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PREPARATION OF NANO-SiO_2 MODIFIED UREA-FORMALDEHYDE PERFORMED POLYMER TO ENHANCE WOOD PROPERTIES

Yifei Jiang, Guofeng Wu, Heyu Chen, Shuping Song and Junwen Pu

College of Material Science and Technology, Beijing Forestry University, Beijing, Qinghua East Road No.35, 100083, China

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Abstract. To obtain high strength wood by impregnating modifier at low pressing pressure and low heating temperature is one of advanced wood modification methods. Urea formaldehyde resins are produced in large amounts and are widely used in wood industry depending on the properties. However, the viscosity of common Urea formaldehyde resins is too high to impregnating into the log. In this case, a modifier with low viscosity called urea formaldehyde performed polymer were synthesized (UFP). In the meanwhile the influence of inorganic rigid particles (nano-SiO_2) on the properties of urea formaldehyde performed polymer, nano-SiO_2/ (urea formaldehyde performed polymer) composites have been made. The effects of different contents of nano-SiO_2 on the properties of nano-SiO_2/UFP composites such as the dispersion of nano-SiO_2 and wood bonding strength were discussed. The results indicated that the bonding strength of wood modified by nano-UFP increased greatly.

1. INTRODUCTION

It is desirable in the twenty-first century to build a sustainable society based on renewable and sustainable resources. As reserves of coal and oil become exhausted, future advanced materials have to be derived from renewable resources such as wood, even though it is one of the oldest and most common materials [1-3]. For these potentials to be realized and to substitute other resources derived from synthetic plastic, ceramics, and metals [4], the utilization of inherent properties of wood should be taken into account. However, some properties of wood are a bane in its utilization; these include dimensional instability with changing moisture, low durability and unsatisfying mechanical properties [5,6]. All of those may prevent wood from replacing materials that are based on unrenewable resources [7-10]. Considering of that, a method to improve the properties of nature wood by nano-particles was studied.

2. MATERIALS AND METHODS

2.1. Raw materials

The raw material was polar wood with an air-dried density 0.214 g/cm^3. The fresh logs were cut into timber with longitudinal of 90 cm, then impregnated by pulse-dipping machine, and finally cut into specimens with 14 cm in the tangential direction (*T*) by 7 cm in the radial direction (*R*) by 90 cm in the longitudinal direction (*L*).

Nano-SiO_2 (Nanjing High Technology Nano Co.Ltd, Style: HTSi01): content of Nano SiO_2 99%; The average particle size is 20 nm; Surface area is 440 $m^2 \cdot g^{-1}$; UV reflectivity> 80%; Density <0.21 g • cm^{-2}; Loss on drying <1.4%; Loss on ignition <1.8%;

Corresponding author: Junwen Pu, e-mail: 30073609@163.com and jwpu@bjfu.edu.cn

Table 1. Physical and mechanical properties of natural and treated wood.

specimens	bending strength (MPa)	bend elastic modulus (MPa)	basic density (g/cm^3)	over-dried density (g/cm^3)	air-dried density (g/cm^3)
natural	64.0	1407	0.214	0.258	0.294
treated	74.5	1759	0.268	0.300	0.331

Table 2. Dimensional stability of natural and treated wood.

specimens	hygroexpansivity			shrinkage		
	tangential	radial	volume	tangential	radial	volume
natural	0.080	0.050	0.120	0.052	0.060	0.138
treated	0.047	0.037	0.104	0.058	0.050	0.108

content of Iron 0.2 × 10^{-6}; content of Cobalt 0.8 × 10^{-6}

UFP: Synthesized in lab of college of materials science and technology, Beijing Forestry University

2.2. Method

The UFP resin and nano-SiO_2, as mentioned above, were mixed together under ultrasonic dispersion for 10 min (UFP: nano-SiO_2 = 100:1, weight/weight). Using the pressurized impregnation machine designed by college of materials science and technology, Beijing Forestry University, the polar wood was impregnated with an aqueous solution of 20% UFP polymer from one-end. At the same time, the serum flowed out from the other end. And then the specimens were kept in the drying and pressing cabinet designed by college of materials science and technology, Beijing Forestry University in which process the polar wood was dried and pressed. The compression ratio was 30% and the moisture content was 12% in the end of the pressing and drying process.

