Fig. 1. Red painted wooden bowl, c. 6000 years old

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A New Method for Treating Ancient Chinese Lacquer on Waterlogged Wood

1. Introduction

Chinese lacquer (raw lacquer, urushi) has a long history. According to Chinese literature, the legendary emperors Shun and Yu are said to have used lacquer painted wooden vessels for food. This is an indication that lacquerware was in use even before the Xia dynasty (c. 21st century B.C.).

Chinese lacquer has undergone a long process of development. It can be traced back at least to the Neolithic period. In 1978, a red painted wooden bowl (fig. 1) was found at a Neolithic site at Hemudu in Yuyao in the Zhejiang province, which has been dated to about six thousand years ago.[1] We studied the red painting by PY/GC-FTIR analysis.[2] The result confirmed that the red material was vermilion lacquer. The lacquer painted bowl must be considered so far as the earliest piece of lacquerware in China. Other Neolithic sites in China have also yielded examples of early lacquerware. At Changzhou in the Jiangsu province, for instance, two wooden objects were excavated: one was painted in black and the other in red and black lacquer. At least during the Shang dynasty, around the 14th century B.C., the lacquer handicraft must have made a considerable advance. Lacquers from the Shang dynasty found in higher quantities show rich and colourful designs. The decorative patterns were dragons and scrolls, similar to those found on Shang bronzes.

In the history of Chinese lacquer there are two golden periods: The first is from the Warring States period to the Han dynasty (4th century B.C. – 2nd century A.D.). The second golden period is from the Song to the Ming dynasty (9th–16th century A.D.). During these two periods, the lacquer production had reached its peak, in quantity as well as in technique. Especially during the first golden period lacquerware was made in a rich assortment of shapes, the art of lacquer painting flourished and reached heights of brilliance.

During the Han dynasty, official lacquer workshops were established. Under the control of the central government, the manufacturing of lacquer articles was provided for the imperial household. A great number of lacquers were discovered during archaeological excavations at a dated Han dynasty tomb. They confirmed the existence of a vital lacquer craft at that time.

1.1 The condition of unearthed lacquer

Large quantities of lacquerware have been excavated at different places in China. For example, there are thousands of pieces of lacquerware found at Tianchang in the Anhui province and at Jiangling in the Hubei province. Besides these, a great number of lacquers dated from the Warring States period to the Han dynasty were discovered in the provinces Hunan and Jiangsu. The lacquerware found in tombs was usually situated in water. The tombs were sealed without air, therefore the lacquers could be kept so long.

The cores of the lacquerware were made from various materials: For instance, the core of a lacquered scabbard was made of wood and fabric, the cores of lacquered arrows were made from iron and bamboo stripes, and even the back of a bronze mirror was painted and decorated with lacquer (figs. 2a–c). Sometimes other materials such as pottery, rattan, leather or the like were also used as lacquer cores.

Fig. 2a. Core of laquered scabbard made of wood and fabric

1.2 The importance of the task

Among the unearthed lacquers, the number of wooden cores are in the absolute majority. The wooden cores were waterlogged. Up to now, most of them are still soaked in water. It is therefore an important task to study the dehydration and consolidation of waterlogged wooden cores of ancient lacquerware in China.

The wooden core of the ancient lacquerware may be made from various sorts of trees, such as fir, three bristle, cudrania or poplar. It should be noted, however, that the permeability of woods is very variable. At the same time, the structures of wooden cores are different, some are solid wooden sculptures, some heavier or thinner, and even more fabric-strengthened thin wood cores.

Besides this and due to the great difference in burial environments, the waterlogged wooden cores might be deteriorated to different degrees, and the amount of water contents may therefore differ widely. Most wooden cores may have maintained their original appearance and shape, in spite of the weakened condition due to the penetration of water into the wood structure. If these unearthed lacquers are taken out of their original environment without any treatment, the wooden core might split or brake along the grain and the lacquer would therefore shrink or be deformed (figs. 3 a, 3 b), the lacquer film layers be wrinkled or cracked. How these ancient Chinese waterlogged lacquered wooden cores can be preserved is the topic of this study.

