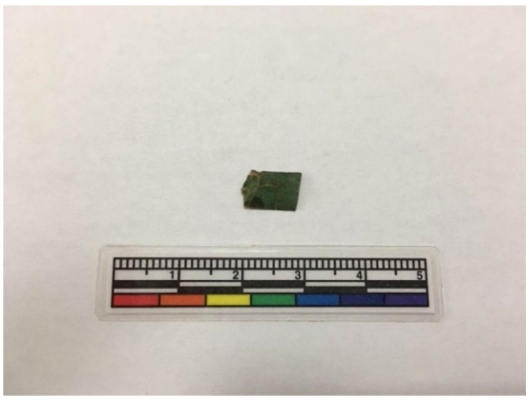
Sample no.	Image of the sample	Description
CQY1		Clay fragment collected from the neck
CQY2		Paper sample taken from the belt
CQY3		Paper sample taken from the dress

Table 1 (continued)

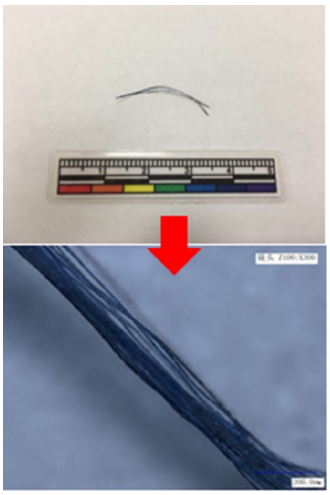
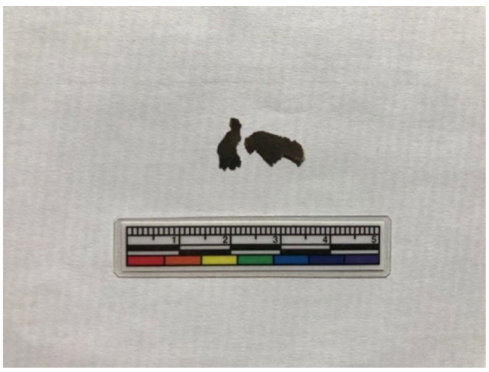
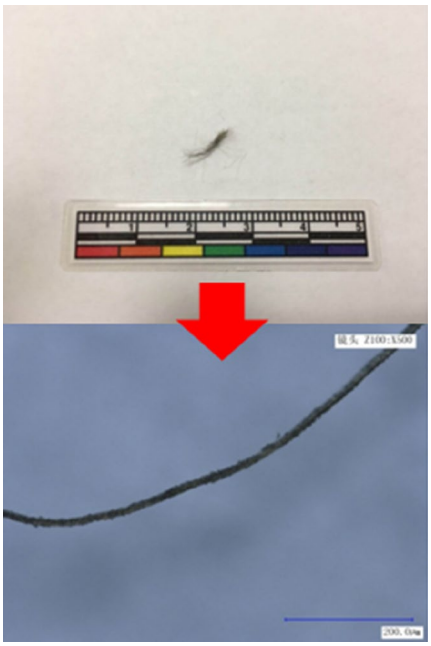
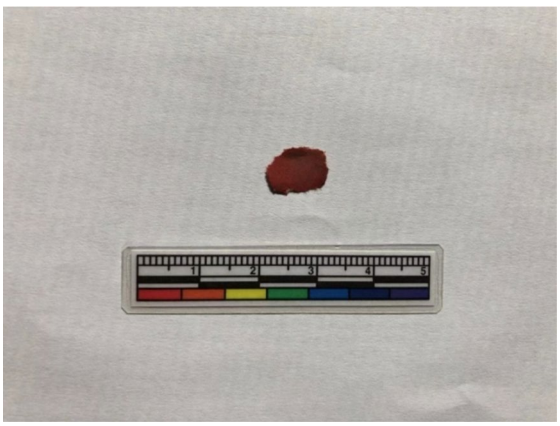
Sample no.	Image of the sample	Description
CQY4		Single textile fiber collected from the belt
CQY5		Paper sample taken from the dress
FXL1		Clay fragment collected from the finger
FXL2		Clay fragment collected from the neck

Table 1 (continued)

Sample no.	Image of the sample	Description
FXL3		Textile fibers collected from the belt
FXL4		Paper sample taken from the dress

figurines artefacts with the highest standard and most exquisite crafts, the whole collection is recognized as the largest collection of exclusive folk paper-made artefacts by UNESCO and is ranked as class A national heritage of China [4]. Therefore, Shage xiren became unique representatives and a valuable source for understanding the traditional folk art as well as exploring rarely inherited crafts. Unfortunately, as a result of the open exhibition, most of the figurines are suffering from severe degradation, various contaminations and damages (as shown in Fig. 2). Several figurines are found with heads missing, fingers fracturing and color fading. It appeared necessary to carry out appropriate conservation and restoration measures to restore them. However, this type of folk art is overlooked for a long time; it is difficult to find relevant research. Few works have been done previously to study Shage xiren but they focused only on the cultural contents or artistic value rather than from the restoration aspect. Overall, there is a lack of reliable evidence of the materials and crafts used in making Shage xiren. To fill in the gap, an analytical approach consists of polarized light microscope, X-ray diffraction (XRD), granulometry, Raman spectrum, digital microscopy and Fourier transform infrared spectrum (FTIR) with attenuated total reflection (ATR) analyses was employed to characterize the materials used in making the figurines. The results

