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A Preliminary Study of Three Finishing Materials for Traditional Chinese Furniture

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Abstract

The traditional Chinese furniture evolved as an important part of the Chinese culture and civilization. Alongside design, structure, ornaments, the original finishes applied define the particularities and value of traditional Chinese furniture. This is because wood finishing not only enhances wood natural beauty by colour, gloss and highlighting of wooden texture, but also can be a means of exquisite decoration (e.g. engraved, gilded or painted lacquer works). Chinese lacquer, Tung oil and Chinese wax represent some of the most important finishing materials employed and were, therefore, selected for this study. The paper presents a brief macroscopic, microscopic and FTIR characterization of these materials. These results will be used as starting data in a further study on the ageing properties of these traditional finishing materials, useful for scientific conservation purposes.

Keywords

Traditional Chinese Finishing Materials, Chinese Lacquer, Chinese Wax, Tung Oil, Microscopy, FTIR

1. Introduction

The traditional Chinese furniture evolved as an important part of the Chinese culture and civilization [1]. The history of the traditional Chinese furniture is divided into four historical periods as follows: *the Youth period* (possible BC 5000 - BC 770), *the Growth period* (BC 770 - AD 220), *the Development period* (AD 220 - AD 979) and *the Maturity period* (AD 960 - AD 1911) [2]. Several dynasties are included in each of these periods, as detailed in a previous publication [3]. Among these it is worth mentioning for instance the Ming Dynasty (1368 - 1644) in *the Maturity period*, when it is considered that Chinese furniture reached a peak of development in its multi-millenary existence [4].

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Alongside design, structure, ornaments, wood species, the finishes of wooden surfaces define the particularities and value of traditional Chinese furniture. This is because wood finishing not only enhances wood natural beauty by colour, gloss and highlighting of wooden texture, but also can be a means of exquisite decoration (e.g. engraved, gilded or painted lacquer works). Moreover, some finishes may impart outstanding time resistance to the wooden objects (e.g. lacquer ware from 5000 BC [11]).

Chinese lacquer, Tung oil and Chinese wax represent some of the most important finishing materials employed and were, therefore, selected for this study. **Figure 1** presents a scheme showing the time sequence of the four periods in the history of Chinese furniture and the employment of the selected wood finishing materials within these periods.

Chinese lacquer is a natural, very durable finishing material. This is actually the sap of some lacquer trees, such as *Rhus vernicifera*, which is tapped (raw Urushi lacquer) and further processed to produce different lacquer sorts (e.g. *Kurome* Urushi) (**Figure 2(a)**). The high resistance of the lacquered surfaces is related to its complex chemical composition and the chemical mechanism of curing [12].

Tung oil is a siccative (drying) oil extracted from the seeds of a group of wood species (around 9), generically called Tung trees (**Figure 2(b)**), such as *Vernicia montana* (Lour.) and *Vernicia fordii* (Hemsl.). The ratio of

	Youth period (possible BC 5000 – BC 770)	*Growth period* (BC 770-AD220)	*Development period* (AD220-AD979)	*Maturity period* (AD960-AD1911)
CL	A wooden bowl with red lacquer (BC5000)	Lacquer finishing with gold and silver peace	Gold inlay and carving lacquer appeared	Carving lacquer, mother-of-pearl inlay lacquer and bodiless lacquer.
TO		Tung oil painting for furniture decoration	Tung oil used for waterproofing on ships	Tung oil mixed with Chinese lacquer
CW		Chinese wax finished for bronze furniture	Chinese wax finished wooden furniture appeared	Chinese wax for furniture polishing

Figure 1. Periods in the history of traditional Chinese furniture and time sequences for the utilization of three Chinese finishing materials: Chinese lacquer (CL), Chinese wax (CW), Tung oil (TO)—compilation of data from References [5]-[12].

(a) (b) (c)

Figure 2. Sources and aspect of the three studied Chinese finishing materials: (a) lacquer tree (*Rhus vernicifera*) and raw Chinese lacquer; (b) Tung tree (*Vernicia montana*), seeds and Tung oil; (c) wax tree (*Fraxinus chinensis*), wax insect (*Ericerus pela*) and Chinese wax (images processed after [15]-[17] and experimental products).