2.3. Measurement

A drop of the nano-UFP composite was put on the copper grid of 300mesh and dried for 30 min at the temperate of 60 °C in the vacuum and then the nano-UFP composites were observed by a Hitachi-H-7500 Transmission Electron Microscopy. A JSM 5900 model scanning electron microscope (SEM) was used to observe the treated wood. Samples to be observed under the SEM were mounted on

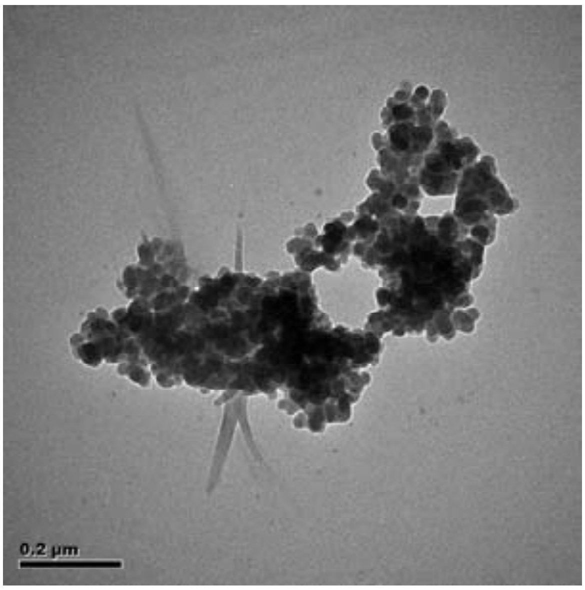

Fig. 1. Transmission electron micrographs of the sample without Ultrasonic.

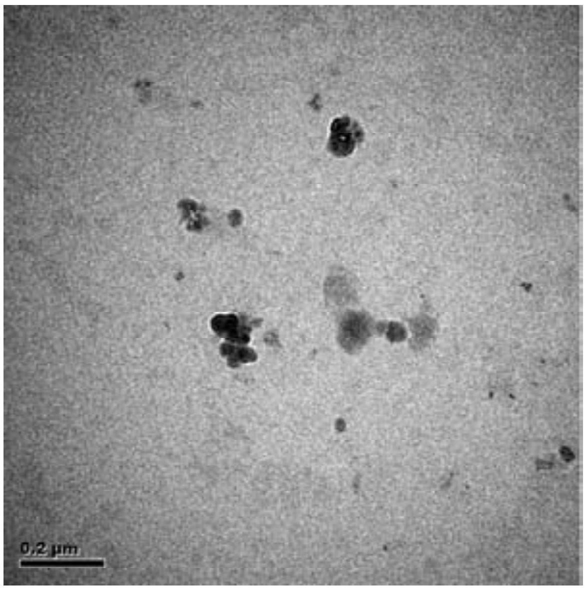

Fig. 2. Transmission electron micrographs of the sample with Ultrasonic.

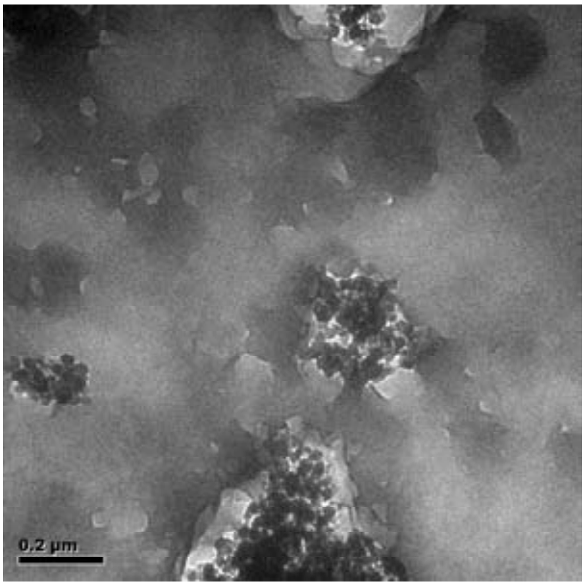

Fig. 3. Transmission electron micrographs of the composites with Ultrasonic.