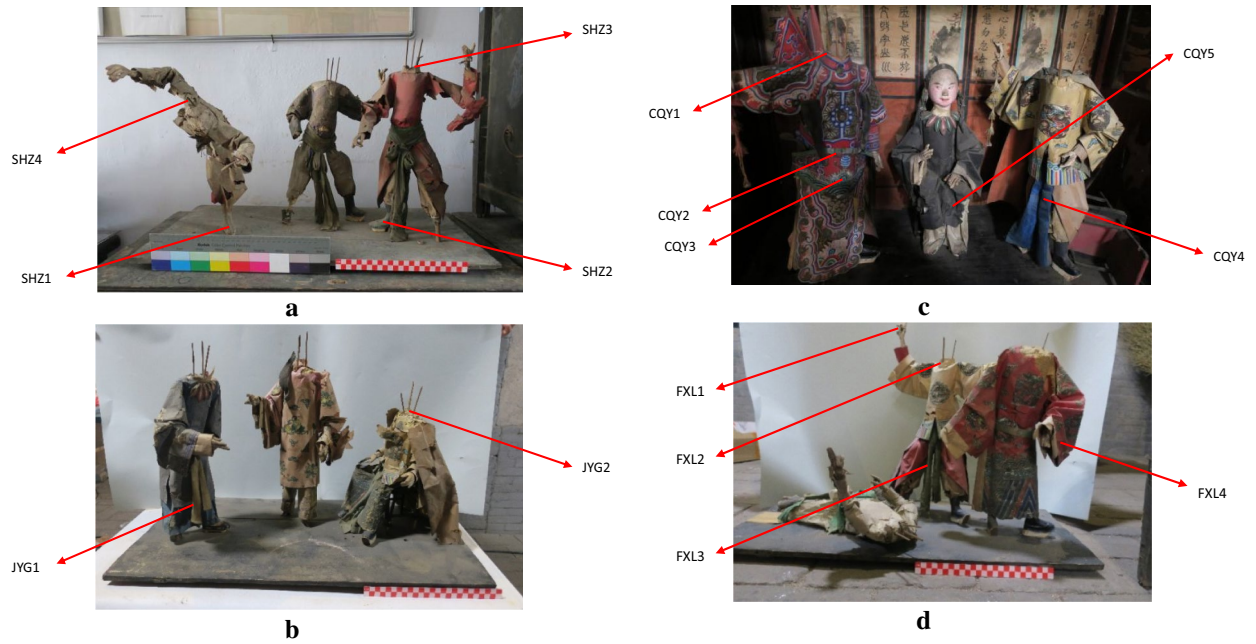


Fig. 3 Images of selected showcases of Shage xiren with sample sites indicated

provided reliable evidence for guiding the restoration treatments and the preservation suggestions were also discussed.

Materials and methods

The samples (listed in Table 1) including wooden stick, plant fibers, paper pieces, clay fragments and textile fibers were collected at Qingxu Taoist Temple from the damaged figurines (sample sites are indicated in Fig. 3).

Polarized light microscope (PLM)

Polarized light microscope (Carl Zeiss Axio Scope A1, Germany) was used to identify the species of the wooden stick (SHZ4), straws (SHZ3) and the raw material used in making the paper costumes (CQY5 and FXL4) and decorations (CQY2 and CQY3), as well as determine the deep blue pigment applied in dyeing CQY3. The samples were prepared in two different ways: the fiber samples were colored with Herzberg's stain [5] (I_2–$ZnCl_2$ solution) and separated by needle before observation; the pigment sample was collected from the original object by using needle and mounted on glass slide using mounting resin at 80–90 °C [6].

Micro-Raman

The samples of colored paper and painted clay (SHZ1, CQY1, CQY2 and CQY3) were subjected to micro-Raman analysis for identifying the pigments. The DXR Raman instrument equipped with the Thermo Scientific DXR microscope and a CCD detector was employed to measure the samples over the spectrum range of 6000–50 cm^{-1}. The excitation source was an Ar laser (785 nm line) with a maximum laser power of 10 mW, the exposure time varies from 10 to 60 s with 3 accumulations. The calibration of the spectrometer was performed with standard silicon and the spectra were recorded by Omnic 8 software.

XRD

The test samples were collected from the non-painted reverse side of the clay samples (SHZ1, SHZ2, CQY1, FXL1 and FXL2) to avoid signal interference. The samples were then pulverized. XRD measurements were carried out using a Bruker-AXS D8 FOCUS diffractometer equipped with a X-ray tube (Cu–Kα radiation: 1.5406 Å, 40 kV and 40 mA). The diffraction patterns were produced over the range of 10 to 70 degree (2θ).

Granulometry

The same samples applied in XRD analyses were utilized for the granulometry following the identical sample preparations. The BT-9300S laser granulometer was employed to measure the particle size ranging from 0.1 μm to 716 μm. The refractive index of the sample was set at 1.63. The results indicated the distribution of the particle sizes.