Fig. 2b. Core of laquered arrows made of iron and bamboo stripes

2. The treatment methods used until today

During the last two decades, the Chinese conservators have made great efforts to study the preservation of unearthed lacquers and could gain some progress. The situation of unearthed lacquer is so different in the degree of deterioration and in the materials used. It is therefore not suitable to develop a treatment method which can be effective for all waterlogged lacquers. For this reason different methods have been studied.

2.1 Dehydration

A useful way of dehydration is to dry the waterlogged wooden core lacquer slowly, so that the moisture can be redistributed as evenly as possible during drying to reduce the drying stresses. Drying stresses are caused by the greater shrinkage of the outer part of the wood, which dries first compared to the interior, which looses water more slowly and thus remains in an expanded condition for a longer time.

The natural drying method is used to put the waterlogged objects in a high and constant humidity environment, drying step by step over a longer period of time, until the water content of the object is constant. The other way of natural drying is to embed waterlogged objects in a sand- or saw-dust bath. This way the water contents can be balanced and the dehydration process can proceed slowly enough. The sand and sawdust is used to stabilize the objects and prevent their deformation. The natural drying method is simple and practical. It is suitable for lower water contents of waterlogged wooden cores, ramie fabric cores or cores made of fir tree. This treatment has achieved some practical successes.[3]

Fig. 2 c. Core of lacquered mirror made of bronze

Fig. 3 a, 3 b. Shrinkage and deformation of lacquer after the excavation

3 b

2.2 Dehydration and consolidation

Most waterlogged wooden cores of lacquerware are rather weak in their mechanical strength. In this case, the percentage of moisture content of the waterlogged wooden core is higher and the treatment must involve the dehydration as well as the consolidation of the piece of lacquerware. The high water content of the wooden core calls for a bulking agent to fill the micropores within the cell wall of the wood. Thus, the cell wall is strengthened and more resistant to collapse and even the shrinkage of the wood can be reduced. Certain successes have been achieved with sugar or PEG as a bulking agent.

2.2.1 Sugar treatment

The molecular structure of sugar allows to build up a hydrogen-bond with the cellulose molecules and the decomposition products of the wood. The treatment of waterlogged wooden lacquerware with sugar has been studied for many years. According to recent reports this method has shown good results. As for the waterlogged wooden bodies coated with lacquer excavated at Cheng Tai Guan in the Henan province, the water content of the wooden core was more than 600 %. The highest one was about 1600 %, based on the dry weight. After treatment, the percentage of shrinkage is about 2 %.[4]

2.2.2 PEG treatment

PEG is well known as a good bulking agent for waterlogged wood. The molecular weight of PEG of about 4000–6000 is useful to replace the water within the wood.[5] The high water content of the wooden cores of lacquerware should be treated with a highly concentrated PEG solution. The heating impregnation of PEG is often used to decrease the viscosity of highly concentrated PEG. A batch of waterlogged wooden lacquerware found in the Mawang Dui tomb was treated with a PEG solution. After the dehydration and consolidation process the lacquerware had kept its original appearance. The beautiful colours had hardly changed.

