Selection of display materials for using in the Shanghai Museum East by the Oddy Test

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Abstract: The Shanghai Museum East has been open to the public in 2024. Since the collections are sensitive to indoor air contaminants such as organic acids, volatile organic compounds and formaldehyde, a series of work was done in order to ensure the qualification of environment in the galleries and showcases. As the showcases are made of different materials including boards, fabrics, sealants, sealing strips, etc., the reliability of these materials are directly relevant to the safety of collections. Established and adopted by the British Museum, the Oddy Test is a simple and intuitive method for judging the reliability of unknown display materials. The test was conducted to screen out the permanently usable materials in over one hundred potential candidates in the showcase preparation stage. The case of nine typical materials was studied and introduced in this work. The result indicates the most suspicious materials, as some kinds of organics like sealants, fabrics, boards, etc. Staffs, conservators and researchers can learn from this study to have a preliminary judgment on the selection of unknown display materials.

1 Introduction

Established in 1952, the Shanghai Museum is one of the most important ancient Chinese art museums in the world. The Museum's collection covers 33 categories, including nearly 1,020,000 items, 140,000 of which are graded national treasures. One of the most complete collections of ancient Chinese art, the Museum's collection presents a comprehensive image of Chinese material culture. The museum has three sites: Shanghai Museum on People's Square, Shanghai Museum East, and Shanghai Museum North (in preparation). Shanghai Museum East, open to the public in 2024, focuses on exhibiting ancient Chinese art. There are twenty galleries and interactive spaces in the building [1]. Since the whole building is newly designed and built, there are many uncertain factors which may cause risks to the collections. One of such factor is the reliability of the showcase materials, such as boards, fabrics, sealants, sealing strips, etc. According to the research from the British Museum, using showcase materials without rigorous tests may lead to significant harm to the metallic collections such as bronzes and silverware [2]. For judging the reliability of the unknown materials, a simple test method called the “Oddy Test” was established in the 1970s by the British Museum [3]. In this test, pure copper, silver and lead coupons are used in order to modify the real corrosion processes of bronze and silverware collections. By placing the three coupons and the potential material in the same device and controlling the temperature and relative humidity of the inner space, the volatiles emitted by the material react with the metal coupons at a higher rate, thus the staffs can get the result in 28 days.

Since several companies undertook the work of producing showcases for using in different galleries, the designs and the materials were quite different. Therefore, the author has performed several times of the Oddy Test and tested over one hundred potential samples to ensure the safety of the precious collections. To the author it was a daily work but to staffs and conservators from most organizations it may be unfamiliar. In this work, the test result is shown and analyzed. By exploring and understanding the mechanism, people can learn the experience of evaluating unknown materials.

2 Materials and methods

Copper, silver and lead foils (99.9%), and isooctane (analytical grade), were purchased from Sinopharm Chemical Reagent Company, China. Metal coupons used in this study were obtained by cutting the raw metal foils into the same size (3.5 cm × 1.0 cm) according to the reference [4]. Isooctane was used without further purification. Deionized water was used throughout this work. The potential materials provided by different companies are shown in Figure 1.

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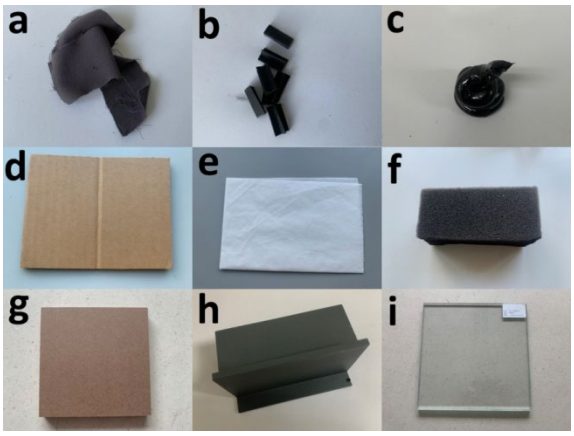

Figure 1. Materials tested in this study. (a) Fabric. (b) Sealing strip. (c) Sealant. (d) Paper board. (e) Acid-free paper. (f) Foam plastic. (g) Density board. (h) Aluminum profile. (i) Laminated glass.