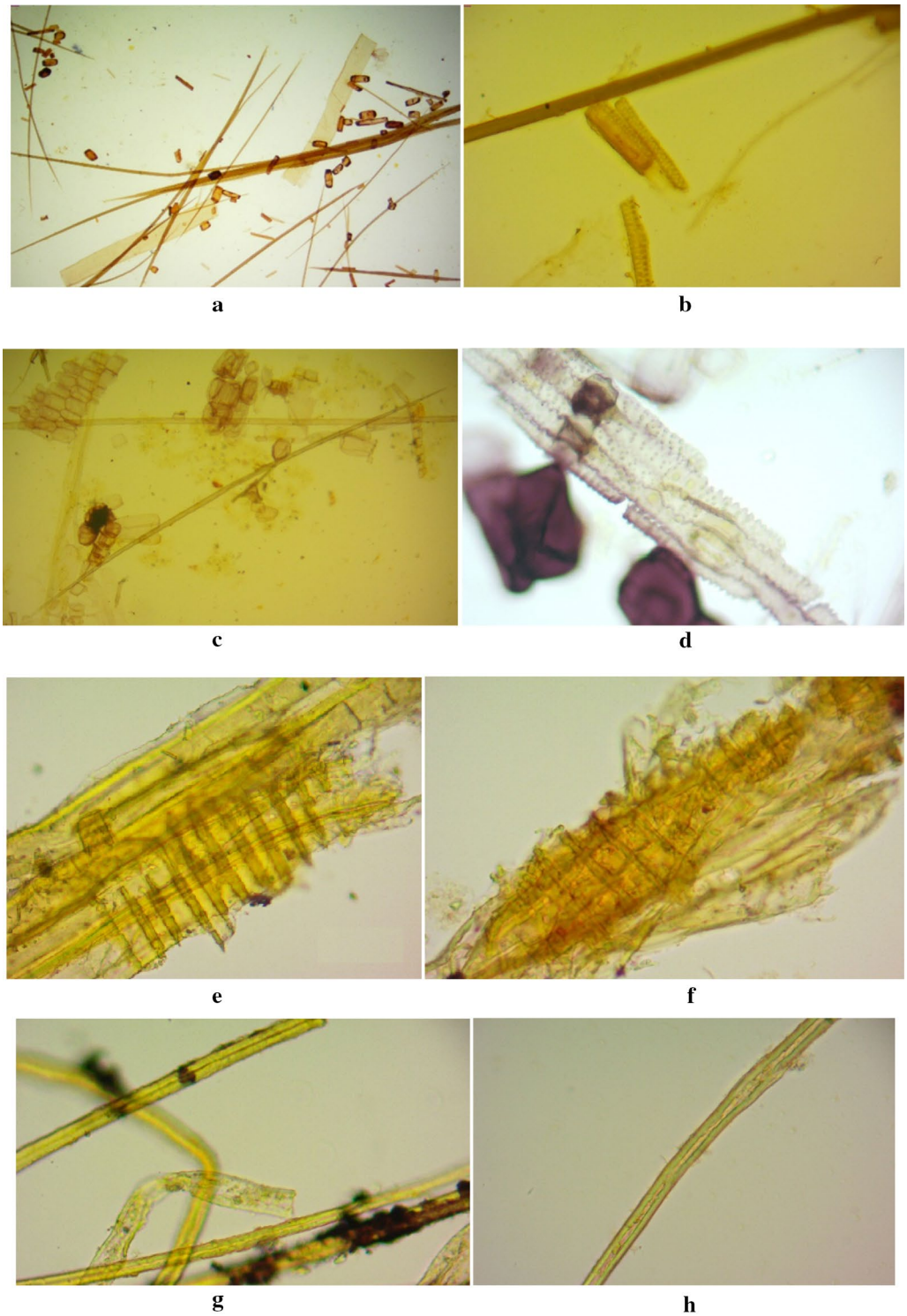


Fig. 4 Fibers of the wooden stick-SHZ4 (**a**, **b**), straw-SHZ3 (**c**, **d**), paper clothes-CQY5 (**e**) and FXL4 (**f**), paper belt-CQY2 (**g**) and paper pattern-CQY3 (**h**)

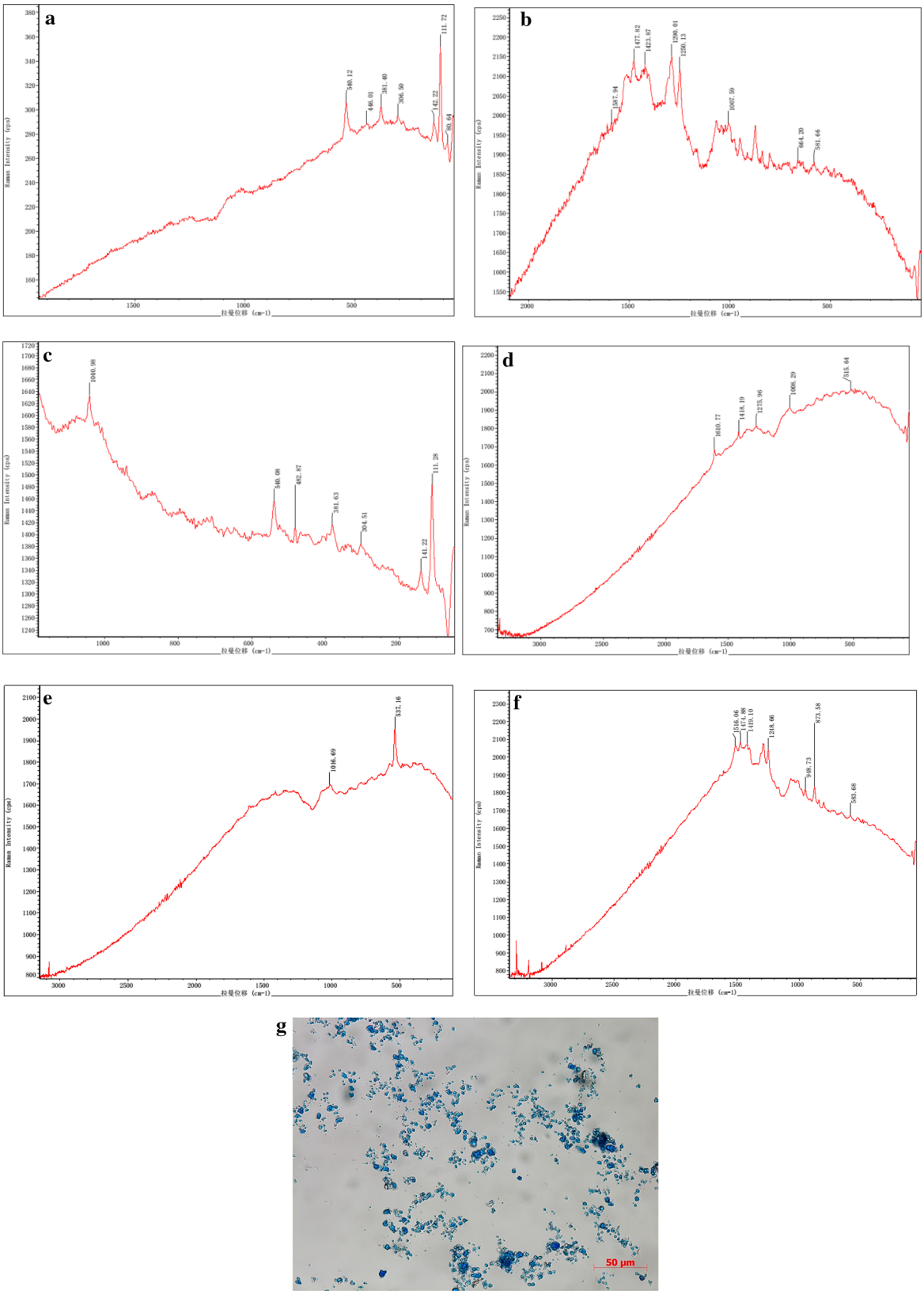


Fig. 5 Micro-Raman spectra of SHZ1 (**a**, **b**), CQY1 (**c**), CQY2 (**d**) and CQY3 (**e**, **f**), and the morphology of pigment particles of CQY3 (**g**)

