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ARTICLE

Preparation and Electromagnetic Shielding Effectiveness of Metal Fibers/Polymer Composite

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Abstract: Composite containing metal fibers are applied widely in the field of electromagnetic interference for its excellent electromagnetic shielding effectiveness (EMSE). In the present study, two kinds of composite, 316L fibers/epoxy resin composite and Cu fibers/epoxy resin composite, were achieved using infiltration and mechanical stirring, respectively, The EMSE of the composite was assessed. The results show that the EMSE of 316L fibers/epoxy resin composite increases gradually with the aspect ratio of fibers increasing from 200 to 1000, while it decreases quickly with that from 1000 to 3000. Furthermore, the EMSE of the composite increases gradually as the content of fibers increases from 10 wt% to 25 wt%. Additionally, for the 316L fibers/epoxy resin composite, the optimum parameters of 316L fibers are the diameter of 8 μm, the content of 25wt% and the aspect ratio of 1000, and the highest EMSE of the composite is about –78dB. For the Cu fibers/epoxy resin composite, the optimum parameters of Cu fibers are the diameter of 120 μm and the content of 2.0 wt%.

Key words: composite; electromagnetic interference (EMI); metal fibers; epoxy resin; electromagnetic shielding effectiveness (EMSE)

In recent years, electric devices and communication instruments have been widely used, but they generate severe electromagnetic radiation, resulting in harmful effects on highly sensitive precision electronic equipment as well as the living environment for human beings[1-3]. Now, electromagnetic shielding is an effective method resolving electromagnetic interference (EMI) and electromagnetic pollution[4], and great efforts have been made for the development of high performance electromagnetic shielding material[5]. The ideal electromagnetic shielding material is expected to absorb electromagnetic waves efficiently which is light, thin, and functional, and can be applied in a wide frequency range[6].

Up to date, the shells of phones, computers, refrigerators, microwave ovens, television, and air-conditioners are made of polymers, but the polymers can't shield off electromagnetic radiation [4]. So, it is very imperative to prepare novel electromagnetic shielding polymers. However, polymers at present are filled with conductive fillers generating electromagnetic shielding effectiveness. Conductive fillers include mainly carbon-based fillers, such as carbon black [7], carbon nanotubes[8-11], carbon nanofibers[12], mesoporous carbon[13], pyrolytic carbon (PyC)[14], graphene[15,16], carbon fibers and nickel-coated carbon fibers[17], metal powders [18], stainless steel fibers[3,4,19], copper wires[20]. But, for the polymer composite containing carbon-based fillers or metal powders, individual conductive fillers are randomly distributed inside the polymer matrix and are surrounded by the molecular chains of polymer, and the electrical conductivity of the material strongly depends on electron percolation between the separated filler particles. Therefore, a high content and good dispersion of carbon-based fillers or metal powders are usually required to make a conductive interconnected network in order to obtain excellent electromagnetic shielding effectiveness (EMSE)[5]. In addition, metal fibers would be used widely in the EMI field due to their excellent conductivity, corrosion resistance, antioxidation and high strength. However, the EMSE of the polymer composite containing metal fibers is low[3,19,21], and the effects of the fibrous characterization on the EMSE have not been investigated so far.

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In the present study, two kinds of composite mixed by epoxy resin and stainless steel fibers or copper fibers were prepared by immersion and mechanical stirring processes, respectively. Through varying the content of metal fibers, the aspect ratio of metal fibers, the diameter of metal fibers, the composite with different structures was obtained. Subsequently, the EMSE of the two kinds of composite in the frequency range of 2.25~2.65 GHz was analyzed and the shielding mechanism was also studied.

1 Experiment

In the study, two kinds of metal fibers, stainless steel fibers (316L) with the diameters of 8, 20, 28, 50, 100, 200 μm and copper ones with the diameters of 80, 100, 120, 160 μm, were used as raw materials. Another two kinds of raw materials were the epoxy resin and the ethylenediamine.

The composite for resolving EMI was manufactured by mixing the metal fibers, the epoxy resin and the ethylenediamine and was described in detail as follows.

