Study on Nano-Silica in Protection of Paper

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Abstract: In this work, the role of Nano-silica in protection of paper works were investigated. Nano-silica was used as protective coating on the surface of the paper. To prove the protective of this coating, the mechanical properties and the ultraviolet absorption of paper were measured, such as tensile strength, folding endurance, tear strength, the glossiness and brightness of paper. The results show that the tensile strength and the folding endurance of paper coated with Nano-silica have increased, the tear strength of paper coated with Nano-silica has decrease, and the glossiness and brightness remained unchanged. The paper coated by Nano-silica has strong absorption peaks for ultraviolet radiation from 200 nm to 300 nm.

Keyword: Nano-Silica; Paper; Mechanical Properties.

1 Introduction

The paper such as old manuscripts are susceptible objects which are influenced by environmental conditions such as climate, pollution, ultraviolet radiation and mechanical stresses [1-4]. In order to slow down these degradation processes, it is necessary to carry out preventive conservation. So, conservation science focused on chemical materials that are able to protect the artistic substrate [5].

In recent years, nanomaterials have been widely used in the protection of cultural

relics such as paper, wood, textile, stone and wall paintings. Nanosale material has excellent physical and chemical properties, such a mechanical, thermal, optical, and electronic properties are remarkably different from that of bull materials and from their atomic counterparts. For example, quantum size, small size effect, surface effect and macroscopic quantum tunnel effect. Due to their particular characteristics, nanomaterials seem to be very suitable for new conservation treatments. The most common nanomaterials used in conservation science are inorganic nanomaterials such as calcium and magnesium hydroxide [6-9], metal oxides (such as TiO_2, ZnO, and Fe_2O_3) [10-16], and their nanocomposites.

Nano-silica is a non-toxic, tasteless and pollution-free inorganic metal oxide nanomaterial [17]. It has three-dimensional network structure [18]. Nano-silica has a strong absorption and shielding effect on the ultraviolet radiation of 200nm~ 400 nm [19]. At the same time, because the volume of Nano-silica is small, it is transparent when it is dispersed uniformly in solution, so it will not affect the color and appearance of paper when it is used in paper cultural relic reinforcement.

2 Materials and Methods

2.1 Materials

Nano-silica, Product No. S104600, Aladdin; Deionized water, Made by oneself; Xuan paper, Market purchase.

Tensile strength Tester, PN-TT300, Folding endurance Tester, PN-NZ135, Tearing strength Tester, PN-TT1000, Glossiness Meter, PN-GM, Brightness Tester, PN-48B, Hangzhou Pinghong Technology Co., Ltd.

2.2 Methods

Nano-silica（1g）were dispersed in water (70g）by using an ultrasonic instrument for 10min. One set paper cut according to the standard (210mm x 297mm) is soaked in Nano-silica suspension for 2 min. Another set of papers was reserved without any treatment for comparison. Then all paper samples that had been coated with Nano-silica were dried at room temperature.

3 Results and Discussion

3.1 Effect of Nano-silica on Mechanical Properties of Paper

The effect of Nano-silica on tensile strength and folding endurance of paper is shown in Fig.1.

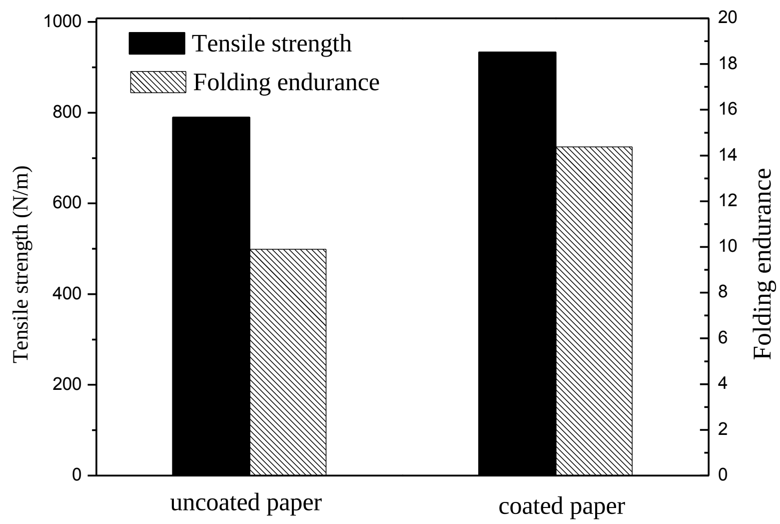

Fig.1 Effect of nano-silica on tensile strength and folding endurance of paper

It can be seen from Fig.1, the tensile strength and folding endurance of coated paper is higher than uncoated paper. This indicates that nano-silica can increase the mechanical strength of paper.

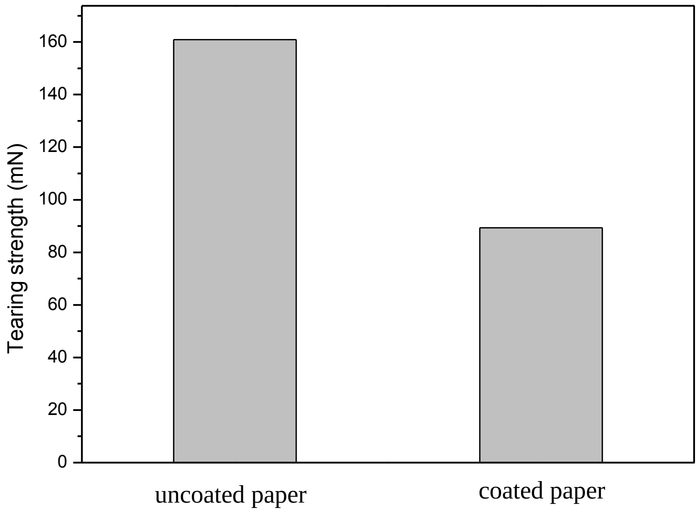

Fig.2 Effect of nano-silica on tearing strength of paper

The effect of on tearing strength of paper is shown in Fig.2. It can be seen from Fig.2, the tearing strength of paper coated by Nano-silica has decrease.