Microscopic analysis

Microscopic analysis was carried out with a KEYENCE VHX-2000C digital microscope to observe the cross-section of the clay fragments (SHZ1, CQY1 and FXL1). The images were collected by the in-built software.

ATR-FTIR

The Thermo Scientific Nicolet 8700 FTIR spectrometer equipped with a Nicolet Continuμm infrared microscope was applied in characterizing the textile fibers (JYG1, JYG2, CQY4 and FXL3). Measurements were taken in the transmission mode; the sample was placed in the diamond anvil cell and observed with a 15× objective. The light spot was set as 60 μm × 60 μm and spectra were collected over 4000–650 cm^{-1} range with 4 cm^{-1} resolution and 128 scans.

Results and discussion

Analysis of the wooden stick, straw and paper fibers

The fibers present in Fig. 4a, b are long and narrow with rounded parenchymal cells which suggest the wooden stick was made of moso bamboo. The fiber of sample SHZ3 is observed with coarse serrated cells and parenchymal cells of different sizes in Fig. 4c, d, indicating that wheat straw is the fiber source [7]. Figure 4e, f show a bright yellow color of the stained fibers, suggesting a high content of lignin. Moreover, the cross helical striations with rounded parenchymal cells are seen along the fibers. All these findings are in accord with the characteristics of coniferous wood pulp. The fibers shown in Fig. 4g, h are long, narrow and stiff with thick-walled and rectangular-shaped cells. It is believed that bamboo is possible the major source for making the paper of CQY2 and CQY3, however, the exact species is hard to determine [8].

Analysis of the pigments

The micro-Raman spectra are provided in Fig. 5a–f and detailed results are available in Table 2. As seen from sample SHZ1, the paintings drew on the white substrate were made of red, blue and black colors. The micro-Raman analysis of the red pigment (in Fig. 5a) identified red lead as the main constituent of the pigment [9, 10]. It is a toxic substance which normally used as a mothproof agent to ensure the long-time preservation of the objects in ancient China [11]. The identified peaks of blue pigment are similar to that of indigo (in Fig. 5b), which is a common natural dye that was widely used in ancient painting and dyeing [12, 13]. However, the black pigment cannot be determined due to significant fluorescence.

The sample CQY1 which presents a flesh color appearance was obtained from the fractured neck of a figurine. As shown in Fig. 5c, the micro-Raman result identified the pigment as red lead mixed with basic lead carbonate [14, 15]. CQY2 and CQY3 were collected on the same figurine, respectively from the green belt and the pattern of the paper-made dress. Due to the color fading, only a limited number of peaks were identified from the Raman spectrum of CQY2 (in Fig. 5d). The relevant peaks of indigo are observed. The peaks presented at 1275.96 cm^{-1} and 1610.77 cm^{-1} indicated possibly another organic yellow dye was added to obtain a green hue. CQY3 was dyed with two different blue pigments, as shown in Fig. 5e, f, the main constituents were identified respectively as ultramarine (for deep blue) and indigo (for light blue) [15]. Since the use of artificial ultramarine blue was widespread across China by the late Qing Dynasty, PLM was employed to further characterize the particle of the pigment. As seen from Fig. 5g, the shapes of ultramarine blue particles are regular and smooth, and the grain sizes are even which suggest the artificial pigment [16].

Table 2 Micro-Raman results

Sample	Identified pigment	Characteristic wave numbers (cm^{-1})
SHZ1	Red lead	111.72, 142.22, 306.5, 381.4, 446, 540.12
	Indigo	581.66, 664.2, 1007.59, 1250.13, 1290.01, 1423.87, 1477.82, 1587.94
CQY1	Red lead	111.28, 141.22, 304.51, 381.63, 482.87, 540.08
	Basic lead carbonate	1040.98
CQY2	Indigo	515.64, 1008.29, 1418.19
	organic yellow dye	1275.96, 1610.77
CQY3	lasurite	537.16, 1016.69
	Indigo	583.68, 873.58, 948.73, 1248.66, 1419.1, 1474.88, 1516.06

Analysis of the clay fragments

XRD analysis was employed to characterize the compositions of the clay samples of SHZ1, SHZ2, CQY1, FXL1 and FXL2. As seen from Fig. 6a, b, d, the main constituents of SHZ1, SHZ2 and FXL1 were indicated as quartz (SiO_2) and gypsum ($CaSO_4{\cdot}2H_2O$). Refer to the relevant studies [17, 18], it is suggested that this kind of clay was widely used in the local-made clay sculptures. In addition to quartz and gypsum, calcium carbonate ($CaCO_3$) which is the main composition of lime was found in CQY1 and FXL1 (in Figs. 6c, e). Since CQY1 and FXL1 were collected from the fractured neck of figurines, lime was probably applied to improve the smoothness and brightness of the surface.

