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Study on the Influence of Superconducting Carbon Black on the Mechanical and Antistatic Properties of Wood Powder /PVC Composites

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This paper aims to uncover the antistatic and mechanical properties of poplar powder / PVC composites added with different masses of Superconductor Carbon Black (SCB). The results show that, as the dosage of SCB increases, the tensile and flexural strengths of the composites gradually beef up. When m(SCB):m(PVC)=16:100, the above two reach the peaks, as compared to the case when m(SCB): m(PVC)=0:100, its tensile strength increases by 39.21%, the flexural strength by 21.94%. When the m(SCB):m(PVC) builds up to 12:100from 0:100, the surface resistance of the composite system presents a steady state transition; when m(SCB):m(PVC)>12:100, the surface resistance shows a downward trend. When m(SCB):m(PVC)=18:100, the composite can be made antistatic.

1. Introduction

Wood-plastic composite is produced in such a way that wood fiber and thermoplastic plastics as the base materials are added with processing agent, then molded. Wood fibers includes poplar powder, peanut shell, flax and other natural fibers; thermoplastic plastics that are a little more common include PE, PP, and PVC. Wood-plastic composites feature the recyclability, environmental friendliness, biodegradability and other excellent properties. In recent years, the ever-growing composites alike as a hotspot topic have aroused wide concern of people, especially PVC-based wood-plastic composite materials which, due to good molding processability, low cost, and woodiness feel, are finding wider and wider applications in many industries (Chen et al., 2008; Henson and Whelan, 1973; Czégény et al., 2015; Pulngern et al., 2016; Binici and Aksogan, 2016; Bai et al., 2011; Kositchaiyong et al., 2014; Chetanachan et al., 2001).

As everyone knows, plastics is a good electrical insulator. It is still a poor conductor of electricity if compounded with wood fiber, etc. Beyond that, it can also accumulate a mass of static charges which easily heap up to explode. For this reason, the applications of wood-plastic composites in some areas such as electronic component production workshops, machine rooms, and operating rooms are limited. Currently, the antistatic materials used in the domestic industry generally are made of molded and machined PVCs with conductive substances (Jiang and PascalKamdem, 2004). On this basis, this study adopts a melt blending process method, uses poplar powder, PVC as the primary materials to prepare an antistatic poplar powder/PVC composite material to which the SCB is then added, so as to further study how the antistatic and mechanical properties of the composite materials are subjected to change with different dosages of this additive. It is hoped that this study will provide the clues to the modification design for antistatic materials applied in electronic component production workshops, machine rooms, operating rooms and the like.

2. Experiment

2.1 Raw materials

PVC: LB110, LG chemistry;
Poplar powder: 40-60 meshes, Hebei Lingshou Guoming Minerals Processing Plant;
Rare earth stabilizers, Gaomi Kaixiang Chemical Co., Ltd;

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ACR, Shandong Gaomi Youqiang Auxiliaries Co., Ltd;
Polyethylene wax, Qingdao Sino Chemical Co., Ltd;
SCB: EC-600JD, Japan Lion Corporation;

2.2 Major equipment and instruments

Pendulum Impact Tester: ZBC7501-B, MTS Systems (China) Corporation;
Precision open mill: ZG-120, Dongguan Zhenggong Precision Testing Instrument Factory;
Box-type resistance furnace: SX2-2.5-10, Shangyu City, Zhejiang Province, Hu Nan Electric Oven Factory;
Plastic pulverizer: SWP/l60, Qingdao Jiaozhou Hongda Plastic Auxiliary Machinery Plant;
Flat vulcanizer: TP1400, Shanghai Wodi Technology Co., Ltd.;
Universal sampling machine: ZHY-W, Hebei Chengde Experimental Machine Plant;
High-speed mixer: SHR-10A, Zhangjiagang Spark Degradation Equipment Factory;
Electronic universal tester: CMT-4304, MTS Systems (China) Corporation;
SEM: JEOL-2010, JEOL Ltd.

