A FEASIBILITY STUDY ON MICROWAVE FABRICATION OF PP/CNT COMPOSITE

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Introduction

Microwave processing has been applied for heating and sintering of a variety of materials [1]. The microwave sintering technique can be generally categorized into two groups: direct sintering in which the fabricating materials themselves act as susceptors, and the hybrid sintering in which the materials are fully or partially heated by external susceptors. The primary advantage of microwave processing as compared to conventional techniques is that microwaves are able to couple energy directly to the materials [2]. Fabrication of ceramic and polymeric materials using microwave has the potential to improve the quality and reduce the manufacturing costs.

Recently, techniques for fabricating carbon nanotubes (CNTs) reinforced polypropylene (PP) have attracted great research interests [3-5]. PP is transparent to microwave. To process such polymeric material, a dielectric material should be incorporated into the polymer to absorb the energy. In this study, CNTs were used as a microwave susceptor material to assist sintering of PP. Moreover, CNTs could act as a reinforcing material.

Materials and Method

PP powders (50-80 μm) were obtained from Goonvean Fibres (Devon, UK) with the melting point in the range of 150-160 ^{o}C. Single-walled CNTs (< 5 nm in diameter and 5-15 μm in length) were purchased from Shenzhen Nanoport (Shenzhen, China), and treated with 38% hydrochloric acid for purification. For each sample, the PP powders and the acid-treated CNTs were weighed in a ratio of 100:1. The powders were ultrasonicated in distilled water separately for 30 mins, followed by mixing with mechanical stirring until a homogenous mixture was obtained. Then, the mixture was dried and compressed at a peak load of 40 kN to form a green compact of 20 mm in diameter and 3.7 mm in thickness. Each green compact obtained was placed in a ceramic crucible and put into a microwave oven (1kW, 2.45 GHz magnetron). The sample was sintered with full power and then cooled down to room temperature under natural convection. The time needed for sintering of the PP/CNT samples was recorded.

The surface morphologies of the sintered PP/CNT samples were polished and then examined by an optical microscope (Leica DM4000 M). A dynamic mechanical analysis (DMA, Perkin Elmer Diamond DMA Lab System) was carried out under nitrogen atmosphere in the tensile mode with oscillation amplitude of 10 μm and at frequencies of 0.1, 1 and 10 Hz, respectively.

Results and Discussion

PP/CNT composite was successfully sintered using the proposed method. The time recorded for sintering was 150 s. Fig. 1 shows a photo of the sintered PP/CNT sample. The optical micrographs of the PP/CNT composite are shown in Fig. 2. In Fig. 2 (a), a few voids (about several ten microns) are observed, indicating low porosity of the PP/CNT composite.

Fig. 1. Photograph of the sintered PP/CNT composite (20 mm in diameter and 3.7 mm in thickness).

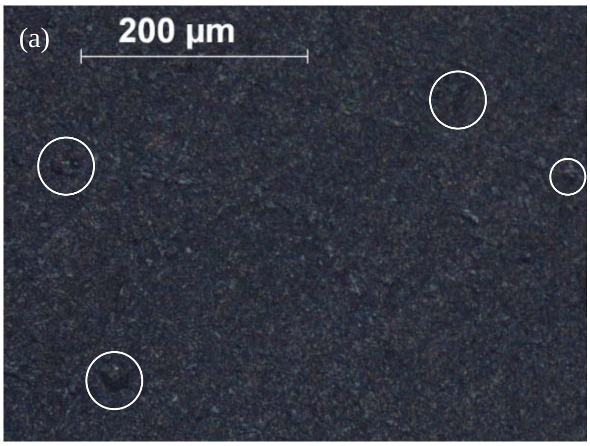

Fig. 2 (a). Optical micrograph of the PP/CNT composite in low magnification, ×100. Voids (white circles) are observed inside the sample.