The results of granulometric analysis presented in Fig. 7 show the particle sizes of the samples are mainly between 1 and 75 μm. The clay fragments were formed

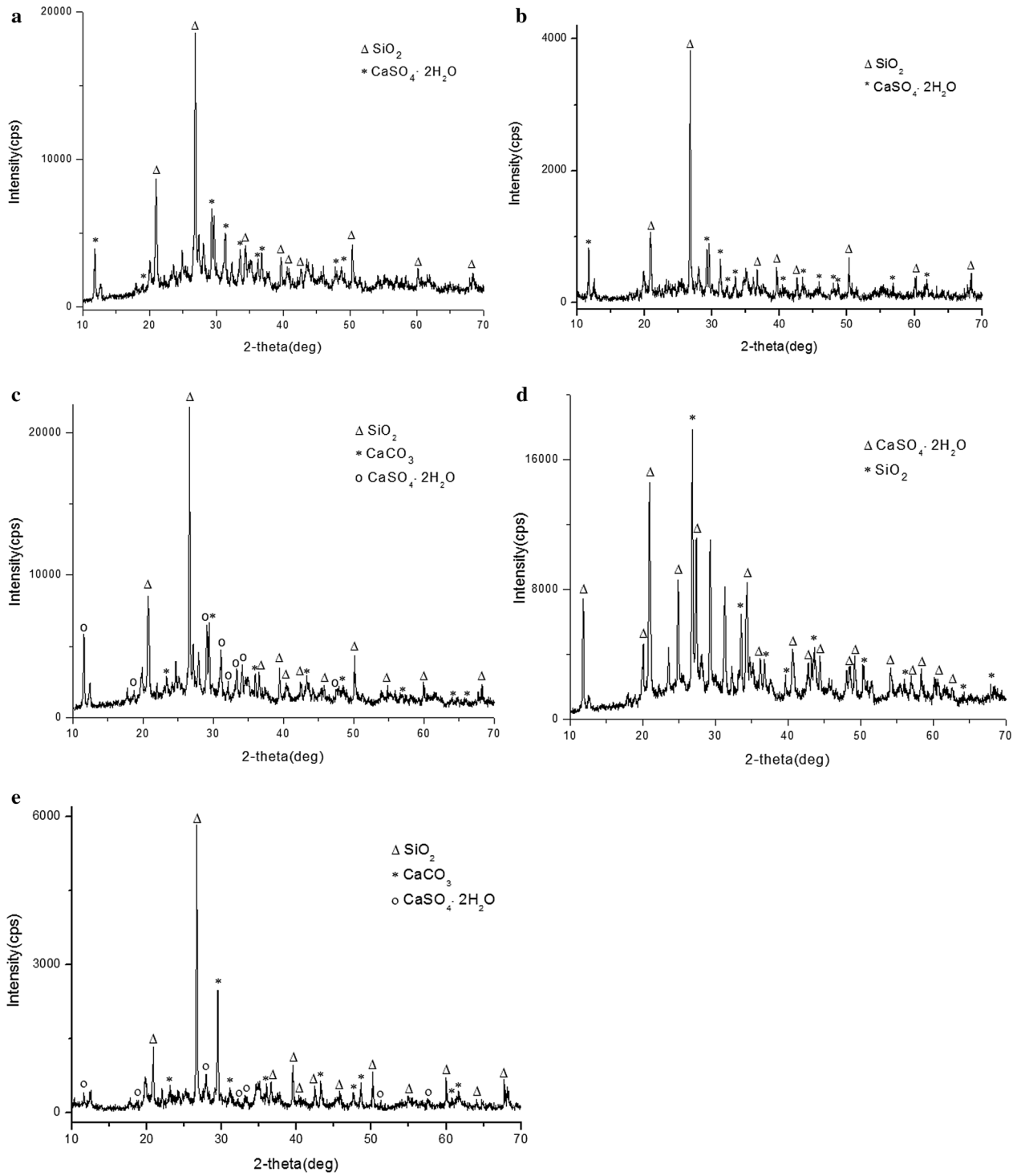
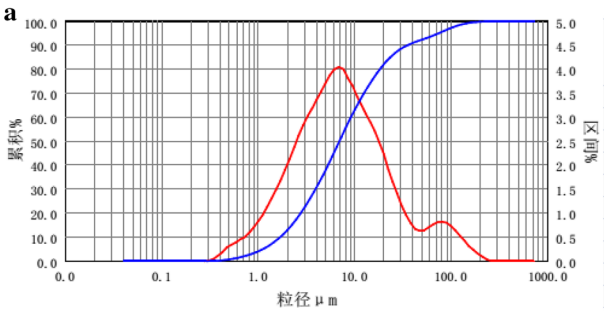


Fig. 6 XRD spectra of the clay samples (**a** SHZ1, **b** SHZ2, **c** CQY1, **d** FXL1, **e** FXL2)

with mostly the particles of 2–5 μm in size. The results further confirmed the fine quality of the clay that used in making the figurines.

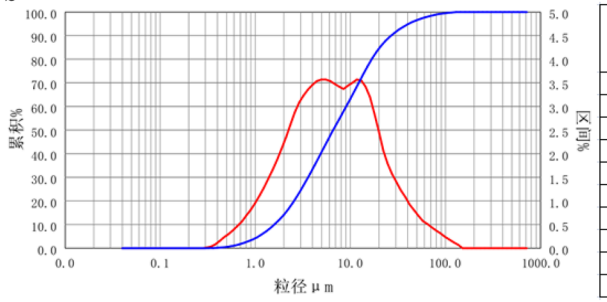
As observed from the cross-section images in Fig. 8, plenty of fibers were found inside the clay samples. Refer to the traditional sculpturing craft, natural cotton or

a



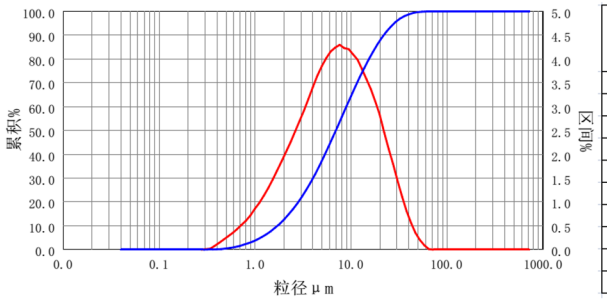
Particle diameter (μm)	Content %
0.200	0.00
0.500	0.50
1.000	4.29
2.000	14.49
5.000	40.96
10.00	63.81
20.00	85.47
45.00	97.41
75.00	99.79
100.00	100.00