2.3 Sample preparation and characterization

According to the recipe, each component is accurately weighed and placed in a high-speed mixer. After all components are fully mixed, the resultant sheet material is crushed in a pulverizer, put pulverized material in a mold and press it into a plate by a vulcanizer (Hot pressing conditions: upper and lower plate temperatures of 180oC, 10 min preheating and melting, 8 min hot pressing, 10 min cold pressing, 10 MPa pressure). In the end, a universal sampling machine cuts the pressed plate into standard strips as specified in size for the test; then, the strips are crimped into 100 mm×100 mm×6 mm by a hot press for the test on the surface resistivity (Zhang et al., 2016).

Impact strength is tested in accordance with GB/T 1843-2008; tensile strength in accordance with GB/T 1040.1-2006; flexural strength in accordance with GB/T9341-2008; SEM, the voltage is maintained at 20Kv, the sample surface is treated with gilding, and the surface resistivity is tested in accordance with GB1410-1989 (Zhang and Wei, 2016).

3. Results and discussion

3.1 Effect of SCB on tensile strength of poplar wood/PVC composites

As shown in Figure 1, within the laboratory area in this study, as the dosage of SCB increases, the tensile strength of the composite system gradually builds up. When m (superconducting carbon black): m(PVC)=16:100, the tensile strength of the composite reaches a maximum, and then lets up little by little as the dosage of SCB continues to increase.

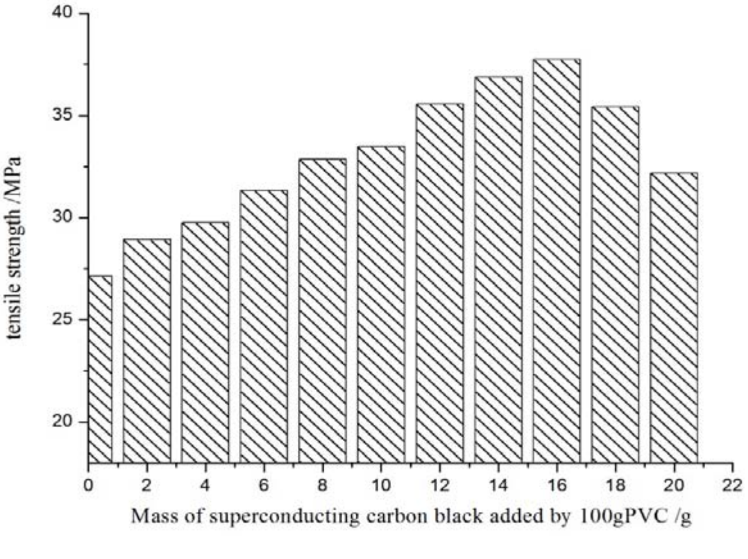


Figure 1: Effect of the dosage of SCB on tensile strength of composite

Compared to the case when m (SCB): m(PVC)=0:100, the tensile strength of composites in this case increases by 39.21% since the SCB particles have a certain surface activity. The reason why it has aneffect on the composite system may be have a direct bearing on the dispersion state of these particles and the interfacial interaction with the PVC substrate. When the dosage of SCB is less than m(SCB): m(PVC)=16:100, it will bind the macromolecules to form a crosslinked structure under the action of an adjuvant, so as to increase the tensile strength of the composite. As the dosage of SCB gradually grows, its dispersibility gets poor, and even agglomeration occurs, resulting in stress concentration. There is relative displacement occurred on the interface between the two, so that the stress cannot be effectively transmitted, the SCB fails to play its due strength potential, resulting in a gradual decrease in the tensile strength of the composite.