Tung oil in the dried source seeds may reach a maximum percent of 68% [13]. It has been extensively used for transparent wood finishing, painting and varnishes. The fast "drying" process and the resistance of the finished surfaces are related to its chemistry [14].

Chinese wax is a sort of insect wax, secreted by *Coccus ceriferus* or *Ericerus pela*, which deposite it on the twigs of some species of ash trees (*Ligustrum lucidum Ait.* or *Fraxinus chinensis*) (**Figure 2(c)**). It is a white to yellowish-white, gelatinous, crystalline water-insoluble substance, with a complex chemical composition [9] with different applications including wood finishing.

2. Research Objectives

The present paper is a part of a PhD research project referring to a comparative study of ageing phenomena of wooden support and transparent traditional finishes for European and Chinese furniture.

The current paper covers some preliminary steps within this project, namely:

- A brief presentation of three important Chinese traditional finishing materials as origin and basic properties based on literature data;
- Their experimental macroscopic, microscopic and FTIR investigation.

The resulted data will be used as reference for the further ageing tests to be carried on.

3. Materials and Methods

The three finishing materials selected for this study were purchased from China: Chinese lacquer from East Lake CO., Ltd., Tung oil from Jin Xing Chemical and Chinese wax from Heng Hong Feng La Jiao Ye CO., Ltd.

The macroscopic aspect of the products was observed directly and pictures were taken on samples placed in Petri dishes employing a digital camera (Sony W80).

In order to observe the macroscopic aspect and the microscopic features of resulting dried coating films, the products were applied on microscopic glass lamellas and allowed to dry in normal conditions. Chinese lacquer (viscous liquid) and Tung oil (fluid liquid) were applied (after homogenisation) with a spatula as thin films of about 30 - 50 μm. In the case of Chinese wax (solid product) a small pellet was put on a glass lamella which was placed on a heating plate at 50˚C and allowed to melt and flow freely to form an uniformous thin film and further cooled down at room temperature for re-solidification. The microscopic lamellas were examined under an optical stereomicroscope OPTIKA SZM fitted with an image capture system (OPTIKAM PRO3 video camera), in transmitted light (TL). For the Tung oil a dark field (DF) device was employed in order to increase contrast. From each sample there were taken several images at magnifications of 40× and 80×.

FTIR investigation was performed on the same film samples applied on glass lamellas which were previously observed under microscope. FTIR spectra were recorded employing an ALPHA FT-IR Spectrometer (BRUKER), equipped with ATR (attenuated total reflection) module. The spectra were recorded in the 4000 - 400 cm^{-1} at a resolution of 2 cm^{-1}, each spectra representing an average of 32 scans.

4. Results and Discussion

The macroscopic aspect of the products can be observed in the pictures included at the bottom of **Figure 2**. Chinese lacquer is a viscous whitish (milky to cream colour) liquid with sour smell, which colour turns to light brown when exposed to open air. The Tung oil is a homogenous liquid with light yellow colour and characteristic smell. Chinese wax is white solid, with a specific structure, including opaque amorphous material and crystalline, translucent, high reflective, granules.

The dry coating films obtained on glass lamellas could be characterised as follows: dark brown, opalescent, glossy (Chinese lacquer), yellowish, transparent, and glossy (Tung oil), whitish, opalescent, satinated (Chinese wax).

Their microscopic investigation revealed characteristic differentiating features, as can be observed in **Figure 3**. For the Chinese lacquer film (**Figure 3(a)** and **Figure 3(b)**) is characteristic a quite regular microscopic structure with a certain roughness, in which can be observed dark brown insular areas (mostly of around 20 - 40 μm) on a more uniform whitish film with micro-crystalline structure. This is in accordance to studies of Takayuki Honda *et al.* (2008) [18] and explainable by the complex composition of this material.