b



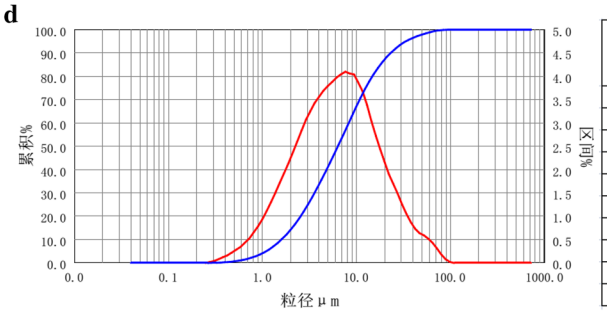
Particle diameter (μm)	Content %
0.500	0.51
1.000	4.20
2.000	14.19
5.000	40.72
10.00	63.30
20.00	84.49
45.00	95.80
75.00	98.66
100.00	99.53
200.00	100.00

c



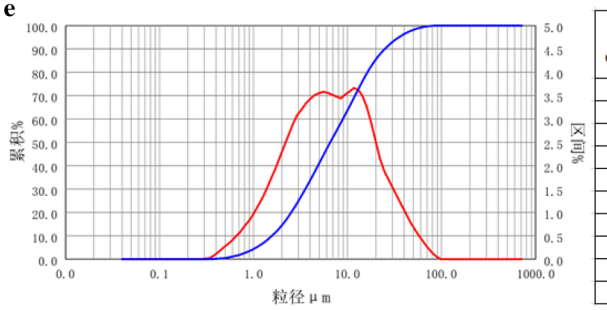
Particle diameter (μm)	Content %
0.100	0.00
0.200	0.00
0.500	0.47
1.000	3.82
2.000	12.64
5.000	37.44
10.00	64.51
20.00	87.71
45.00	99.39
75.00	100.00

d



Particle diameter (μm)	Content %
0.200	0.00
0.500	0.65
1.000	4.12
2.000	14.28
5.000	41.21
10.00	67.17
20.00	87.21
45.00	97.30
75.00	99.68
100.00	100.00

e



Particle diameter (μm)	Content %
0.200	0.00
0.500	0.50
1.000	4.29
2.000	14.49
5.000	40.96
10.00	63.81
20.00	85.47
45.00	97.41
75.00	99.79
100.00	100.00

Fig. 7 Results of granulometric analysis (**a** SHZ1, **b** SHZ2, **c** CQY1, **d** FXL1 and **e** FXL2)

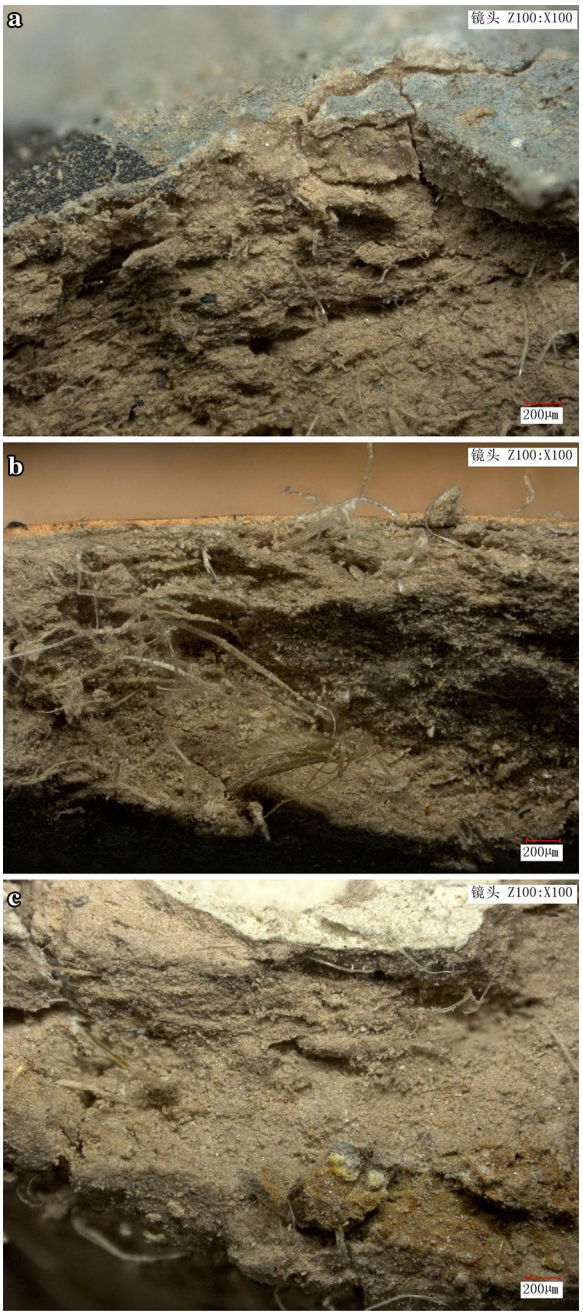


Fig. 8 Cross-section images of samples SHZ1 (**a**), CQY1 (**b**) and FXL1 (**c**)

similar plant fiber is commonly mixed with clay to prevent cracking [19].

Analysis of the textile fibers

The IR spectra of the textile fibers are available in Fig. 9. In Fig. 9a, c, d, the presence of a broad band from 3297 to 3279 cm^{-1} is commonly related to the inter-molecular hydrogen bonding of silk sericin. The fine absorption around 1636 cm^{-1} can be assigned to C=O stretching vibrations in amide I proteins, and peaks at about 1510 cm^{-1} are generally associated with the N–H in-plane bending and C–N stretching bending [20]. The bands observed at about 1444 cm^{-1} and 1165 cm^{-1} are the fibroin bands arise from the vibrations of alanine and tyrosine side-chains [21]. These characteristic bands identified the composition of JYG1, CQY4 and FXL3 as silk.

