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Energy Harvesting Capability of PVDF/rGO Composite

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Abstract

Reduced graphene oxide (rGO) was added to PVDF (Poly (vinylidene fluoride)) to prepare high-performance piezoelectric polymer composite films. The open circuit voltage and power harvested measurements indicated that the rGO improved the piezoelectricity significantly. To uncover the mechanism, we also performed XRD (X-ray Diffraction) to analysis the crystal structure of the composite and confirmed the efficient phase transformation induced by rGO. The present work shows PVDF/rGO as a promising material for future power devices.

1. Introduction

Energy harvested devices converting energy from environment attracted much attention in recent decades. Among them, piezoelectric material based devices possess many advantages. Compared to the most commonly used PZT (Lead Zirconate Titanate)[1], in spite of PVDF's (Poly (vinylidene fluoride)) relatively lower electromechanical coupling factor, it is not toxic, recyclable, flexible, high resistant ability to halogen, acid and fatigue[2,3], making it a promising material for future power devices.

To realize the PVDF based power devices, the improvement of piezoelectricity of the polymer remains a challenge. Addition of nanofillers such as carbon nanotube (CNT) or carbon nanofiller (CNF) is an available path.

For instance, Levi *et al.* blended CNT with PVDF and its copolymers to improve the piezoelectricity [4]. It is found that the morphological change leads to the enhancement. The X-ray diffraction (XRD) and differential scanning calorimetry (DSC) analysis were carried out to confirm this argument. PVDF/VGCF (vapor grown carbon fiber) composite was prepared by solution casting method by Costa *et al.*[5] Their study indicated that the nanofiller affected the phase transformation from α-phase to β-phase. It was also observed that the β-phase showed typical ionic conduction behaviour.

However, the research about improvement of the energy capability by addition of nanofiller is rarely reported.

2. Materials and Experiments

Materials

We prepared rGO used a modified Hummers method from natural flake graphite powder [6]. The poly (vinylidene fluoride-co-hexafluoropro-pylene) (PVDF-HFP) and Dimethylformide (DMF) were commercially obtained from Arkema Inc. and Wako Pure Chemical Industries Ltd., respectively.

The piezoelectric films were fabricated by the solution casting method described in our previous work [7]. The rGO contents of the composite were 0 wt.%, 0.05 wt.%, 0.1 wt.% and 0.2 wt.%, respectively.

The measurements of open circuit voltage, harvested power for AC and DC circuits were carried out in this study.

The measurement setup of the experiments is illustrated in Fig. 1. Three composite films of the same rGO content were attached on an aluminum (Al) beam to generate voltage when the beam was excited by electromagnet. It should be noted that in the open circuit voltage measurements, the three piezoelectric films were independent, on the other hand, in harvesting power experiments, they were parallel to enhance the amount of harvested energy.

3. Results and Discussion

Open circuit voltage measurements

The results of open circuit voltage measurements are shown in Fig. 2. From Fig. 2, it can be concluded that the open circuit voltage is significantly affected by the content of rGO. The open circuit voltage of films with 0.05 wt.% rGO is about 2 times of that of pure PVDF films.

However, if the content is over 0.05 wt.%, the open

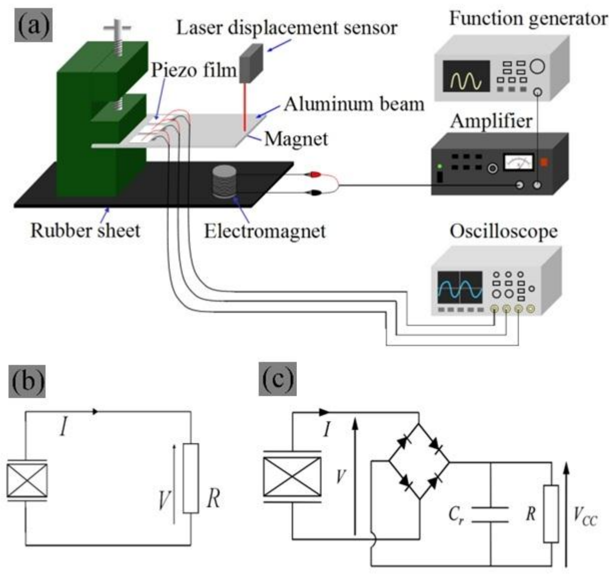

Fig. 1 Measurement setups. (a) setup for open circuit voltage measurements; (b) standard AC circuit; (c) standard DC circuit. The rectifier diode is DX5342 and the capacitance is 33 μF.