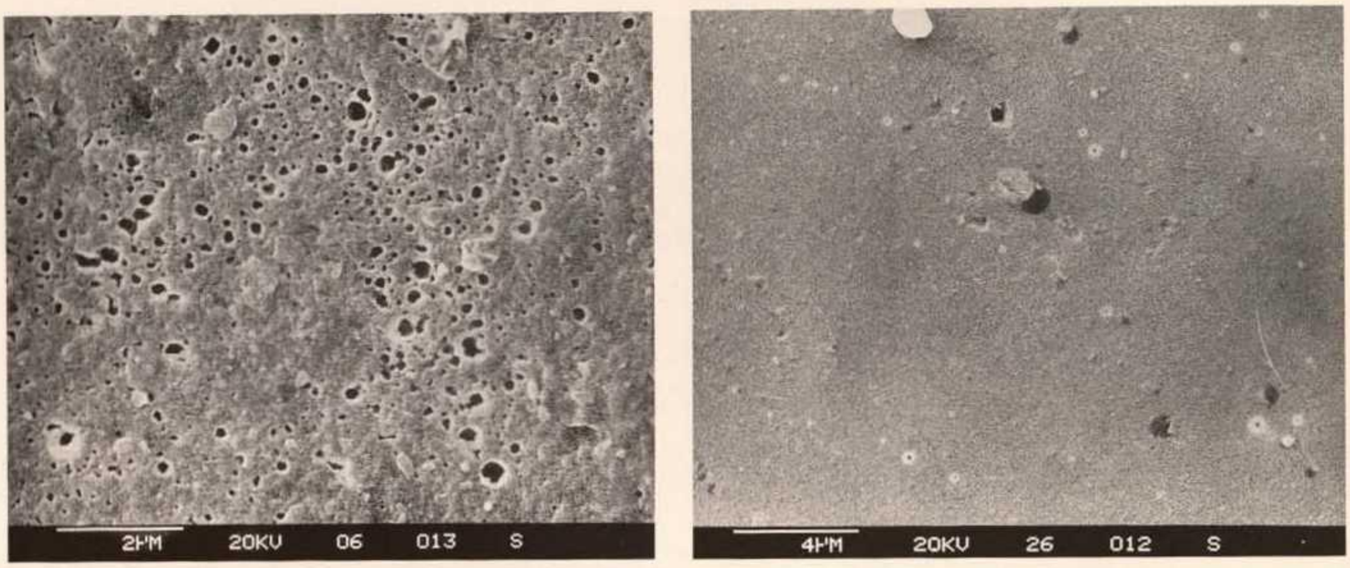
3. A new method: mono-glyoxal

Though the conservation methods for waterlogged wooden lacquerware have made some advances, it has not been able to find a single method that could be used in all circumstances for unearthed lacquerware.

It might seem at first, that there is no difference between treating waterlogged wooden objects or waterlogged wooden lacquerware. But in practice, the latter is more difficult not only in hydration, but also in consolidation. There are several reasons: First, the thickness of the lacquer film on the wooden core is about 0.2–0.8 mm. It is impermeable if the lacquer film is in an intact condition and does not show any cracks or fissures on the surface. This will be of disadvantage for the progress of dehydration and consolidation of waterlogged wooden lacquerware. Second, the percentage of shrinkage must be as small as possible after the dehydration and consolidation, otherwise the lacquer film will turn wrinkly and crack, or the lacquer be deformed. Third, we cannot see the degree of degradation of the wooden body and the sort of wood with the naked eyes and the construction of lacquered wooden bodies can hardly be shown by soft x-ray when the lacquer is painted with a red pigment i. e. vermilion (HgS). In order to solve these problems, the lacquer film and a bulking agent that can easily enter the cell wall of the wood must be studied.

3.1. The surface state of the lacquer film

The modern and unearthed lacquer films are examined by SEM (figs. 4 a, 4 b). We find that there are many micropores dispersed in the surface of the unearthed lacquer film and only a few micropores in the modern lacquer film. The diameter of a micropore is about 100 nm. The micropores may be caused by the lacquer layers eroded under the burial environment over thousand years. Perhaps the origin of the micropores is the gum. The raw material of lacquer contains some gum, the gum is degradated and formed micropores. These micropores provided the passway for the dehydration and the bulking agent entering the wooden body of the lacquerwork.