The reliability of the above samples was evaluated by performing the improved Oddy Test [4]. For materials a-f which can be cut into any sizes, six customized glass bottles with ground glass stoppers were used. Fixed inside the stopper of each bottle, a thin iron wire was made into a hanger, playing the role as holding three coupons. About 2.0 g of each sample was put into the bottle first. Then, a 2 mL glass tube was filled with water, plugged with a small ball of cotton wool and finally placed into the bottle. The small tube was kept standing during the whole test. Three coupons made of copper, silver and lead respectively were fixed in the iron hanger by using cotton strings. After that, the bottle was plugged with the stopper. The three metal coupons were kept away from each other, as well as from the sample and the small tube. The joint between bottle and stopper was sealed by using two layers of parafilm. Thus, a typical experimental vessel was assembled. Also, the control vessel was assembled like this but without adding any material samples. For materials g-i which cannot be cut in the test, three glass desiccators with ground glass covers were used. Due to the difference of volume between the desiccator and the bottle, the amount of deionized water placed in each desiccator was set as 150 mL and the water was held in a beaker. Other instructions were generally the same as that for the bottles. The ten devices were then moved into a Memmert HPP 750 thermo-hygrostatic chamber to perform the Oddy Test. The temperature and the relative humidity inside the chamber were respectively set as 60 ℃ and 40% in order to accelerate the corrosion and promote the evaporation of water stored in the devices while prevent the metallic chamber from being affected by high relative humidity. After 28 days, the devices were moved out and the coupons' appearance was observed.

3 Results and discussion

The Oddy Test was established for evaluating the risk of metallic collection disease caused by the display materials. The principle is based on the surface appearance variation in oxidation and corrosion of copper, silver and lead, which can be observed by naked eyes, showing a simple and intuitive feature. Detail of the evaluation criteria can be found in reference [2]. Of course, the display materials' impact on organic collections such as paper, fabrics, animal bones, etc., cannot be assessed by the Oddy Test, but other methods with similar principles such as accelerated ageing tests. In the construction of the Shanghai Museum East, the first batch of gallery open to the public included the bronze gallery, the special exhibition gallery (for displaying the ancient bronzes unearthed from Sanxingdui and Jinsha sites) and the sculpture gallery. As most items displayed in these three galleries were inorganics, especially metallic, the Oddy Test was adopted.

As shown in Figure 2, different samples led to different appearances of the coupons in the test. Copper tends to be oxidized to cuprous oxide (Cu_2O) with crimson color in the air [5], which can be accelerated in a high temperature and high relative humidity environment. If the copper coupon leaves the crimson color without having other changes, the corresponding material did not have emitted substantial amount of volatiles harmful to copper. In another word, the tested material is safe to copper. In this study, the materials were all safe to copper except the fabric (see Figure 2a) and the density board (see Figure 2g) which made the copper coupon partly darkened (but not completely darkened), indicating slight corrosion, thus the two materials were regarded as temporarily usable [2]. Compared with copper and lead, silver is more stable in chemistry, making it less likely to be corroded, thus most samples did not have an impact on the silver coupons' appearance, indicating their permanent safety to silver. The only exception was the sealant which made the edge of the silver coupon tarnished (see Figure 2c), which means slight corrosion [2], implying that the sealant was only temporarily safe to silver. Lead is the most active among the three metals, making contaminants easier to have impacts on its appearance. As a result, only five of the nine samples reached the standard of permanently usable, as they did not make the corresponding lead coupons significantly changed compared with their initial appearances. The paper board and the density board produced several tiny white spots on the lead coupon surface (see Figures 2d and 2g), as the corrosion products of lead, making their reliability judged as only temporarily safe to lead [2]. The fabric and the sealant produced, however, more significant corrosion of the lead coupons, as a rather large area of the white spots (see Figure 2a) and some white particles of bigger sizes (see Figure 2c), thus they were judged as unsafe to lead according to the literature [2]. Since the total judgment of each material's reliability is based on the coupon reflecting the severest corrosion among the corresponding three coupons, the sealing strip, the acid-free paper, the foam plastic, the aluminum profile and the laminated glass were judged as permanently usable; the paper board and the density board were regarded as temporarily usable; while the fabric and the sealant were evaluated as unusable. The results are listed in Table 1.

