Camphor Wood Used as a Museum Storage Material: An Indoor Air Pollution Source Harming Metallic Objects

Jingyi Shen

Abstract Camphor wood is welcomed by many museums for its insect-repelling effect, yet the smell indicates a potential risk to the collections. In order to judge the suitability of camphor wood as a museum storage material, camphor wood samples of different ages were evaluated by using the Oddy test. Gas chromatography-mass spectrometry (GC-MS) and X-ray diffraction (XRD) were applied to identify the volatile organic compounds (VOCs) emitted by the materials and the corrosion products, respectively. The results showed that the camphor wood samples led to visible corrosion on copper and lead coupons. GC-MS indicated that the major VOCs emitted were terpenes and their derivatives. $Pb_{10}(CO_3)_6(OH)_6O$ was identified as the corrosion product of lead coupons. The study provides conservators with abundant information to reassess the application of camphor wood to museums as well as a different way to understand the mechanism of metallic corrosion caused by camphor wood.

Keywords Camphor wood · Museum storage material · Indoor pollution · Oddy test · Volatile organic compounds · Metallic corrosion · Instrumental analysis

1 Introduction

Differing from natural disasters and human errors, environmental factors impact on cultural heritages in a slow but irreversible way. Among the environmental factors, the volatile corrosive matters emitted by storage or display materials have been investigated by the British Museum since the 1970s [1]. Many collections are sensitive to the volatile matters, especially when metallic objects are surrounded by acidic atmosphere, corrosion occurs significantly. A convenient method called the Oddy test was developed in order to judge the suitability of uncertain storage materials [1–3]. In this test, copper, silver, and lead coupons are employed to simulate the

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cases of metallic objects. Corrosion is observed by naked eye, which detects the concentration of volatile corrosive matters and the suitability level of materials, while the specific contaminants and the corrosion mechanisms have to be given by other methods.

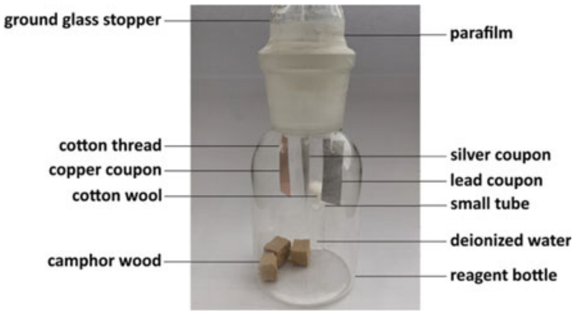
Wooden materials are welcomed by museums due to their advantages in availability, breathability, mechanical property, and texture. Camphor wood is especially favorable in many cases given that its smell is a natural insect repellant and a fumigant, which has been approved since the era of Ancient Egypt and Babylon, as well as in Europe in the Middle Ages [4]. Nevertheless, as a volatile mixture, the smell indicates a potential risk to the collections. It is necessary to evaluate the suitability of camphor wood as a museum storage material and provide conservators with useful information.

2 Materials and Methods

Camphor wood (*Cinnamomum camphora*) samples were collected from Jiangxi Province, China. They were about 30, 50, and 100 years old, respectively. Isooctane (analytical grade) and copper, silver, and lead foils (99.9%), were purchased from Sinopharm Chemical Reagent Company, China. Isooctane was used without further purification. Deionized water was used throughout this work.

The preparation of material bricks and metallic coupons, the assembling of experimental devices, and the testing process, were based on the previous work [5]. The typical device is shown in Fig. 1. Coupons were analyzed using Rigaku Smart Lab X-ray diffractometer (Cu Kα, 40 kV, 100 mA) *in situ* to identify the corrosion products when the whole test was finished. Volatile matters emitted by the wood samples were identified using an Agilent 7890B-5977B gas chromatography-mass spectrometer (GC-MS) through solid-phase micro-extraction (50/30 μm CAR/DVB on PDMS, shaking for 15 min and extracting for 30 min at 50 °C). The total volatile organic compound (TVOC) emitted by each wood sample was measured using an RAE PGM-7340 portable TVOC analyzer in a 16 L closed desiccator placing 2.0 g of sample.

Fig. 1 The typical experimental device used in this study



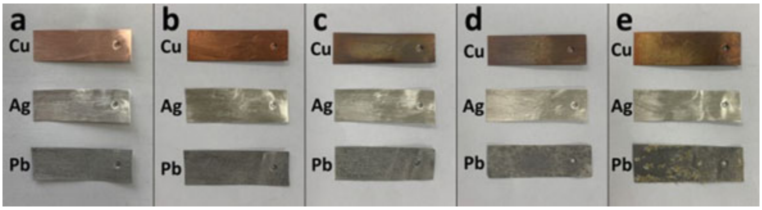


Fig. 2 Coupon appearances. **a** Initial. **b** Control coupons at day 28. **c** Affected by 30a camphor wood. **d** Affected by 50a camphor wood. **e** Affected by 100a camphor wood

Table 1 Major compounds emitted by the camphor wood samples. The data in the brackets represent the peak area (%)and the reliability value (%) in sequence

No.	Constituent (30a sample)	Constituent (50a sample)	Constituent (100a sample)
1	*D*-(+)-Camphor (12.71)(96)	*D*-(+)-Camphor (19.97)(98)	α-Copaene (14.60)(99)
2	Nerolidol (9.99)(83)	Eucalyptol (17.47)(97)	Eucalyptol (10.14)(93)
3	α-Terpineol (7.52)(90)	(-)-α-Santalene (16.91)(99)	*D*-(+)-Camphor(9.88)(98)
4	Safrole (6.60)(96)	(-)-β-Santalene (8.50)(83)	β-Elemene (7.91)(62)
5	*L*-(-)-Camphor (5.91)(91)	(*E*)-β-Famesene (7.28)(60)	α-Terpineol (6.94)(94)

3 Results

3.1 Coupon Appearances

Coupon appearances before and after the test are shown in Fig. 2.