In Fig. 9b, the main vibration at 3340 cm^{-1} can be assigned to intra-molecular hydrogen bonding of cellulose. The absorption band at 1635 cm^{-1} is related to O–H bending of adsorbed water. The peaks presented at 1428 cm^{-1} and 1316 cm^{-1} are respectively corresponded to CH_2 scissoring and CH_2 rocking, while 1370 cm^{-1} and 1200 cm^{-1} are respectively assigned to C–H bending and C–O stretching. The anti-symmetrical bridge C–O–C stretching is observed at 1161 cm^{-1} and the band at 1057 cm^{-1} is related to C–O stretching. And the β-linkage of cellulose presented at 897 cm^{-1} further confirmed the fiber of sample JYG2 as natural cotton [22].

Discussion

In addition to the traditional crafts, Shage xiren were better designed, and further employed with more sophisticated skills and various materials. In summary, three moso bamboo sticks were used to hold the body of the figurine. The sticks were initially cut into appropriate size and positioned to support the posture of the figurine. They were then covered by wheat straws and filled with natural cotton to form the well-shaped body. The paper made of mainly coniferous wood pulp was used in producing the paper costumes and dressed onto the body of the figurines. The heads, hands and feet were made with fine local clay mixed with natural fibers to prevent cracking. The heads were further applied with lime to improve surface smoothness and brightness, which was to sever the purpose of coloring. The pigments, including organic and inorganic pigments were used in painting the heads and shoes. Red lead which is a toxic substance was identified as the main constituent of the red pigment. It is also a mothproof agent to ensure the long-time preservation of the figurines. Moreover, red lead mixed with basic lead carbonate was used in painting the skin of the heads. The paper-made decorations, for instance, the belt and the pattern on the dress were both made from bamboo paper. They were either dyed with natural organic dyes or painted with artificial pigment. The textile belts were made from silk. Although the figurines were made of accessible materials, the sophisticated crafts combining sculpturing, paper folding and fine decorating made it a unique type of artefact. Owing to the careful selection and flexible use of

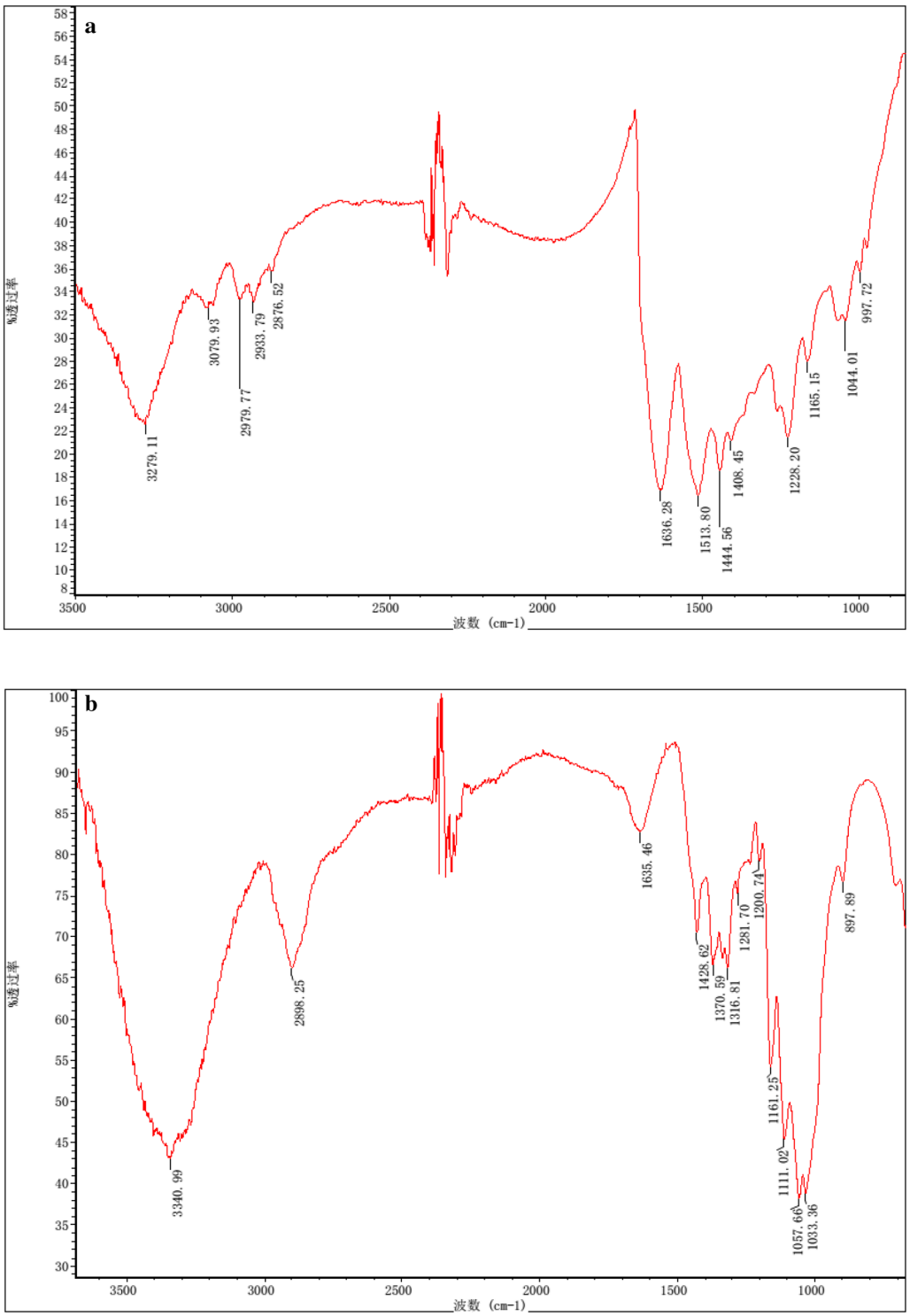


Fig. 9 ATR-FTIR spectra of samples JYG1 (**a**), JYG2 (**b**), CQY4 (**c**) and FXL3 (**d**)

the materials, and the accurate grasp of the characters' personality, the figurines are endowed with vivid expressions and elegant appearances.