A characteristic microstructure, with wavy aspect, could be distinguished also for the Tung oil film when

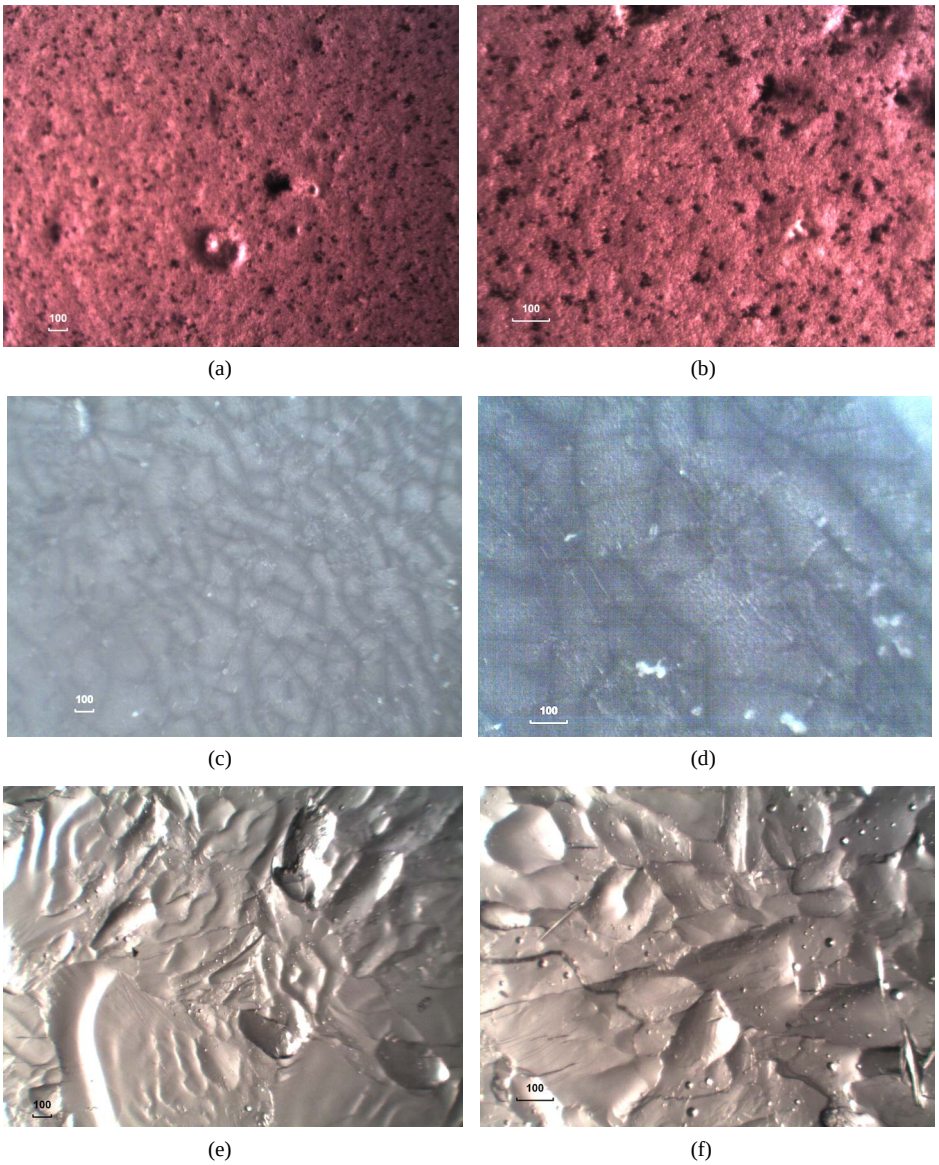
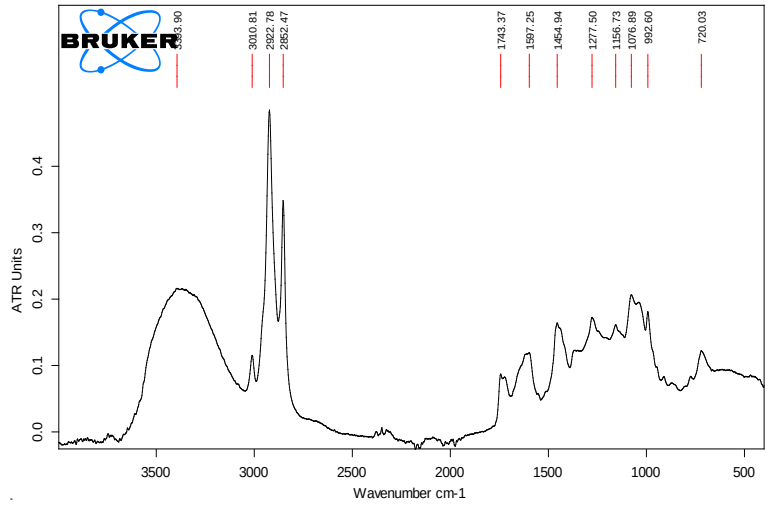


