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Ferroelectric and Piezoelectric Properties of P(VDF-TrFE) Gels

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Abstract

Poly(vinylidene fluoride-trifluoroethylene)(P(VDF-TrFE))/ poly(pyridinium-1,4-diyliminocarbonyl-1,4-phenylenemethylene)(PICPM-SCN) composite gels were structurally and electrically investigated. The FT-IR spectra of gels revealed that the P(VDF-TrFE) molecules in the composite gels formed with the ferroelectric form I(*β*) crystal phase. The polarization switching and piezoelectric response of P(VDF-TrFE)/PICPM-SCN gel films were measured the coercive electric field of P(VDF-TrFE)/PICPM- SCN gel films dramatically decreased by an effect of solvent in the gels.

1. Introduction

Piezoelectricity is one of the functions of ferroelectric materials, which has been applied for the actuators, hydrophones and generators. Poly(vinilidene fluoride) (PVDF) and its copolymers with trifluoroethylene [P(VDF-TrFE)] are well known to be the ferroelectric polymers with large electric dipole moments.[1,2,3] P(VDF-TrFE) have the good biocompatibility, therefore, it have much attention for the biomedical devices as the artificial muscle. However, the operation voltage is too high to apply in electric devices and the displacement is not enough to practical use. To achieve the low operation voltage and large displacement for piezoelectric actuator, materials need to the high flexibility of piezoelectric. P(VDF-TrFE) composite gel is one of the potential candidates for high piezoelectric performance, because of their superior softness. In this study, the ferroelectric polarization switching and piezoelectric properties of P(VDF-TrFE)/PICPM-SCN gel were investigated.

2. Experiment

P(VDF-TrFE) powder was dissolved in dimethylformamide (DMF) solvent. A certain amount of gelator PICPM-SCN was added to the P(VDF-TrFE) solution and stirred at 90 ℃. The mixed solution was cooled to the room temperature and then P(VDF-TrFE)/PICPM-SCN composites were become the gel states obtained.

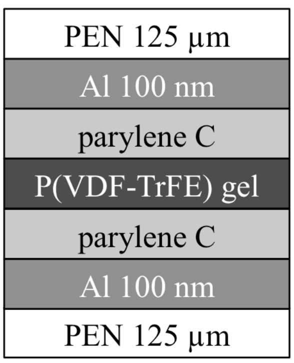

Fig.1. Device structure of P(VDF-TrFE)/PICPM-SCN gel.

Effect of the composition ratio of P(VDF-TrFE)/PICPM-SCN for molecular conformation were examined by Fourier Transform Infrared Spectroscopy(FT-IR).

PEN film/Al/parylene C/P(VDF-TrFE) gel/parylene C/Al/PEN film was fabricated for electrical measurement as show in Fig. 1. Electrical behavior was observed by J-E curves and the piezoelectric displacement was measured by the laser Dopplar vibrometer measurement systems.

3. Results and Discussion

Figure 2 shows the FT-IR spectrum of P(VDF-TrFE)/PICPM-SCN gel on Si substrate. The absorption peaks at 655 and 1680 cm^{-1} corresponding to the DMF solvent in the P(VDF-TrFE)/PICPM-SCN gel include the solvent DMF. The absorption peaks at 840, 880, 1177, 1270 and 1428 cm^{-1} correspond to the FormI(*β*) of the P(VDF-TrFE), thus this means that the P(VDF-TrFE)/PICPM-SCN gels showed the ferroelectric phase. The absorption peaks at 736 and 1510 cm^{-1} correspond to the gelator PICPM- SCN. Thus, the P(VDF-TrFE)/PICPM-SCN gels were stabilized with three component (DMF, P(VDF-TrFE), PICPM-SCN).

Figure 3 shows the result of *J-E* curves of the P(VDF-TrFE)/PICPM-SCN gels. The broad current peaks were observed in both positive and negative electrical field comparing with the typical P(VDF-TrFE) films. When the P(VDF-TrFE)/PICPM-SCN gels were applied with positive

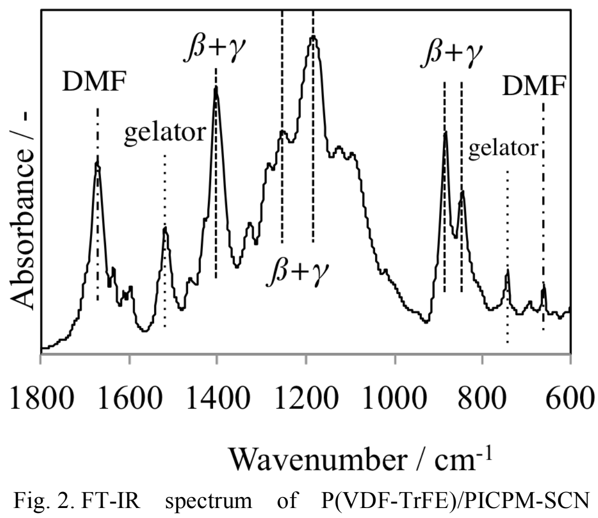

Fig. 2. FT-IR spectrum of P(VDF-TrFE)/PICPM-SCN gels.