These analytical results also provided reliable information for selecting appropriate materials in restoration work. To avoid any unnecessary damage, it is better to

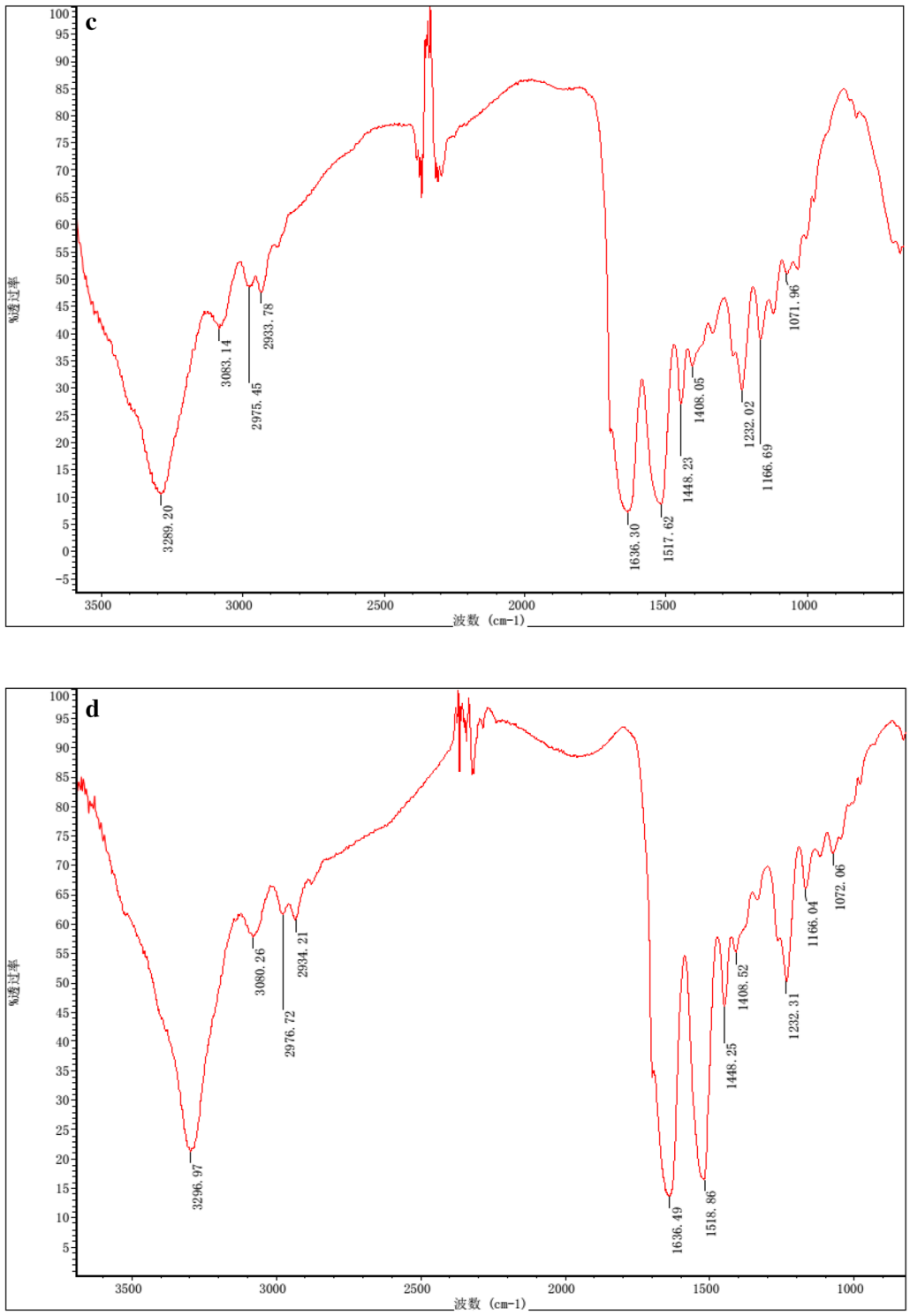


Fig. 9 continued

perform in situ restoration rather than removing figurines from the showcases. Extra care is required when handling the severely damaged figurines. Moreover, since those organic materials are sensitive to air, moisture, dust and so forth, the contaminations and damages were largely resulted from open exhibition. It is suggested

to improve the preservation conditions by placing the showcases of figurines into vitrine and further installing environmental control device to maintain the favorable temperature and humidity.

Conclusions

Being a unique type of paper-made figurines, the precious collections of Shage xiren are the most well preserved artefacts with the highest standard and most exquisite crafts. Unfortunately, due to the frail nature of the materials, some were badly contaminated and damaged. It appeared necessary to carry out appropriate conservation and restoration work to rescue the heritage. However, very few researches have been done to investigate the materials and crafts used in making the figurines which resulted in a lack of reliable evidence. In this research, an analytical approach consists of polarized light microscope, X-ray diffraction, granulometry, Raman spectrum, digital microscopy and Fourier transform infrared spectrum analyses was employed to characterize the materials used in making the figurines. The results provided relevant and reliable information in selecting the applicable materials for restoration. Lastly, suggestions on the preservation of these cultural relics were discussed in this research.

Abbreviations

PLM: Polarized light microscope; XRD: X-ray diffraction; ATR-FTIR: Attenuated total reflection flourier transformed infrared spectroscopy.

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Authors' contributions

YG performed the examination, analyzed and interpreted the patient data, and was a major contributor in writing the manuscript. CQ and BZ assisted in performing the experiments. JZ provided the samples. DG supervised the entire research procedures. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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