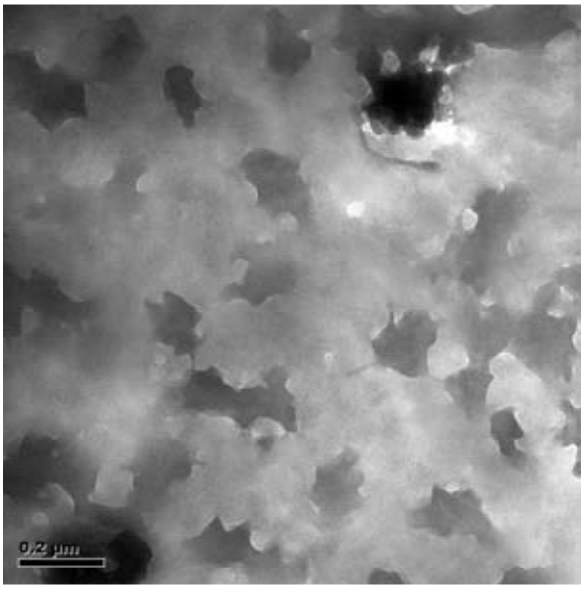

Fig. 4. Transmission electron micrographs of the composites without Ultrasonic.

conductive adhesive tape, sputter coated with gold, and observed in the SEM, using a voltage of 15 kV.

2.4. Mechanical properties

Ten specimens of untreated and treated were analyzed with a universal mechanical testing machine (MWW-50). Tests were carried out according to GB/T 1936.1 - 91 (Method of testing in bending strength of wood, China), GB/T 1935 - 91 (Method of testing in compressive strength parallel to grain of wood, China), and GB/T 1933 – 91 (Method for determination of the density of wood, China).

2.5. Water uptake

In order to measure the water absorption characteristics of untreated and treated wood, rectangular specimens were prepared having dimensions of 20 mm (*L*) x 20 mm (*T*) x 20 mm (*R*). The specimens were dried in an oven at 105 °C, cooled in a dessicator containing silica gel, and immediately weighed. The specimens were immersed in distilled water. After immersion, the excess water on the surface of the specimens was removed using a soft cloth. The weight of the specimens was then taken. The increase in the weight was calculated using the following equation, Water Uptake

$$(\%) = \frac{m - m_0}{m_0} \times 100,$$

where m is the final weight and m_0 is the original weight.

3. RESULT AND DISCUSSION

3.1. Property change of the wood

Table 1, Table 2 show the physical and mechanical properties of natural wood and treated wood. All of the mechanical properties of the treated wood were improved compared to the natural wood. The basic density of polar wood increased from 0.214 g/cm^3 to 0.268 g/cm^3 from the Table 1; and the dimensional stability was also improved as shown in Table 2.

3.2. Dispersion of SiO_2 by ultrasonic

Dispersion of SiO_2 by Ultrasonic in the UFP

Transmission electron micrographs (TEM) of dispersion of SiO_2 in UFP are shown in Fig. 1. As the nano-surface interaction energy intensity, nano-materials are easy to aggregate to formation of double or multiple structures. It showed the particle size of the aggregate structure was more than 500 n in the nano-UFP system. Transmission electron micrographs (TEM) of dispersion by Ultrasonic for 10 min of SiO_2 are shown in Fig 2. The multiple structures were dispersed after 10min ultrasonic dispersion. High surface energy of nano-particles are interaction with e-cloud of UFP which with high reactivity unsaturated molecular group, in that case the surface activity of nanoparticles is reduced and enhanced the stability of the nano-UFP system. Therefore, UFP can play a role in the nano-materials

