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Electromagnetic interference shielding properties of carbonyl iron powder-carbon fiber felt/epoxy resin composites with different layer angle

Tao Hu*, Jun Wang, Julin Wang, Runhua Chen

School of material science and engineering, Wuhan University of Technology, Luoshi Road No. 122, 430070 Wuhan, China

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ABSTRACT

Carbonyl iron powder-carbon fiber felt/epoxy resin composites with different layer angles were prepared to evaluate electromagnetic interference shielding properties in the *X* band. The average shielding effectiveness decreased from 53.9 dB to 8.6 dB with increase in the layer angle from 1.98° to 84.6°. The average power absorption coefficient increased first and then decreased, and had a maximum value at about 45°. The volume conductivity and the average dielectric constant decreased with increase in layer angle. It is found that the composites shield by absorption and reflection and the ratio depends on layer angle.

1. Introduction

Electromagnetic interference (EMI) shielding materials are widely used in electric, aerospace and military applications because of the increasing electromagnetic interference problems [1–3]. Shielding effectiveness (SE) can evaluate the relative intensity between power of incident wave (P_I) and power of transmitted wave (P_T) after transmitting through shields and can be calculated as $SE = 10\log(P_I/P_T)$. Metal-based shields and conductive polymer-matrix composites are two main kinds of EMI shields with high SE, and conductive polymer-matrix composites can overcome the shortcomings (high cost in raw material and processing, prone to corrosion, and heavy weight) of metal-based shields [4–6]. Multilayer composites with radio wave absorber between layers are attracting great attention due to their high shielding effectiveness (SE) and large absorption loss (AL) [7–9]. The function layers are usually parallel to sample surface and supposed perpendicular to incident waves. However, if the function layers have included angles with the sample surface, the electric parameters and the EMI shielding properties will change remarkably, which needs further study.

Carbon fiber felts (CFFs) with plane network structure are good shielding materials for good electric conductivity and good mechanical properties [10–12]. Carbonyl iron powders (CIPs) are good radio wave absorbers for prominent magnetic loss [13,14]. In this paper, CIP-CFF/epoxy resin (EP) composites were prepared and made into samples with different layer angle to evaluate EMI shielding applications in the *X* band. Fig. 1(a) shows the angle between functional layers and sample surface which is named layer angle (θ). Since shielding properties and electric parameters are also affected by frequency, the tested values from 8.2 GHz to 12.4 GHz were calculated into average values to study the independent effect of layer angle.

2. Experimental

The CIP-CFF/EP composites were prepared by vacuum bag molding. The mass ratio of the EP (CYD-128, epoxide group content: 0.0051 mol/g, Baling Petrochemical co., LTD, Hunan, China), the modified amine curing agent (active hydrogen content: 0.0213 mol/g, prepared by our laboratory) and CIP (diameter: 2.5∼3.5 μm, mass content ≥99.5%, Xingrongyuan Technology co., LTD, Beijing, China) was 100:24:75. The CFFs (fiber length: 6 mm, fiber diameter: 6∼7 μm, areal density: 28 g/m^2, Aoda Composite co., LTD, Shandong, China) were infiltrated by the mixed resin system to prepare prepregs. The composites were cured at the room temperature (about 25 °C) at 0.1 MPa for 24 h and post cured at 80 °C for 4 h. The composites were cut into samples at the designed size ($22.86 \times 10.16 \times 4.00 \pm 0.02$ mm) to fit the wave guild for the *X* band with the designed layer angle. The sample with layer angle (θ) was shown in Fig. 1(a). The layer angle of each sample was measured through image analysis on the side [the *X*–*Z* plane in Fig. 1(a)] of the sample. Fig. 1(b) shows the measurement of layer angle. The layer angle between fiber layers

* Corresponding author. Tel.: +86 15827640909.
E-mail address: htgfrp@163.com (T. Hu).

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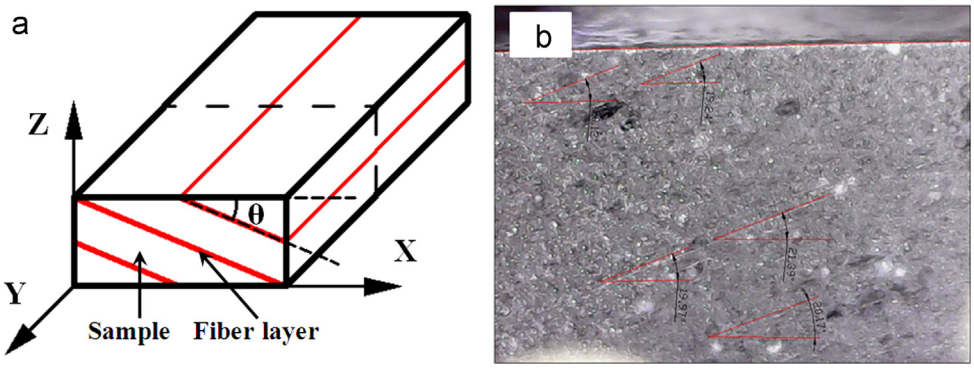

Fig. 1. (a) sample with layer angle (θ), and (b) measurement of layer angle through image analysis.