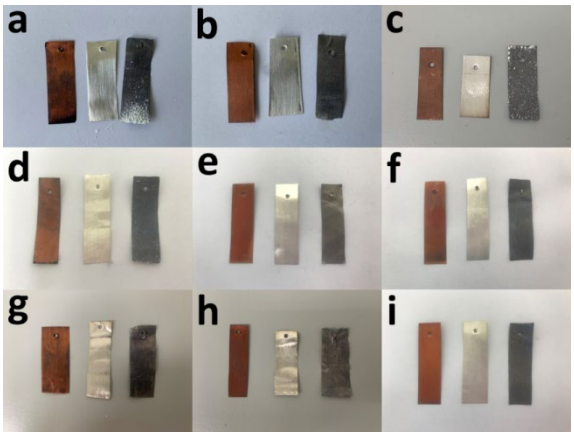

Figure 2. Metal coupons corresponding to the material samples after the Oddy Test. (a) Fabric. (b) Sealing strip. (c) Sealant. (d) Paper board. (e) Acid-free paper. (f) Foam plastic. (g) Density board. (h) Aluminum profile. (i) Laminated glass. The coupons from left to right are respectively copper, silver and lead in each figure.

The permanent usability of the aluminum profile is undoubted, as it is fully composed of common inorganics which are unlikely to emit volatiles in most cases. Similar materials include iron, steel, single-layer glass, etc., which are also permanently usable in most cases. Although the sealing strip and the foam plastic are organics, they are safe to the metals, as their chemical composition (silicon rubber and polyurethane, respectively) is inert. The laminated glass is composed of glass and inactive organic polymers such as polyvinyl butyral, ethylene vinyl acetate copolymer, polyurethane, etc., which indicates a "permanently usable" judgment in most cases. Paper can be judged as permanently usable or not based on whether it has been treated to remove the acidic matters introduced in pulping and bleaching processes. The density board consists of wood fibers and organic resins. Since wood tends to emit volatiles including formic acid, acetic acid and some other volatile organic acids in all lifecycle [6], it is unlikely to be permanently safe to metals. The typical example is the camphor wood which is useful for repelling insects and inhibiting mold but at the same time significantly harmful to metallic collections of museums [4]. The case of fabrics is based on the specific chemical composition. In most cases, fabrics may be permanently safe to metals, but if they are made of natural silk or wool which are actually proteins containing element sulfur, they are probably harmful to silver because the sulfur-containing proteins may be hydrolyzed to amino acids including methionine, cysteine and cystine which can be further decomposed to hydrogen sulfide with the effect of microbes, making the nearby silverware tarnished. In this study, the silver coupon during the test maintained its initial appearance, while severe corrosion was observed on the lead coupon, indicating that the contaminant was not originated from the fiber itself (actually the fabric is not made of natural silk or wool) but probably some foreign substances added in the production process. The case of sealants is the most complicated in the Oddy Test because the chemical composition of various sealants is rather different, as well as that the solidifying process of sealants has a very important impact on the final judgment. Sealants are composed of complex chemicals. They can be classified as the neutral type and the acidic type based on the specific chemical properties. The acidic type emits acetic acid during the solidifying process, thus it is prohibited from use in museums. In fact, even the neutral type can be judged as unusable if the test begins without letting the solidifying process thoroughly finished, as other contaminants such as the volatile organic compounds may also be emitted during the process.

Table 1. Reliability of the samples based on the coupon appearance after the Oddy Test.

Sample	Copper coupon	Silver coupon	Lead coupon	Total judgment
Fabric	Temporarily usable	Permanently usable	Unusable	Unusable
Sealing strip	Permanently usable	Permanently usable	Permanently usable	Permanently usable
Sealant	Permanently usable	Temporarily usable	Unusable	Unusable
Paper board	Permanently usable	Permanently usable	Temporarily usable	Temporarily usable
Acid-free paper	Permanently usable	Permanently usable	Permanently usable	Permanently usable
Foam plastic	Permanently usable	Permanently usable	Permanently usable	Permanently usable
Density board	Temporarily usable	Permanently usable	Temporarily usable	Temporarily usable
Aluminum profile	Permanently usable	Permanently usable	Permanently usable	Permanently usable
Laminated glass	Permanently usable	Permanently usable	Permanently usable	Permanently usable