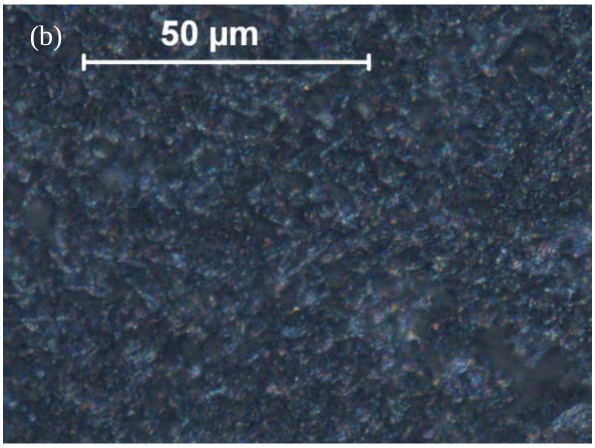

Fig. 2 (b). Optical micrograph of the PP/CNT composite in high magnification, ×500.

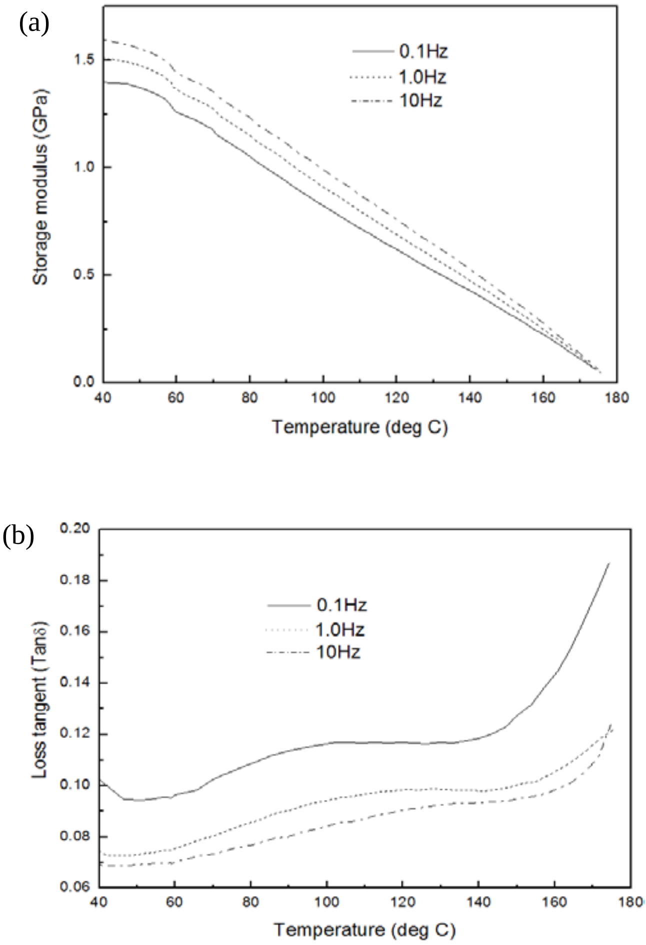

Fig. 3. DMA thermograms of the PP/CNT composites at various frequencies: (a) storage modulus and (b) loss tangent.

The DMA thermograms of (a) storage modulus and (b) loss tangent at frequencies from 0.1 Hz to 10 Hz are shown in Fig. 3. It can be seen from Fig. 3(a) that the storage modulus decreases with an increase in temperature. The storage modulus was found to be lower when compared with that of the MWCNT/PP composite prepared by melt mixing technique [6]. The variation of the loss tangent, an indication of the ratio of the energy dissipated to the energy stored during a cycle, is shown in Fig. 3(b). For all the frequencies, the loss tangent values are generally stably low and change gently in the range between 80 and 140 ^{o}C, suggesting a stable low damping capability and high dimensional stability. The loss tangent rose sharply when the samples melted at around 160 ^{o}C. Moreover, a higher frequency induces a more elastic-like behavior in terms of a higher storage modulus and a lower loss tangent.

Conclusion

PP/CNT composite was successfully fabricated using the microwave sintering technique. The microwave sintering of microwave transparent PP has been made possible with an addition of CNT as a microwave susceptor.

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