IOP Conf. Series: Materials Science and Engineering **292** (2018) 012093 doi:10.1088/1757-899X/292/1/012093

Preparation and characterization of flexibility and lightweight CF-RGO composites

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Abstract. Absorbing materials are developed with the concept of "thin, light, wide and strong", and various methods and materials have been attempted to satisfy the demand. In this work, the in situ growth method were conducted to grow reduced graphene (RGO) into carbon fiber (CF) to prepare CF-RGO composites. Moreover, the phase, microstructure and electromagnetic performance of the flexibility and lightweight composites were characterized. Consequently, the XRD and SEM results indicate the RGO is well grown on the surface of CF. The microwave absorption performance of the as-prepared samples were calculated, and the results show that the effective absorption band of the composites move towards low frequency once the RGO were introduced into the CF.

1. Introduction

Wave-absorbing materials that have been widely applied in electromagnetic controlling and communication technology are considerably explored in the recent years [1-5]. Among the pursued nanoscale fillers, carbon nanomaterials, one-dimensional (1D) carbon nanotubes (CNTs) and two dimensional (2D) graphene nanosheets (GNs) in particular, have received great attention coupled with extensive development effort due to their exclusive chemical structures and tunable electrical properties [6-9]. In the past decades, CNT- and GN-based nano-fillers with low percolation threshold and appropriated electrical loss have already demonstrated dramatically enhanced microwave absorption performance in the pursed composites [10-14]. Among various strategies, combination of electrical loss and magnetic loss has shown great potential owing to the excellent flexibility in manipulating complex permittivity and permeability, and thus has been extensively explored. In the early examples, Che and coworkers have encapsulated iron into the tubular space of the multiwalled CNTs (MWCNTs). The as-prepared Fe@MWCNT heterostructures (filler loading of 20 wt%) were further fabricated into epoxy-based composites and exhibited a broad effective microwave absorption region with the peak absorption up to 25 dB in the span of 2-18 GHz [15-17].

With presence of wave-absorbing materials, the electromagnetic wave energy would be weakened via absorption patterns and reflection patterns. Reduced graphene oxides (RGOs) have drawn significant attention since it posssess large specific surface area, high young's modulus, high thermal conductivity, high optical transmittance and good electrical conductivity. In this work, the RGO were in situ created into the CF network by electrochemical deposition technology. similar explorative studied have also been attempted in the fabrication of graphene-heterostructure filler with combined electrical loss/magnetic loss [18-22]. For instance, Chen et al. have recently converted graphene oxide (GO) and Ni precursors into reduced graphene oxide (RGO)/Ni heterostructures. The composites incorporated with such heterostructures at filler loading of 60 wt% possessed a maximum reflection

loss ~17 dB. In the report by Sun et al, concentration of Fe_3O_4 was tuned in the process of converting GO into RGO, and the wax-based composites with Fe3O4/RGO heterostructures exhibited a reflection loss up to 27 dB at 40 wt% filler loading. Likewise, Fu et al. synthesized $NiFe_2O_4$ nanorods on the RGO and fabricated the heterostructures into wax-based composites, showing the best absorption performance up to 29.2 dB at 60 wt% filler loading [23].

In the preparation, graphene oxide (GO) aqueous solution was prepared by modified hummers method. And the in situ growth method were conducted to grow reduced graphene (RGO) into carbon fiber (CF) to prepare CF-RGO composites.

2. Results and discussion

X-Ray diffraction (XRD) spectras of the as-prepared composite textiles are shown in figure 1. The structure and morphology of the samples were investigated by X-ray diffraction (XRD, Rigaku Ultima IV, Cu-Ka) in the range of 10°~90° with a scan speed of 3 s and a step size of 0.02° in 2θ. As exhibited in the spectrum of the CF, there is a broad peak around 21~25°, indicating the existence of the carbon of amorphous CF. Meanwhile, there is a distinct peak around 25~26° in the spectrum of the CF-RGO, referring to the growth of the RGO in the CF. the results indicate the RGO were successfully introduced into CF.