Figure 3. Micrographs of the films on glass lamellas(unit is μm): (a) Chinese lacquer 40× magnification; (b) Chinese lacquer 80× magnification; (c) Tung oil 40× magnification; (d) Tung oil 80× magnification; (e) Chinese wax 40× magnification; (f) Chinese wax 80× magnification.

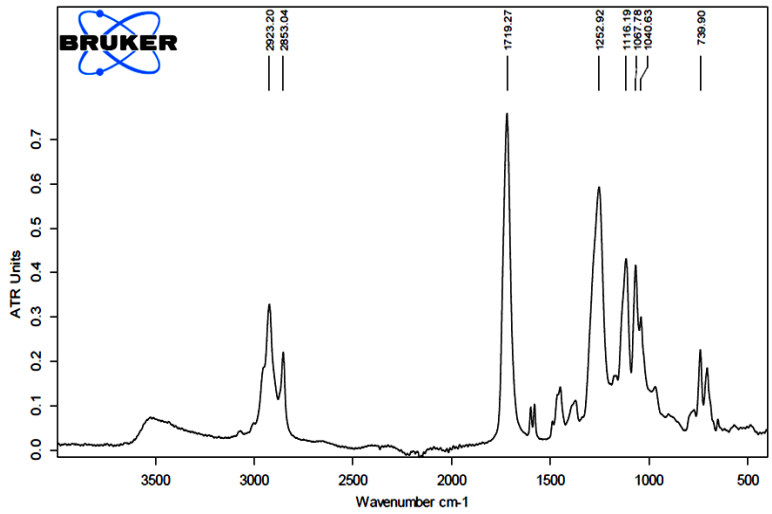
studied in dark field (**Figure 3(c)** and **Figure 3(d)**). Chinese wax forms a high reflective film with a specific less regular pattern (wavy areas alternating with geometrical/rhomboidal areas of 100 - 200 μm), as can be observed in **Figure 3(e)** and **Figure 3(f)**.

In **Figure 4** are presented the FTIR-ATR spectra experimentally recorded for the studied products, while in **Tables 1-3** are summarised the main absorbance bands found in these spectra and their assignment in accordance to literature. To facilitate understanding of bands assignment to different functional groups/structural elements, the chemical structure of the main components of these finishing products, as presented in literature, is also included.