(1) Composite containing 316L fibers

Firstly, the 316L fibers were cut into short fibers with different aspect ratios, including 200, 1000, 2000, 3000, and then the fiber felt was prepared by an air-laid process. The fiber felt was sintered at 1250 °C for 2 h to form porous metal fiber materials as shown in Fig.1. Secondly, the epoxy resin and the ethylenediamine were mixed together, and then the mixture was immersed into the porous metal fiber materials and solidified to form the composite[22]. Then, the final dimensions of the composite were 150 mm×150 mm×5 mm (length×width ×height), as shown in Fig.2a. In the paper, the process was defined as the first process.

(2) Composite containing Cu fibers

Firstly, the Cu fibers were cut into short fibers with the aspect ratio of 200, and then the short fibers and the epoxy resin was mixed together using the ethylenediamine as a solidified agent by the mechanical stirring method. Secondly, the mixture was poured into a mold and solidified to form another composite, as shown in Fig.2b. Then, the final dimension of the composite was *Φ*200 mm×5 mm. In the paper, the process was regarded as the second process.

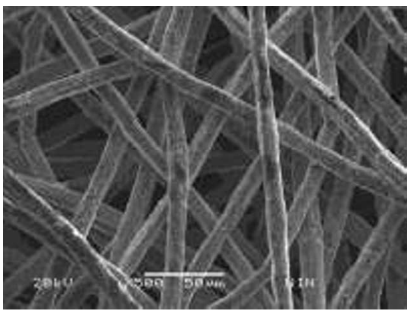

Fig.1 SEM image of porous metal fibers materials with the diameter of 8 μm

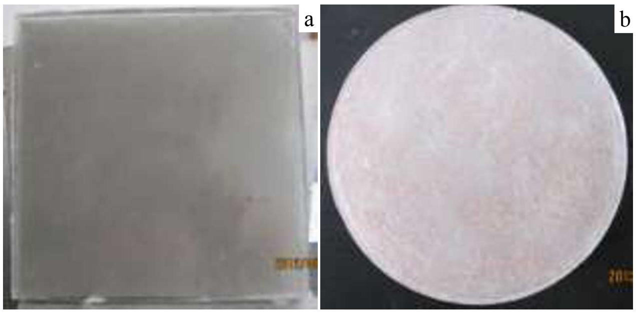

Fig.2 Images of composites made by two processes: (a) the first process and (b) the second process

Following the corresponding national standard of China (GJB 5313-2004), the EMSE of two kinds of composite was tested by a coaxial-waveguide network analyzer.

2 Results and Discussion

2.1 Effect of the aspect ratio of metal fibers on EMSE

When the content of the 316L fibers is 25 wt%, the EMSE of the specimen made by the first process is affected by the aspect ratio of the fibers and the tested results are shown in Fig.3. It can be seen that the EMSE increases gradually with the aspect ratio increasing from 200 to 1000, while it decreases quickly with that from 1000 to 3000. Furthermore, the EMSE is the highest for the aspect ratio of 1000, about –72~ –79 dB, while it is the lowest for that of 3000, about –58 ~ –65 dB. When the aspect ratio of the fibers is 1000, the metal fibers can form an effective electric network in the polymer matrix [19], leading to higher EMSE. However, when the aspect ratio is higher than 1000, the amount of the fibers decreases gradually per unit area as the aspect ratio increases, decreasing in the amount of crunode. As a result, the conductivity of the composite decreases and thus the EMSE decreases. Therefore, for the composite manufactured by the first process, the optimum aspect ratio of the 316L fibers is 1000.

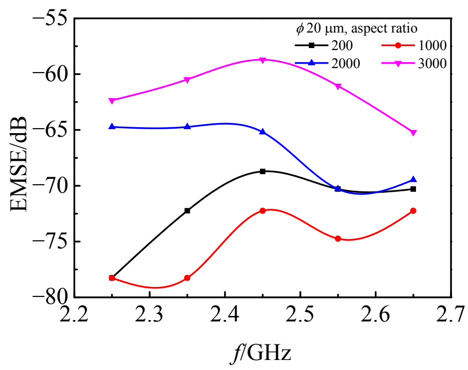

Fig.3 Effect of the aspect ratio of 316L fibers on the EMSE of the samples made by the first process at the same content of the fibers