This is because paper is a material with both elasticity and plasticity [20]. When it is subjected to external force, its deformation has the following characteristics: (1) the elongation of paper increases with the increase of load, but the stress and strain are not proportional to each other. When the load increased to a certain extent, the elongation of paper will increase faster than the increase of load. This shows that the paper is an elastic object at first, and it begins to have plastic denaturation after a certain deformation. （2）under a certain load, the paper can be continuously elongated or creep. When the load increases to the plastic change of the paper, if the load is kept constant, the paper will continue to plastic change until it breaks. This delayed plastic transformation is called "creep". (3) when the load rate is increased, the load at break increases and the elongation decreases. When the load is slowly increasing, the load at break decreases and the elongation increases. It can be found in printing that the paper with higher tensile strength is more prone to fracture than the paper with lower tensile strength.

This phenomenon shows that the strength of tensile strength does not accurately describe the ability of paper to resist tension failure. The ability of all kinds of paper to resist destruction is not only strength, but also toughness, that is, it has a certain stress and strain relationship. If the paper elongation is small, when the force is affected by external force, it is difficult for the paper to have a larger strain, and it is easier to break. If the elongation is large, the paper first takes place when the force is the same, but it is not easy to break. In fact, the paper with high tensile strength and low elongation is not necessarily better than the paper with little tensile strength and large elongation. The reason is that the latter can absorb more energy and show higher toughness.

Table 1. Effect of on glossiness of paper

	G75Glossiness/ Gu				
Uncoated paper	4.5	4.2	4.9	4.4	4.5
Coated paper	4.3	4.2	4.8	4.5	4.1

Table 2. Effect of nano-silica on brightness of different paper

	R457Brightness/ %				
Uncoated paper	60.2	61.0	59.8	60.1	62.0
Coated paper	60.1	57.5	55.7	59.1	55.7

Additionally, the glossiness and brightness of paper is listed in Table 1 and Table 2. It can be seen from Table 1 and Table 2, the glossiness and whiteness of the paper coated by nanometer SiO_2 remain basically the same. This is because of the small volume of nano-silica, it is transparent when it is dispersed in the water, and will not affect the color and appearance of the coated paper.

3.2 Effect of nano-silica on the ability of paper to resist ultraviolet radiation.

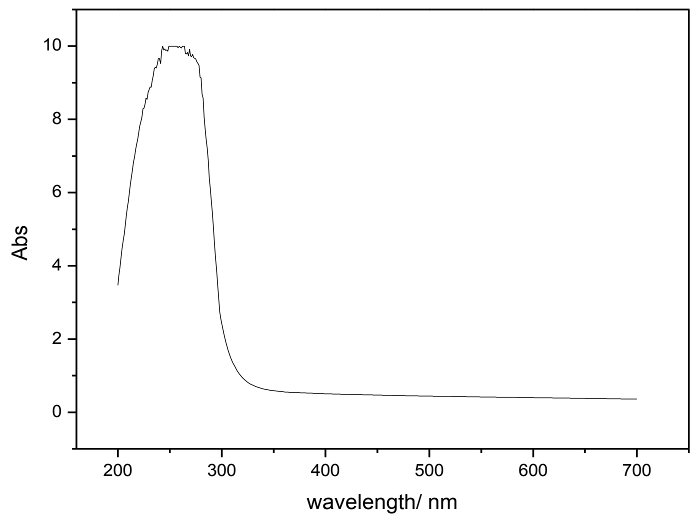

Fig.3 UV absorption Spectra of paper coated by nano-silica

The ultraviolet absorption of paper coated by nano-silica is shown in Fig.3, It can be seen from Fig.3 that coated paper has strong absorption peaks for ultraviolet radiation from 200 nm to 300 nm. As the literature says, light is an environmental factor that poses a greater threat to paper. The natural light that can affect paper in the general atmospheric environment is visible light and ultraviolet radiation. Ultraviolet radiation is the most harmful to paper. Usually, ultraviolet radiation can be subdivided into three bands, the wavelength of UVA type ultraviolet radiation is 320nm-400nm. The wavelength is longer than other ultraviolet radiation, but its energy is smaller. The wavelength of UVB type ultraviolet radiation is 280nm-320nm. The wavelength and energy are between the other two kinds of ultraviolet radiation. The wavelength of UVC ultraviolet radiation is 200nm-280 nm, the wavelength is the shortest in three ultraviolet radiation, and the energy is the largest. The ozone layer in the atmosphere absorbs UVC ultraviolet radiation before they reach the earth, Therefore, there are two kinds of ultraviolet radiation on the earth's surface: UVA and UVB. The wavelength that have an impact on paper are mainly focused on 280 nm-400 nm.

Therefore, nano-silica can resist ultraviolet radiation very well as a protective material for paper reinforcement. In addition, the coated paper can absorb nano-silica suspension almost 100%, the absorption is very good.

4 Conclusions

In this research, the nano-silica for reinforcement of paper were investigated. Results showed that the the tensile strength and folding endurance of paper coated by nano-silica have increase greatly, and tear strength of paper coated by nano-silica has decease. Also, a good glossiness and brightness of paper had no change. At the same time, nano-silica has strong absorption peaks for ultraviolet radiation. Therefore nano-silica has great application prospect as paper strengthening material.

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