voltage for three times, the broad current peak was observed at only first cycle (Fig. 4). This suggests that the current peaks. were probably related to the polarization switching of P(VDF-TrFE). The coercive electric field (E_c) of P(VDF-TrFE)/PICPM-SCN gel was estimated to be approximately 2 MV/m, whereas 50 ~ 60 MV/m for typical P(VDF-TrFE) films. The P(VDF-TrFE) molecules surrounded with a solvent in the gel network may be easy to response to the applied electric field, because the intermolecular interaction between the P(VDF-TrFE) molecules will be decreased. So, the E_c of P(VDF-TrFE)/PICPM-SCN gels were dramatically decreased.

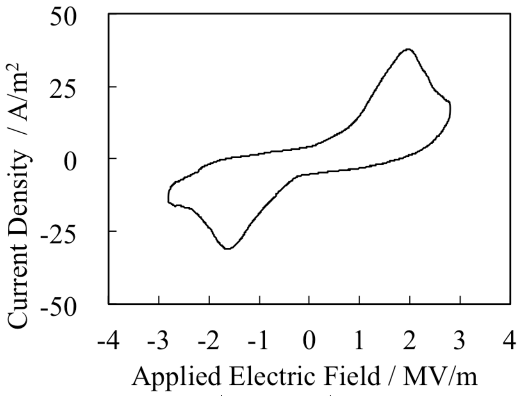

Fig. 3. J-E curve of P(VDF-TrFE)/PICPM–SCN gels.

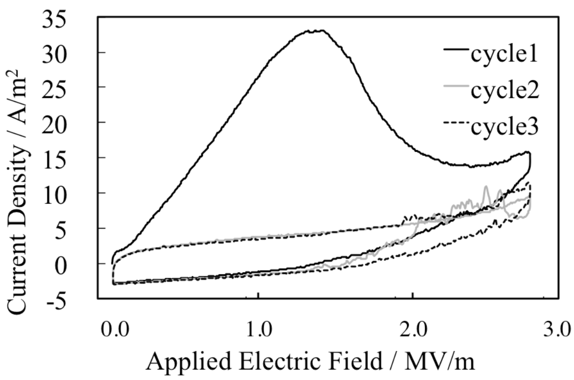

Fig. 4. J-E curves applied only positive voltage to P(VDF-TrFE)/PICPM- SCN gels for 3 cycles.

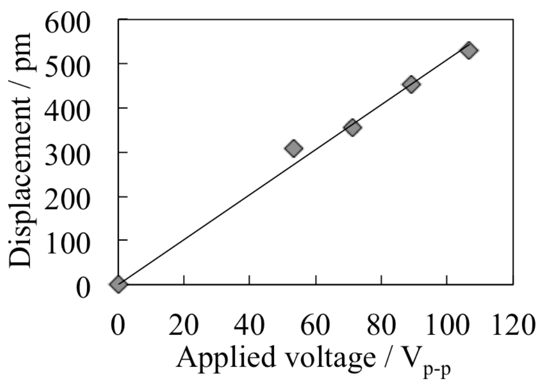

Fig. 5. Piezoelectric displacements of the P(VDF-TrFE)/PICPM-SCN gel at various applying voltages.

Figure 5 shows the relationships between the piezoelectric displacement and applied voltage to P(VDF-TrFE)/PICPM- SCN gels. The displacement is proportional to applying voltage. The liner relationship indicated the piezoelectric property of P(VDF-TrFE)/PICPM-SCN gels. The piezoelectric constant d_{33} in P(VDF- TrFE)/ PICPM-SCN gel was estimated to be 5~7 pm/V.

3. Conclusions

P(VDF-TrFE) gels were fabricated by adding the PICPM-SCN as a gelator. The structure of P(VDF-TrFE)/PICPM-SCN gels including solvent DMF were measured by using FT-IR. The polarization switching of P(VDF-TrFE)/PICPM-SCN gels and drastic decrease of coercive electric field were observed. Furthermore, P(VDF-TrFE)/PICPM-SCN gels showed the piezoelectric properties. The piezoelectric constant d_{33} was estimated to be 5.09 pm/V, it is expected to increase by modifying device structure. The P(VDF-TrFE)/PICM-SCN gels indicate potential application to artificial muscle, actuator and so on.

Acknowledgements

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