Figs. 4 a, 4 b. Unearthed and modern lacquer film examined by SEM. There are many micropores dispersed in the surface of the unearthed lacquer film and only a few micropores in the modern lacquer film

3.2 The bulking agent mono-glyoxal

The molecular of the bulking agent needs to be small enough to penetrate the micropores of the lacquer film and to diffuse into the cell wall in order to be effective. The molecular structure of mono-glyoxal is a plane type structure. The chemical structure is as follows: The distances between C–C, C–H, C=O is 0.147 nm, 0.109 nm, 0.12 nm respectively. The volume of the molecular is small enough to diffuse into the microcapillaries and fills the cell walls (capillaries =10–100 nm). Since the cell walls are to be filled, it will be effective to control the shrinkage of the waterlogged wooden body of the piece of lacquerware.

3.3 Penetrating test and treatment

3.3.1 Penetrating test

A waterlogged wooden body immersed the solution of glyoxal, a month later, after drying, the cell wall is examined by SEM. The thickness of the cell wall is increased from the original 1–3 nm to over 5 nm. These experiments have proven, that glyoxal entered into the cell wall.

3.3.2 The treatment method using mono-glyoxal

The procedure is as follows: The waterlogged lacquered wooden body is immersed in a solution of mono-glyoxal and some additional agent. The concentration of the solution is successively increased from 40 % to 65–70 % until the weight of the immersed objects is not increasing any more. The objects are taken out of the solution and the surface blotted, then drying slowly in a suitable environment. When the weight of the objects remains constant, the processes of dehydration and consolidation are finished. Poly-oliga glyoxal will be formed and the cell walls are strengthened. The treatment of some waterlogged lacquered wooden bodies with glyoxal proved successful (figs. 5 a–c).

5a

Fig. 5 a–c. Waterlogged wooden bodies of lacquer after treatment with mono-glyoxal and additional agents

5b

4. Discussion and conclusion

Discussion

1. During the treating periods it is advantageous to maintain more mono-glyoxal in the solution, the small moleculars will help to penetrate and transport a high percentage of bulking agent into the cell wall.
2. White crystal poly-oliga hydrated glyoxal is easily formed in the glyoxal solution. This will retard the passway of replacement water from the waterlogged wooden body of the lacquerwork. It is important to prevent the production of white crystal, and small crystals like crystal seed. A large number of crystals will be produced in a few days.
3. The aqueous of glyoxal is an acidic solution. The PH value is about 1–3. It must be denatured.
4. When the waterlogged wooden body of lacquerwork is treated with PEG, sometimes the lacquer film may bulge and blister. This phenomenon is probably due to the exchange passway retarded by the big molecular PEG in the lacquer film. In order to prove this interference, the blistered lacquer is taken out of the PEG solution and cleaned, then replaced in the bulking agent of the glyoxal solution. After a few weeks, the blisters on the lacquer will disappear so the treatment using glyoxal can avoid occasionally the blistering phenomenon.

Conclusion

As the molecular size of mono-glyoxal is so small that they can easily pass through the lacquer layers and enter the cell wall of wood, the cell wall of waterlogged wooden lacquerware is strengthened and thus the collapse and shrinkage of the wooden body much reduced. Glyoxal is an excellent bulking agent for waterlogged wooden cores of lacquerware. Some waterlogged wooden bodies of lacquerware are treated by using a mono-glyoxal solution and proved successful. The works need to be studied continuously.

Notes

1 Zhijiang Museum, Zhijiang Wen Wu, 1987.
2 Chen, Yuansheng/Xie, Yulin/Lu, Heng et al.: 'Studies on the analysis and identification of prehistoric Chinese lacquers', *Sciences of Conservation & Archaeology*, vol. 7, no. 2, 1995, pp. 12–30.
3 Wu, Jugao: 'Talking about the conservation of lacquerwares unearthed', *Wen Wu*, no. 3, 1986, pp. 28–33.
4 Chen, Jinliang/Cui, Zhanhua: 'Dehydrolyzing and shaping investigation of unearthed, waterlogged, painted woodenware at Changtaiguan of Xinyang in Henan', *Sciences of Conservation & Archaeology*, vol. 6, no. 2, 1994, pp. 1–5.
5 Grattan, D.W.: 'Conservation of waterlogged wood', *Conservation of Marine Archaeology Objects*, 1987, pp.15–16.

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