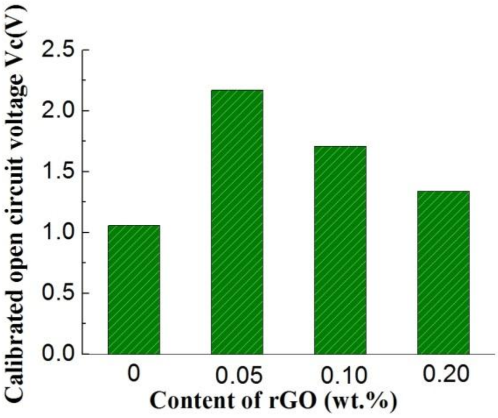

Fig. 2 Open circuit voltage for PVDF/rGO nanocomposite films

circuit voltage decreases. Since the piezoelectricity depends on the fraction of piezoelectric β-phase, it indicates that an extremely low content of rGO can promote the phase transformation while exceeding rGO may hinder it.

Harvested Power for AC Circuit

The density of harvested power of AC circuit is shown in Fig. 3.

As shown in Fig. 3, the density of harvested power of 0.05 wt.% samples is 253% of that of the pure PVDF. And it can also be found that the optimal resistance decreases as the rGO content increases.

Harvested Power for DC Circuit

The density of harvested power for DC circuit is shown in Fig. 4. Similar to that of AC circuit, the density of

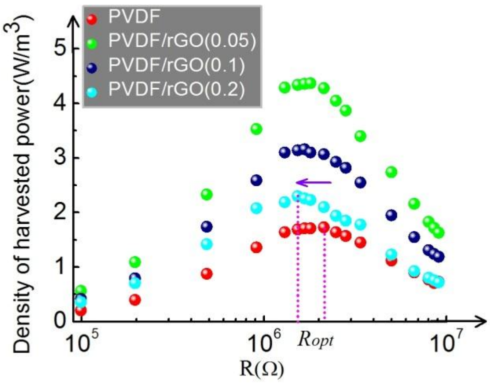

Fig. 3 Density of harvested power for AC circuit

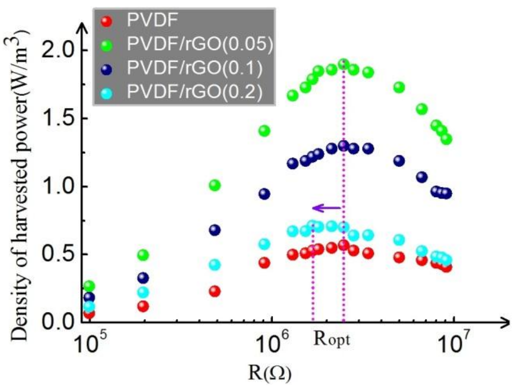

Fig. 4 Density of harvested power for DC circuit

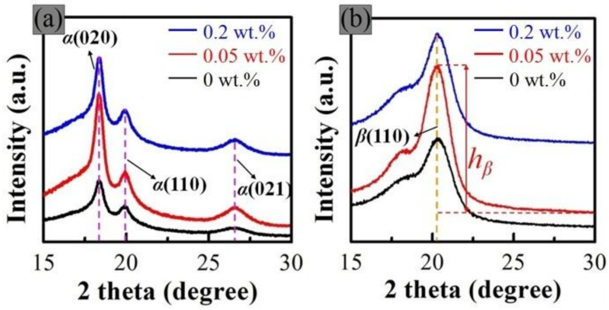

Fig. 5 FTIR spectra of PVDF/rGO nanocomposites. (a) before stretching; (b) after stretching.

harvested power reaches the peak at 0.05 wt.% and the optimal resistance also shifts left. However, the density of harvested power for DC circuit is much lower than that for AC circuits, just about 1/3. That is because in the DC circuit, the diode group needs about 0.4 V voltage to start to work, which consumes part of voltage.

4. XRD analysis

Figure 5 is the XRD spectra. In Fig. 5(a), in the films before stretching, the peaks at 18.4°, 20.0° and 26.5° corresponding to the α-phase are observed, while the peak at 20.6° corresponding to β-phase does not exist [8]. The results indicate that the α-phase is majority in the films before stretching. However, as shown in Fig. 5(b), the peaks related to α-phase nearly disappear, meanwhile the peak related to β-phase becomes notable. Based on the comparison of Fig. 5(a) and Fig. 5(b), we can conclude that the efficient phase transformation occurs during stretching process. Also, the highest relative peak height of 0.05 wt.%, i.e., h_β, indicates that the optimal addition of rGo can improve the β-phase crystallinity compared with other added contents.

5. Conclusions

We blended rGO and PVDF to prepare PVDF composite films of high piezoelectricity by the solution casting method. Measurements on open circuit voltage and harvested power were carried out to evaluate the energy capability of the composite. The results showed that even a little addition of rGO could improve the piezoelectricity obviously, while too much nanofiller would hinder it. The XRD spectra confirmed that the stretching induced the phase transformation, which agreed well with the open circuit voltage and harvested power measurements. This work showed the potential of PVDF/rGO composite as a promising material for future energy harvested devices.

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