According to the previous study [4], the copper coupon can be corroded to various products based on the contaminants emitted, which makes its appearance varied from crimson to dark. Among the colors, the following three are the most typical: i) crimson: it means the copper has only experienced an accelerated process of its natural oxidation and the product is totally cuprous oxide, thus the corresponding material can be permanently safe to copper; ii) dark: it indicates that the copper has almost totally been corroded to its highest valence oxide CuO, thus the corresponding material must be unsafe to copper; iii) green or blue: it implies that the copper has been corroded to certain salts including inorganic or organic, thus the corresponding material can be unsafe or just temporarily safe to copper, as the state of salts can be regarded as a transitional stage in the corrosion of copper. On the other hand, the case of lead is more complicated because the stable corrosion products are usually carbonates or basic carbonates rather than oxides. The products are easy to recognize because of the notable crystallites, as well as their white or light yellow color. Last but not least, the tarnish of silver is usually the sulfide with brown color, which represents the simplest corrosion mode among the three.

Based on the above analysis, the following points are generalized for museum staffs to consider before

conducting the Oddy Test. First, staffs need to consider the chemical property of the potential materials. Inorganic materials are usually safe to the metallic collections unless one of the following three cases is present in the test: i) they are unstable in chemistry and tend to be converted into active chemicals reacting with metals; ii) they have complex microstructures such as abundant porous structures adsorbing active volatiles harmful to metals; iii) certain foreign substances harmful to metals are added in the production process but not thoroughly removed. Cases i and ii are rarely found, while case iii is common and particular attention is required. Second, although most risks are originated from organic materials, various materials have different levels of risk to the metallic collections. According to the author's working experience, the most harmful materials usually come from wooden boards, sealants, fabrics and paper boards. If the sample smells obviously, it can hardly pass the Oddy Test to have a "permanently usable" judgment. Special attention should be paid on wooden boards and sealants. In most cases, wooden boards cannot reach the standard of permanently usable regardless of whether they are particle boards, density boards or solid wood boards. Actually, wooden boards even can hardly access to the level of temporarily usable, as severe corrosion is often observed on copper and lead coupons. For sealants, the acidic type should be eliminated first. For the neutral type, the solidifying process may take one week or even longer, but the time cannot be easily compressed, otherwise the final judgment may probably be incorrect. Fabrics and paper boards are of lower risks to metals in most cases. Key points for estimating their reliability include understanding whether the fabric is made of natural silk or wool, and whether the paper has been treated to remove the acidic matters. Besides performing the Oddy Test, what could the museum staffs do to prevent the metallic collections from being influenced by the volatiles emitted by display materials? As a preventive conservation scientist, the author has participated in over thirty special exhibitions in the Shanghai Museum since 2017. In view of the preventive conservation, the principle is trying not to use the wooden boards in producing the showcases. However, one important thing is to ask the workers to carefully cover the wooden boards using Al-plastic films in case that the principle could not be followed due to cost or design considerations. By using the film, the distribution of volatiles can be limited effectively. The field measurement of contaminants including volatile organic compounds, formaldehyde, formic acid, acetic acid, etc., and the preparation of adsorbents for potential treatment, are also necessary.

At the end of the discussion, it must be pointed that although the Oddy Test is applicable to the preventive conservation, it is a judgment method depending on personal experiences rather than an analytical method based on data measurable. Judgment results can be obtained from the phenomena such as color change or corrosion advance, but measurable data useful for deeper studies cannot be directly obtained in the test. Aiming at the disadvantage, the author has made the effort to introduce several instrumental methods such as scanning electron microscopy – energy dispersive X-ray spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy and time of flight – secondary ion mass spectrometry to the scientific analysis of the Oddy Test results [4,7,8]. The modern techniques seem irrelevant to the daily work of museum staffs, but actually they are helpful in understanding the mechanism of corrosion, so that the application of them should be further promoted in the future.

4 Conclusion

Display materials of higher risk to metallic collections usually come from organic materials, especially wooden boards, sealants, fabrics and paper boards. Based on this knowledge, museum staffs could have the anticipation and try to avoid using the suspicious materials. In case the use of some suspicious materials is inevitable, monitoring and treating the contaminants are necessary.

Acknowledgments

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