3.2 Species and Amount of the Volatile Matters

Major volatile matters identified by GC-MS are shown in Table 1. The TVOC values were 600, 670, and 780 ppb for 30-, 50-, and 100-years-old samples, respectively.

3.3 Corrosion Products

As shown in Fig. 3, $Pb_{10}(CO_3)_6(OH)_6O$ (JCPDS 19-0680) was identified as the corrosion product of lead coupons affected by the camphor wood samples, but no new diffraction peaks were found on the patterns of copper and silver coupons.

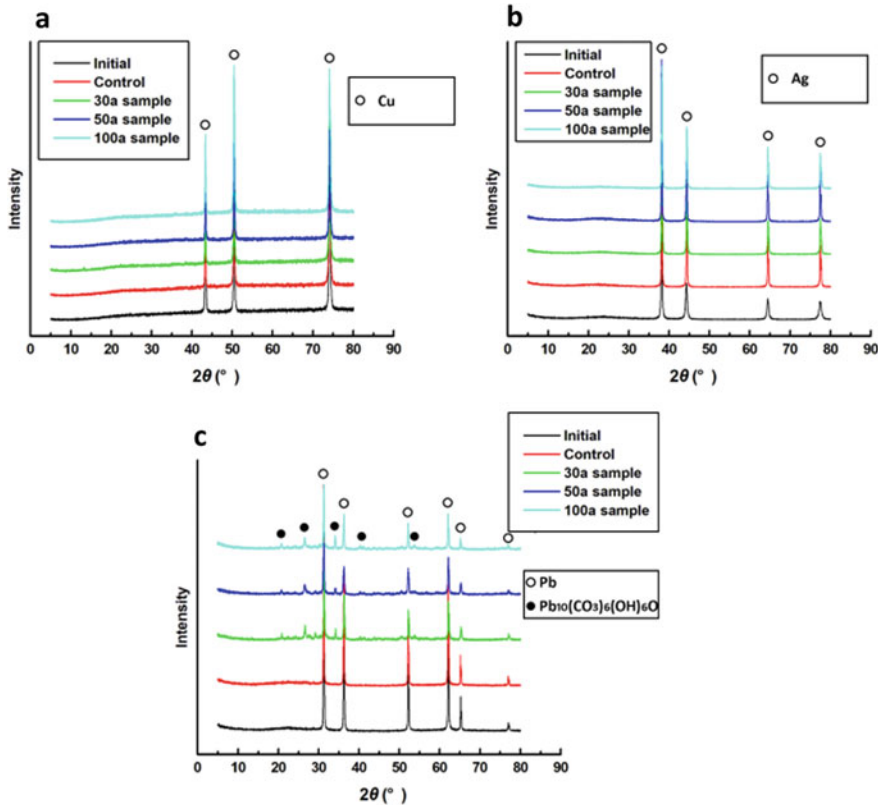


Fig. 3 Coupon phases identified by XRD. **a** Copper. **b** Silver. **c** Lead

4 Discussion

As shown in Fig. 2, corrosion was observed on lead and copper coupons, while the silver coupons were in good condition. It is easy to find that the corrosion level of lead coupons increased along with the aging of camphor wood, which was in accordance with the monotonic increasing tendency of the corresponding TVOC values; while in the cases of copper, the corroded coupons featured partly discolored surfaces compared with the control. According to the standard [2], the 100-years-old sample was found to be unusable, while the other two were temporarily usable.

According to Table 1, terpenes and their derivatives were abundant in the volatile species emitted by the samples. These matters are typical volatile organic compounds (VOCs). Some studies have shown that unsaturated terpenes have a high potential to react with ozone indoors; carboxylic acids are produced as a result [6, 7]. The essential elements are common indoors and present in this study as well. Considering that the acetic acid emitted only covered 0.08, 0.01 and 0.05% of the total peak area for 30-, 50-, and 100-years-old samples, respectively, the oxidation of terpenes is probably a major factor leading to the metallic corrosion in this study.

As a weak metallic element, lead tends to be corroded into $Pb(OH)_2$ in air through the oxygen absorption process, which is promoted by the increasing of system pH. Then, carbon dioxide participates in the reactions, producing $Pb(OH)_2{\cdot}2PbCO_3$ and $Pb_{10}(CO_3)_6(OH)_6O$ in turn. However, the corrosion products of copper coupons were not identified due to the low yield. In general, it is interesting to further study the relations among oxidants, terpenes, and metals in the system.

5 Conclusions

Although camphor wood is useful for repelling insects, it is unsuitable for permanent use as a museum storage material, especially for the conservation of metallic objects. The predominant VOCs emitted by the camphor wood samples are terpenes and their derivatives. With the coexistence of traces of ozone, terpenes have a high potential to be oxidized to carboxylic acids, which promote the corrosion, especially on lead and copper. The main corrosion product of lead coupons is $Pb_{10}(CO_3)_6(OH)_6O$. The relations among oxidants, terpenes, and metals in the system need further investigations.

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