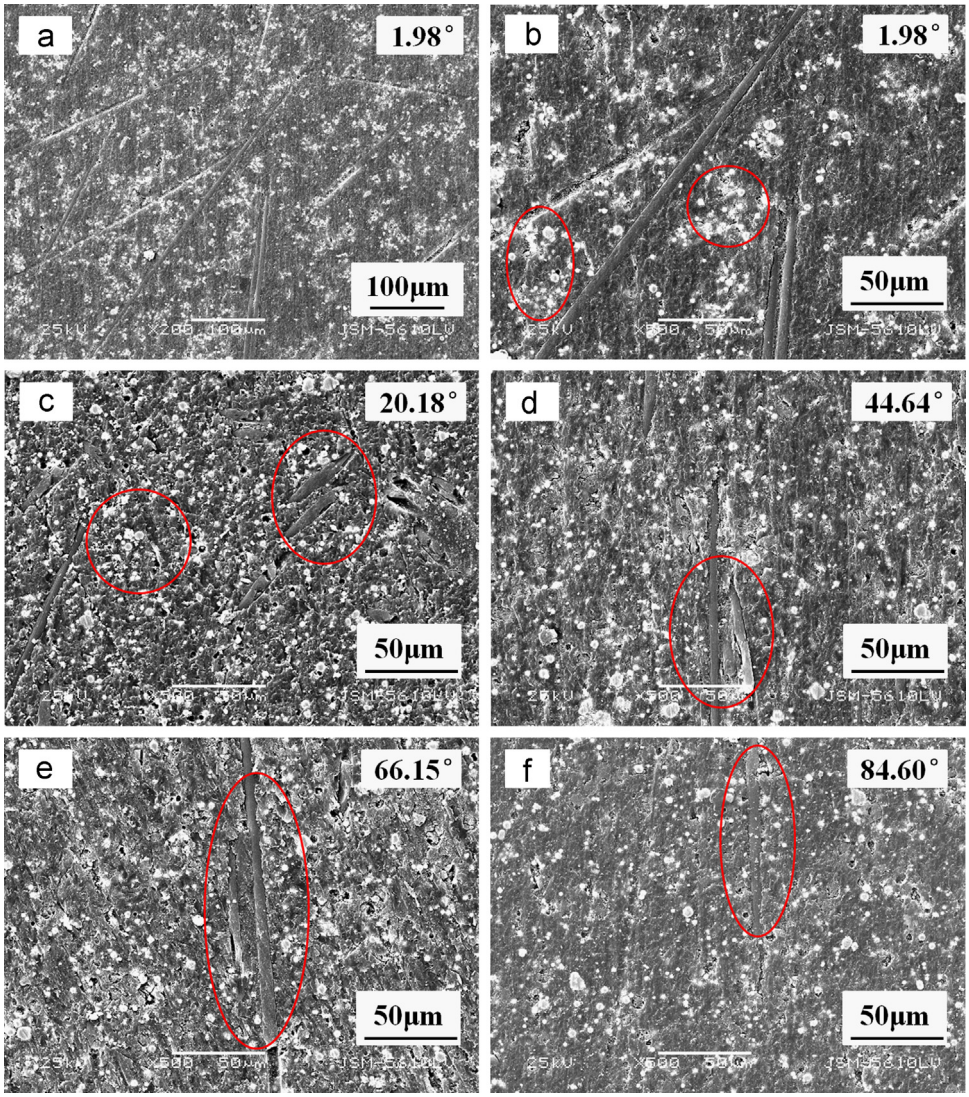

Fig. 2. SEM images of CIP-CFF/EP composites with different layer angle.

and sample surface were measured for 5 times and got the average value. The SEM (JSM-5610LV, Japan Electronics Ltd., Japan) analysis was on the surface [the *X*–*Y* plane in Fig. 1(a)] of the sample. The electrical conductivity was measured by the 4 probe resistance tester (RTS-8, 4 Probes Tech. Ltd, Guangzhou, China). The test direction was parallel to the *X* axis on the *X*–*Y* plane showed in Fig. 1(a). The shielding effectiveness, dielectric constant, and magnetic permeability were calculated by the scattering parameters (S_{11}, S_{12}, S_{21} and S_{22}) measured through the vector network analyzer (Agilent N5247A) and the wave guides for the *X* band whose inner dimensions were 22.86 mm × 10.16 mm.

3. Results and discussions

Fig. 2 shows the distribution of CIPs and carbon fibers in samples with different layer angle. (a) shows that carbon fiber network can be found in the sample surface with the layer angle