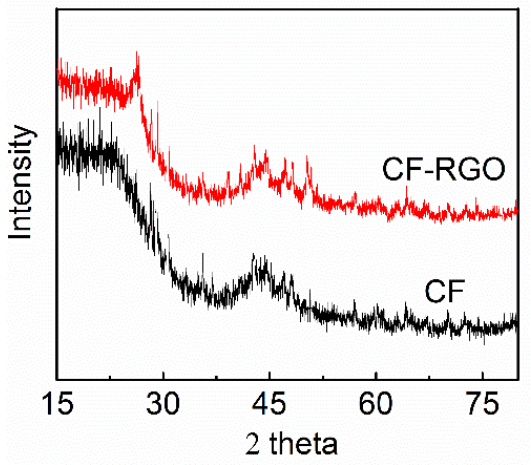

Figure 1. XRD spectras of the as-prepared samples.

FESEM images of CF textile and CF-RGO textile are demonstrated in figure 2. As is shown in figure 2a, the CF textile possesses a smooth surface. Figure 2b indicates that the RGO layers are successfully deposited on the surface of the CF, and the separated CF wire are bonded together by the graphene nanosheets. Consequently, as is, the conductive network were gained.

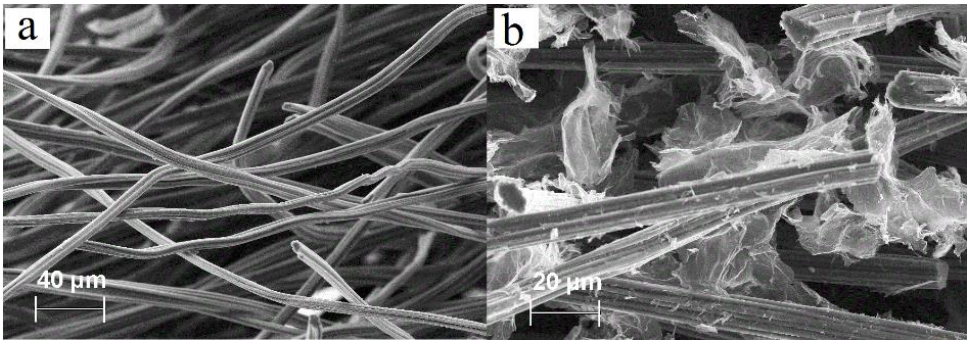

Figure 2. SEM images of the neat CF (a) and CF-RGO (b).

Coaxial method was conducted to measure electromagnetic properties and dielectric properties of the wax-based composites in the range of 2~18 GHz. To explore the influence of the filler loading in the wax-based composites, the samples with different proportions (10%, 15%, 20%, and 30%) have been prepared. Consequently, the complex permittivity of the samples (figure 3) are given as marked in the related figures. According to figure 3, the real permittivity of CF-RGO is much higher than that of CF, indicating the growth of RGO in the CF would obviously improve the real permittivity of the composites. Such increase is associated with the introduction of RGO interfaces.

The reflection loss (R_L), which could be a direct reflection of the ability of the microwave absorption performance of the absorber, is achieved by the relation

$$R_L = 20\log(|Z_{in}-1|/|Z_{in}+1|). \quad (1)$$

Here the Z_{in} refers to the input impedance of the absorption layer, which could be achieved by

$$Z_{in} = (\mu_r/\varepsilon_r)^{1/2}\tanh[j2\pi fd(\mu_r\varepsilon_r)^{1/2}/c]. \quad (2)$$

where, μ_r and ε_r is the complex permittivity and permeability of the samples, respectively. f is frequency. d is thickness of the absorber, and c is the light velocity.