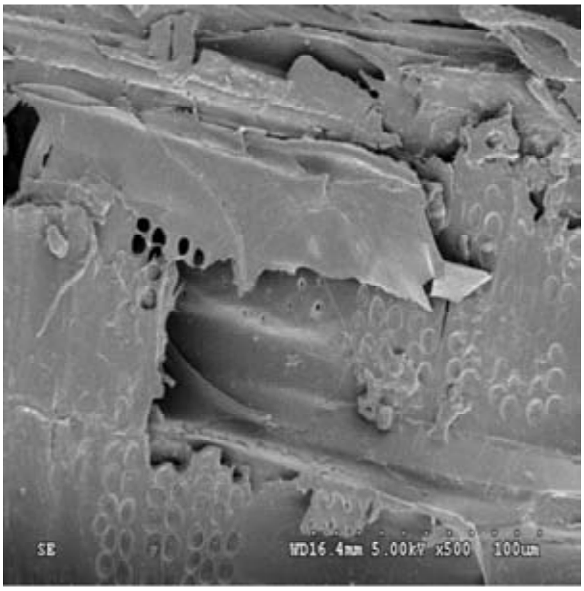

Fig. 5. Scanning electron micrographs of the wood.

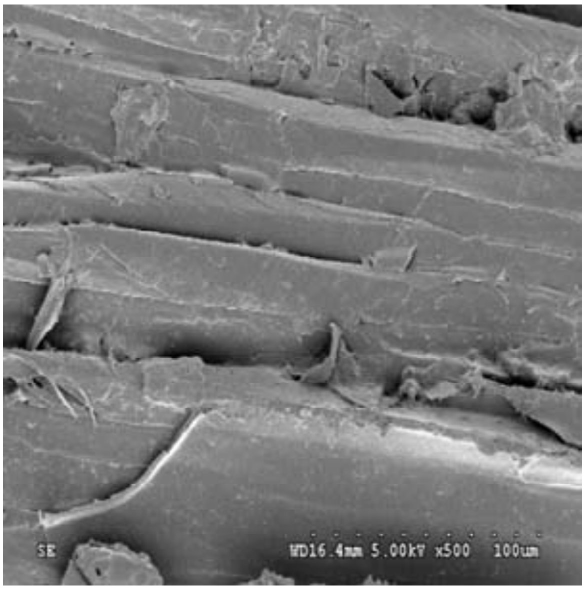

Fig. 6. Scanning electron micrographs of the wood.

dispersion and Contribute to the stability of the whole system.

Dispersion of SiO_2 by Ultrasonic in the composites

Fig. 3 shows the composites without ultrasonic dispersion. As can be seen, the nano-SiO_2 was not uniformly distributed in the system. Compared with the Fig. 4 which dispersion by ultrasonic for 10min, the nano-SiO_2 were dispersed uniformly in the system. The UFP and SiO_2 compounded together after the solidification process. Because of the Three-dimensional of nano-structures, the bonding strength of the composites increased after the solidification process. As the bonging strength of the nano-UFP composites increased, the physical properties of wood can be indirectly improved.

Effect of the properties by the composites

The deformation and metamorphism of wood are always caused by moisture and external moisture penetrates to the interior of the wood easily as the porosity of wood itself. Scanning electron micrographs(SEM) of treated wood shown in (Figs. 5 and 6) indicated that some porosity of the treated wood were filled with the nano-UFP composites, so that external moisture were hardly to penetrate to the interior of the wood and the bulking coefficient and water absorption decreased. In the meanwhile, cross-linking reaction between the resin and wood fiber also increased the strength of wood.

4. CONCLUSIONS

1. It is a feasible way to improve the bond strength of UFP by adding the nano-SiO_2.
2. Ultrasound is a simple and effective method of distributing the nano-materials. Nano-SiO_2 is distributed uniformly in the UFP system by ultrasonic for 10 min.
3. Nano-UFP composites can improve the mechanical properties of wood.

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