3.2 Effect of SCB on flexural strength of poplar powder / PVC composite

From Figure 2, we can learn that in the lab area involved in this study, as the dosage of SCB increases, the bending strength of the composite gradually beefs up. When m (SCB): m (PVC)=16:100, the flexural strength of the composite system reaches a maximum, and as the dosage of SCB keeps growing, the flexural strength of the composite material gradually decreases. As compared to the case when m (SCB):m(PVC)=0:100, the flexural strength of composites in the case of m (SCB): m(PVC)=16:100 increases by 21.94% since the crosslinked structure generated from mutual binding between superconductor CBs and macromolecule under the action of adjuvant improves the flexural strength of composites. In parallel, as the SCB builds up little by little, the dispersibility gets poor so that a certain degree of agglomeration occurs therein, stress transfer will be blocked, weakening the release of crosslinking strength. It is possible that the bending strength of the composite gradually becomes poor (Li et al., 2018).

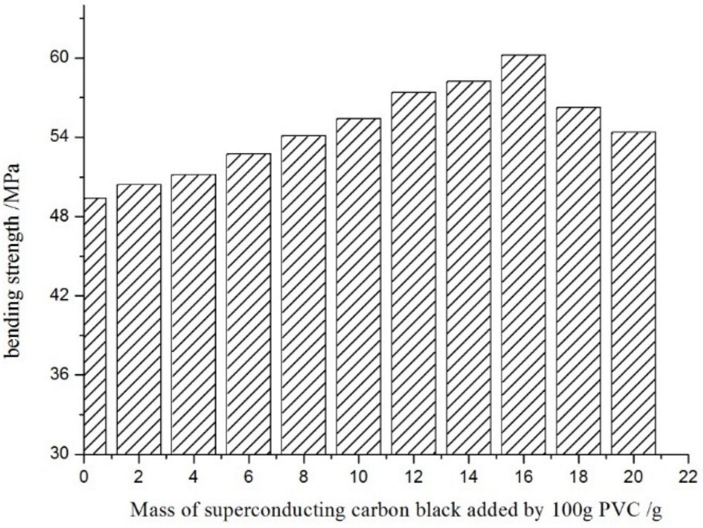


Figure 2: Effect of the dosage of SCB on the flexural strength of composite

3.3 Effect of SCB on the surface resistivity of poplar powder / PVC composite

As shown in Figure 3, the surface resistivities of the SCB/ poplar powder/PVC composites are subjected to decrease with the increase in the dosage of SCB, when m(SCB): m(PVC) gradually builds up to 12:100from 0 :100, the surface resistivity of the composite system presents a steady-state transition at a low rate. When m (SCB): m(polychloroethylene)>12:100, the surface resistivity of the composite system shows a downward trend; the percolations of SCB in the poplar powder/PVC composites are approximately m (SCB): m(PVC)=12:100. In general, when the surface resistivity of the composite is less than 1 $\times 10^{12}$ Ω, the surface static electricity of the composite material can fade away. When m (SCB): m(PVC)=18:100, the surface resistivity of the composite is 5.76 $\times 10^{8}$Ω, having an antistatic effect. When the dosage of SCB is lower than its percolation value, the distance between conductive particles of SCB is relatively large. For the transmission of electrons, it can only achieve this via ion and space charges, and no conductive path cannot be form. In this sense, the surface resistivity is less subjected to change with the dosage of SCBs. When its dosage increases to a certain threshold, the distance between adjacent conductive particles of SCB gets narrow. The particles can penetrate an intermediate polymer film to achieve conduction with an electron tunnel effect. At that time, its surface resistivity falls sharply.

