THE RESISTIVITY OF CARBON FIBERS / ABS RESIN COMPOSITES

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Introduction

Polymers filled with conductive particles and fibers have been widely used in electromagnetic interference (EMI) shielding, electrical static discharge (ESD), and other regions. In these combinations, the carbon fibers filled polymer composites are special interest due to their excellent mechanical properties and high conductivity as well as good durability to environmental conditions. However, a lot research is about the acceleration of material strength and few papers involve the influence of carbon fibers oxidation on the conductivity of the composites. Here, we investigate the influence of carbon fibers oxidation on the conductivity of the materials.

Experimental

After immerged into boiled concentrated nitric acid (68%) for 30 min and 60 min, polyacrylonitrile (PAN) based carbon fibers (T300) with volume resistivity of 1.8 × 10-3 W×cm are extracted in de-ionized water for 72 hours and dried at 120 °C under about 10 MPa vacuum for 24 hours. All carbon fibers (unoxidized and oxidized) are chopped into 6 mm. Then they are dispersed by mechanical stirring in ABS resin, which had been dissolved into paste in chloroform. The fiber filled paste then dried at room temperature. Finally, the composites were molded by hot pressing under 40 MPa at 150 °C for about 5 min. Relative to the volume of ABS resin, the volume fraction of carbon fibers in composites is 5 %, 10 %, 20 %, 30 % and 40 %. The resistivity of composites with dimensions of 40×9×1 mm was measured in the direction of perpendicular to the pressure by four-probe method. The electrodes are connected with samples with conductive silver paste.

Results and Discussion

The variation of the electrical resistivity as a function of fiber volume content is shown in Fig.1 for different oxidation time of carbon fibers. It can be seen from Fig.1 that there is very high resistivity at low fiber loading, which is less or more equal to the resistivity of pure polymer. When carbon fibers content increase from 1 vol % to 2 vol % the resistivity of composites sharply decreases. This denotes the conversion of composites from inductor to conductor and a critical volume concentration of carbon fibers between 1 vol % and 2 vol %. With increasing fiber fraction, the resistivity of composites tends to decrease more and more slowly. Moreover, the influence of oxidation on the resistivity of composites is also obvious in Fig.1. At fibers loading of 2 vol %, the resistivity of composites, filled with fibers oxidized for 30 min, is some 22 times higher than that of composites filled with unoxidized carbon fibers. When oxidation time increases to 60 min, the resistivity of composites goes up sharply to 1.32×10^4 Ω×cm, about 1500 times as high as the resistivity of composites loaded with unoxidized fillers. The oxidation layer on fiber surface could be the reason that the resistivity of composites increases. The oxidation layer on fibers surface increase the electron tunneling distance, causing the reduction of tunneling current and the raise of fibers contact resistance, which increase the

resistance of a conductive path. Especially, if the distance within which the electron tunneling can take place enlarges beyond a critical value, the tunneling current will disappear and the conductive path disconnects, which results in the reduction in the amount of conductive paths. The longer the oxidation time, the deeper the oxidation layers [1]. Therefore, the composite resistivity of composites decreases with the increase of oxidation time of carbon fibers.

The equation 1 shows the curve fitted results of samples whose volume fraction is larger than 2 %.

$\rho_c = A \times (\phi - \phi_c)^t$ (1)

where

ρ_c = composites resistivity ($\Omega \times cm$)

A = fitted constant

ϕ = volume fraction of reinforcement

ϕ_c=percolation threshold, which is determined by experiment and is considered as 1.5 % here

t = fitted constant

Table 2 shows the fitted constant A and t for different carbon fibers. Equation 1 is in agreement with the percolation thery in form [2]. A is considered as the resistivity of conductive reinforcement in the theory, but it can be seen from the table 2 that the fitted constant A is not equal to the resistivity of carbon fibers and it depends on the surface conditions of carbon fibers.

Conclusions

The resistivity of composites falls with increasing volume fraction of carbon fibers. The composites suddenly convert from inductor to conductor at critical fiber volume content between 1 % and 2 % for all composites. The surface treatment of carbon fibers increases the resistivity of composites and when filler volume concentration is larger than the critical fiber fraction, the relationship between composites resistivity and fibers fraction is in good agreement with the percolation theory.

References

[1] Jones C, Effects of Electrochemical and Plasma Treatments on Carbon Fibres Surfaces, Surface and Interface Analysis, 1993; 20: 357-367

[2] Weber M, Kamal M, Estimation of the Volume Resistivity of Electrically Conductive Composites, Polymer Composites, 1997; 18(6): 771-725

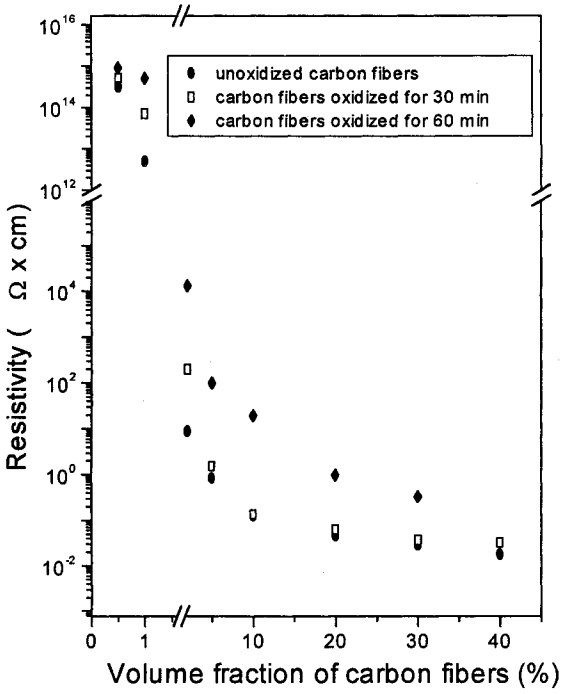

Fig.1 resistivity versus volume fraction of carbon fibers

Table 1 The fitted parameters of different carbon fibers

Samples	A	t
UCF-6	3.61	-1.46
OCF30	27.5	-2.04
OCF60	2.57×10^3	-2.61

UCF-6: samples filled with unoxidized carbon fibers which length is 6mm

OCF30: samples filled with carbon fibers oxidized for 30 min

OCF60: samples filled with carbon fibers oxidized for 60 min