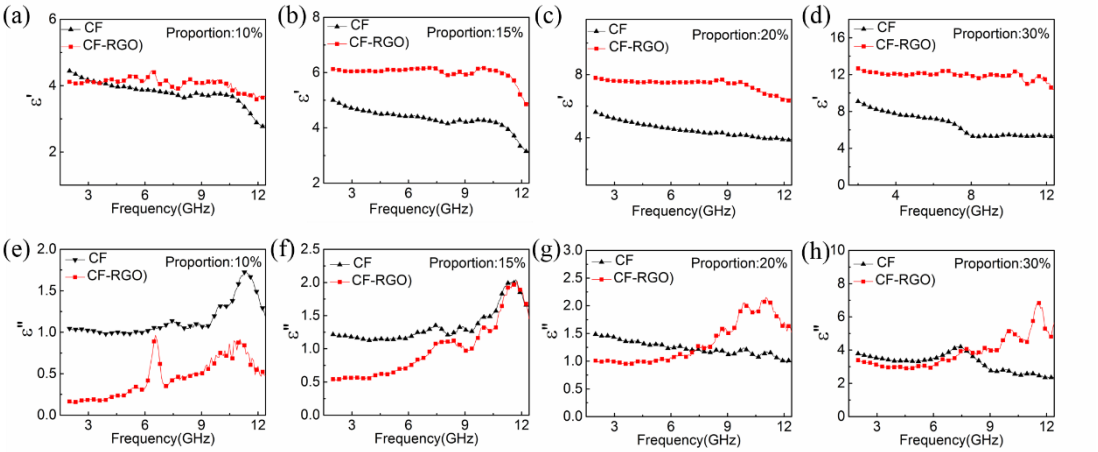

Figure 3. Complex permittivity of the wax-based composites embedded with the samples in different proportion.

Figure 4 show the microwave absorption performance of the as-prepared samples at different thickness. It is obvious that the three composites all possess best microwave absorbing abilities at the proportion of 30%. And the maximum reflection loss values of CF and CF-RGO are up to 36.62 and 27.78 dB, respectively. It is obvious that the CF-RGO composites possess better absorbing performance than that of CF composites at lower frequency. The results suggest that the effective microwave absorption band would move towards low frequency with the introduce of two-dimensional RGO interfaces, which might be a potential method to enlarge the microwave absorption band towards low frequency.

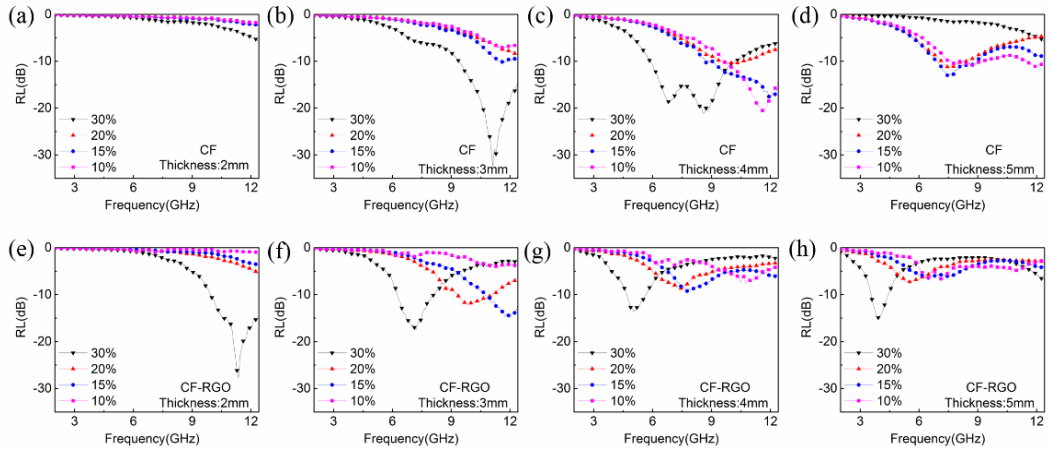

Figure 4. Microwave absorption performance of the as-prepared samples.

3. Conclusions

In summary, in-situ synthesis method was conducted to introduce the RGO into CF composite textiles. Consequently, the lightweight and flexible CF-RGO composite textiles were fabricated. Meanwhile, the dielectric properties, magnetic properties and microwave absorption performance of the composites were studied, and the effects of the textiles and the filler loading of the composites were discussed. Therefore, due to the exceptional advantages of the CF-RGO composite textiles, the composites could serve as the potential absorbing materials to broaden the wave absorption band towards low frequency.

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