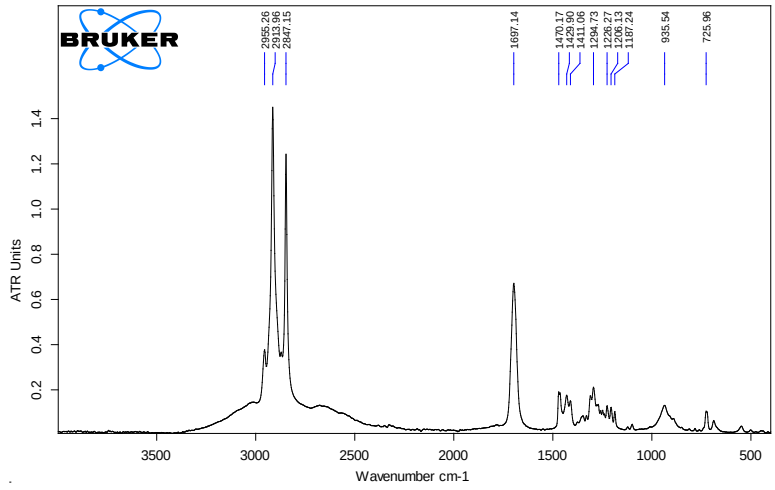
The comparative analysis of the spectra and associated tables allows a differentiation of these products based on their characteristic chemical features, which include both common and specific structural elements. For instance, the phenol type structure of the Chinese lacquer is well revealed by a strong –OH band at around 3400 - 3600 cm^{-1}, while the ester type structure of Tung oil and Chinese wax explain the strong C=O band at around 1700 - 1740 cm^{-1}. All the three products contain in their structure long aliphatic chains, presenting therefore



(a)



(b)



(c)

Figure 4. The FTIR-ATR spectra of three finishing materials: (a) Chinese lacquer; (b) Tung oil; (c) Chinese wax.

Table 1. Bands assignment for the FTIR spectra of Chinese lacquer (experimental vs. literature).

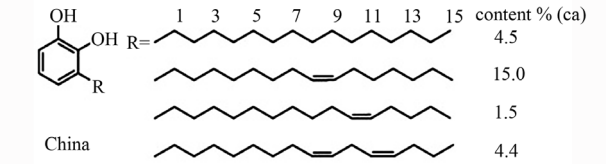
Material	Chinese lacquer	
Main component		
Band assignment [19]	Absorbance bands (cm^{-1})	
	Experimental	Literature [20]
O-H stretching band	3393	3605
C-H stretching band	2922 2852	2966
COO^- stretching vibration	1597 1454	1454
C-O stretching band	1277 1076	1180
	992	920
C-H torsion bands	720	729

Table 2. Bands assignment for the FTIR spectra of Tung oil (experimental vs. literature).

Material	Tung oil	
Main component	$CH_3(CH_2)_3$-CH=CH-CH=CH-CH=CH-$(CH_2)_7$-$COOCH_2$ $CH_3(CH_2)_3$-CH=CH-CH=CH-CH=CH-$(CH_2)_7$-COOCH $CH_3(CH_2)_3$-CH=CH-CH=CH-CH=CH-$(CH_2)_7$-$COOCH_2$	
Band assignment [19]	Absorbance bands (cm^{-1}) [14]	
	Experimental	Literature
C-H stretching band	2923 2853	3020 2930
C=O stretching band	1719	1750
COO^- stretching vibration	1562 -	1550 1452
C-O stretching band	1116 1067	990
C-H torsion bands	739	-

strong characteristic CH absorption bands (as a two peaks band) at around 2900 cm^{-1}/2850 cm^{-1}. The recorded spectra and data on characteristic bands are in good accordance to literature.

Table 3. Bands assignment for the FTIR spectra of Chinese wax (experimental vs. literature).

Material	Chinese wax	
Main component	$CH_3(CH_2)_{25}COO(CH_2)_{25}CH_3$	
Assignment [19]	Absorbance bands (cm^{-1})	
	Experimental	Literature [19]
C-H stretching band	2913	2918
	2847	2849
C=O stretching band	1679	1734
COO^- stretching vibration	1470	1466
C-O stretching band	1226	1182
	935	
C-H torsion bands	726	724

5. Conclusion

Three traditional finishing materials important for Chinese historic furniture: Chinese lacquer, Tung oil and Chinese wax, were comparatively investigated. Optical microscopy revealed characteristic microscopic features of the resulting coating films, while the FTIR spectra highlighted both the common and differentiating chemical structure features. These FTIR spectra will be used as references in a further study on the ageing properties of these finishing materials and finished wooden surfaces. This is important for scientific conservation of valuable historic Chinese furniture or other old wooden artefacts.

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