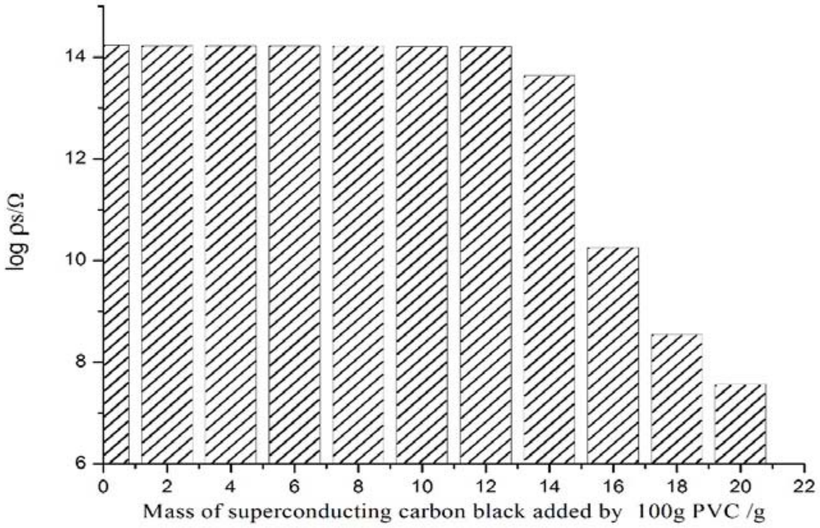
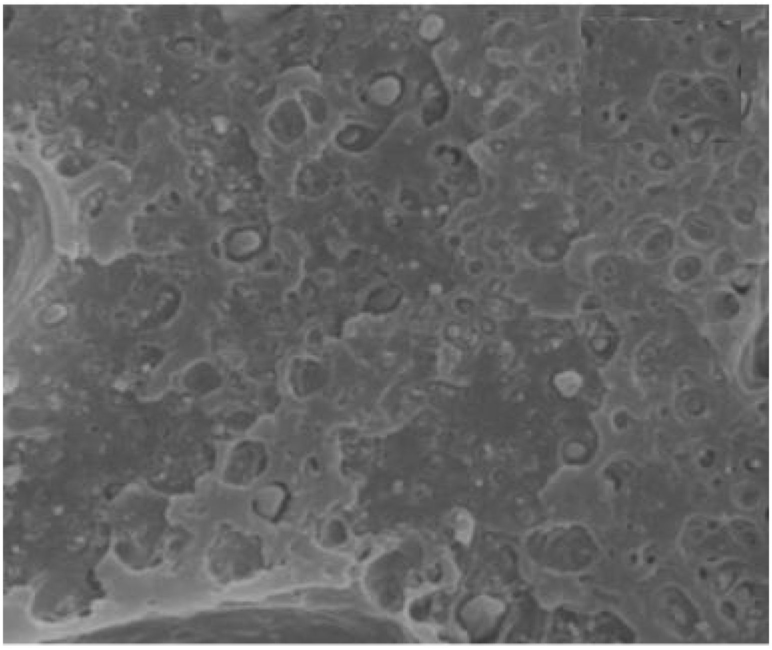


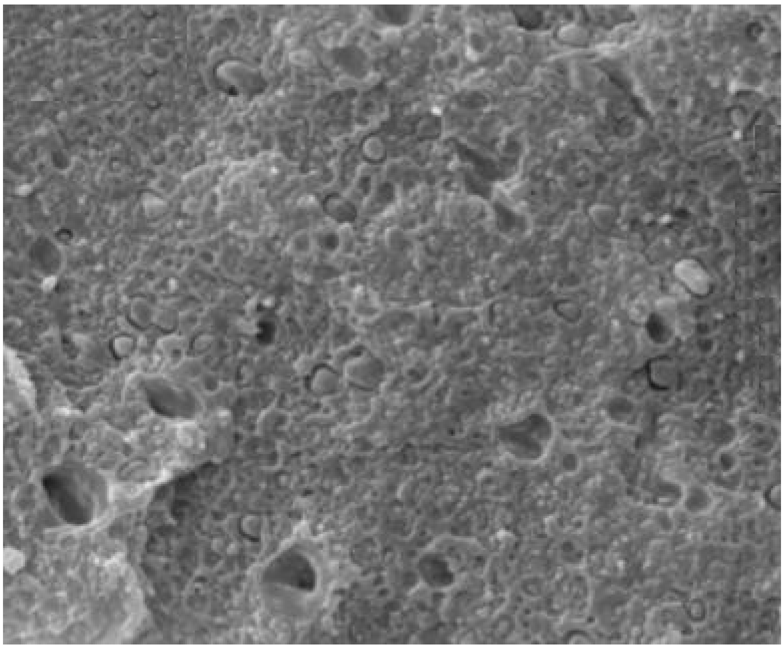
Figure 3: Effect of dosage of SCB on the surface resistivity of composite

3.4 Analysis of SEMs of SCB/poplar powder/PVC composite

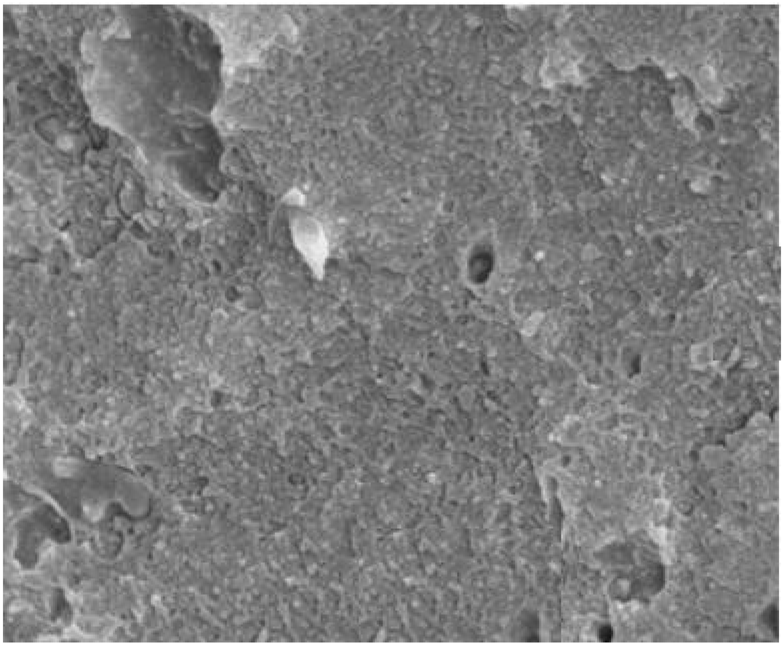
In Figure 4 below, a, b, and c are electron microscopes at 10,000 times magnification of the section of the composites when m (SCB): m (PVC)=2:100, 12:100, and 18:100, respectively. As compared to common carbon black, the SCBs exists in a bead-like heap that resembles a bunch of grapes. There is obvious drape in the interior, and the SCB particles is uneven in color on the surface, not a smooth solid sphere but a rough porous structure with high specific surface area and good constitutive property. Since the surface of SCB often contains a huge mass of polar groups with the polarity extremely like that of PVC resin. As a result, when m (SCB): m(PVC)=2:100, 12:100, 18:100, SCBs well disperse in PVC substrate more uniformly. When the dosage of SCBs is low, the degree of isolation between the SCB particles is relatively high. When the SCBs build up to a certain value, the interparticle isolationareas are balanced so that a conductive network structure is formed.



a. m(Superconducting carbon black):m(PVC)=2:100



b. m(Superconducting carbon black):m(PVC)=12:100



c. m(Superconducting carbon black):m(PVC)=18:100

Figure 4: Photograph of 10,000 x magnified section of composite at different dosages of SCB

4. Conclusions

(1) SCB can be well compatible with poplar powder/PVC composites after blending, fully exerting its own good physical and chemical properties, which significantly improves the mechanical properties of poplar wood/PVC composites.

(2) As the additive dosage of SCB increases, the tensile and bending strengths of the composites gradually beef up. When m(SCB):m(PVC)=16:100, the above two parameters reach the peaks. While increasing continuously, they gradually go the other way around. As compared to the case when m(SCB):m(PVC)=0:100, composite material tensile strength, in the above case, the tensile strength of composite increases by 39.21%, and the flexural strength by 21.94%.

(3) The surface resistivity of SCB/ poplar powder/PVC composites decreases with the increase of the dosage of SCB and presents steady state transition when the value of m(SCB):m(PVC) builds up from 0:100 to 12:100. When m(SCB):m(polychloroethylene)>12:100, the surface resistivity of the composite system shows a downward trend, percolation for SCB in poplar powder/PVC composites is approximately m(SCB):m(PVC)=12:100.

Acknowledgments

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