Dielectric behavior of (PZT/PVDF) nanocomposites for temperature sensors

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INTRODUCTION

The discovery of ferroelectric effect and its application brings progress in materials science with a growth in search of new materials, which have best properties for specific application. PZT has been the best properties transducer material for a long time period, however, for some applications, PZT offers some limitations. That is the reason why researchers are still searching for a new single-phase material, or heterogeneous systems satisfying the required conditions. In opposition to heavy and rigid ceramics they found ferroelectric polymers, specially the poly (vinylidene fluoride) (PVDF) [1], Copolymers of PVDF [2] and composites [3]. But PVDF has less thermal and mechanical properties, to improving these properties we added same group gel polymer of poly (methyl methacrylate) (PMMA). Light and flexible, ferroelectric polymers show many advantages over ceramics for several applications. A great impact in the electronic industry was observed with the progress on ferroelectric polymer research.Oliver [4] reported two-phase polymer blend GPE, which includes a first phase-including one polymer for absorbing the electrolyte solution, and a second phase –including one polymer for enhancing the mechanical integrity of the polymer blend. The continuous development and ceaseless search for new materials lead to the study of heterogeneous materials. The present paper report some results obtained in elecromechanical characterization of a PZT/PVDF nanocomposites.

EXPERIMENTAL

Preparation of PZT pellets

The weight of 40gm of PZT was taken in to morter to make fine powder by using PVA binder. These fine powders were made a pellet at 15MPa and dried in furnace at 800 ° C over day to drive out binder. The binder free pellets were dried in the furnace at 1290 ° C for 24 hours. Silver electrodes were coated on both sides of pellet for polarizing and measuring d_{33} value. The d_{33} value was determined for examine the material useful or not to the Piezoelectric applications. After conformation of usefulness of the material the silver paste was removed and the PZT pellets grinded as a fine powders.

Preparation of PZT/Polymer

PZT/PVDF and PZT/polyblends powders were mixed in different wt% using acetone for homogenous spreading of the materials. The mixture was dried in a vacuum furnace at 85°C for 24 hours to remove of the acetone traces. The dried mixture was pressed(15MPa) at 180°C. Silver electrodes will be deposited on both sides of the samples for electrical measurements. Samples will be poled by applying the electrical field of 20MV/m for 1h at 90°C.

Measurements

The longitudinal piezoelectric coefficient d_{33} of the composite film poled as early described was measured using the d_{33} piezo tester model ZJ-3AN. Dielectric measurements were made using Aglient 4294A precision impedance analyzer in the range 1-100kHz at room temperature. For the DSC measurements a Netzsch STA 409 PC, operating in dynamic mode (heating rate =10K/min), was employed. Samples of ≈ 5mg weight were placed in sealed aluminium pans. Prior to use the calorimeter was calibrated with metal standards; an empty aluminium pan being used as a reference. The morphology of the samples was characterized by an JSM-6398 scanning electron microscope (SEM).

RESULTS AND DISCUSSION

The dielectric response is generally described by the complex permittivity, ε*=ε'-iε", where real ε' and imaginary ε" components are the storage and loss of energy in each cycle of applied electric field. The frequency dependence of ε' and ε'' for the (PZT+PVDF) composite at room temperature is shown in Fig 1(a, b). The values of ε' are high at low frequencies, but at high frequencies these are relatively constant with frequency. Such high values of ε' may be due to the interfacial effects with in the bulk of the sample and the electrode effects [5]. At high frequencies, the periodic reversal of the electric field occurs so fast that there is no excess ion diffusion in the direction of the field. The polarization due to the charge accumulation decreases, leading to the decrease in the values of ε' and ε'' [6]. The low value of ε'' at low frequencies due to the motion of free charge carrier with in the material. As a result of it, a power law dispersion in ε'' is observed and it does not reveal any peak in the measure frequency range. In the low-frequency range both the ionic conduction and low-frequency dispersion(LFD) were observed. According to Jonscher [7] several polymers shows similar behaviour. The low value of the permittivity gives a high pyroelecric figure of merit indicating that this material can be used to built a temperature sensor in spite of the lower pyroelectric coefficient compared with PZT.

The PZT/PVDF microphotographs showed in Fig. 2(a,b) reveals the homogeneity of the PZT grain distribution and also that a 0 to 3 connectivity is predominant in that composite. Besides, the Furukawa's model [8] for two phase systems could be used for dielectric, elastic and piezoelectric constants.

Conclusions

Composite films of PZT/PVDF were obtained heating the mixture at 180 ºC and with at 15 MPa pressure. Thermal characteristics of PVDF have been assessed by thermal analysis method. Decomposition route was found to be of a two-step process. The large value of ε' at low frequency arises from the electrode polarization rather than the interfacial polarization within the material. The decrease in dielectric permittivity with increasing (PVDF) composition in PZT also observed.

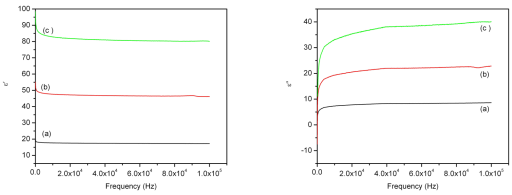
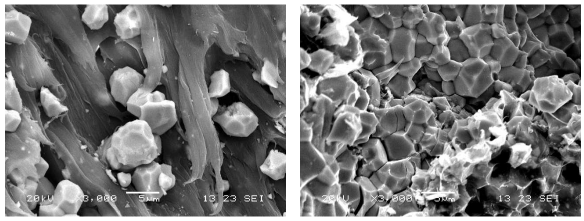


Fig. 1(a,b). The frequency dependence of ε' and ε'' for the (PZT+PVDF) composite.



(a) (b)

Fig. 2. SEM images of the (a) PZT/PVDF(50:50) (b) PZT/PVDF(75:25).

References

1.H.Kawai, The piezoelectricity of poly(vinylidene fluoride), Jpn.J. Appl.Phys., **8** (1969) 975-976.

2.Y. Oka, Y. Murata, N.Koizumi, Structure and spontaneous polarization in fast-quenched copolymers of vinylidene fluoride and trifluoroethylene, Polymer.J **18** (1986) 417-427.

3.C.J.Dias,D.K.Das-Gupta,
Inorganic ceramic/polymer ferroelectric composite electretsIEEE Trans. Diel. Elect. Ins **3**(1996)706-734.

4. M. Oliver, Motorola, *"Blended polymer gel electrodes"*, US patent 5658685, issued Aug.19,1997.

5. S. Ramesh, A.H. Yahaya, A.K. Arof, Dielectric behaviour of PVC-based polymer electrolytes, Solid State Ionics 152-153(2002) 291-294.

6.J.A.Campbell, A. A.Goodwin, G.P.Simon, Dielectric relaxation studies of micible polycarbonate/polyester blends, Polymer **42**(2001) 4731-4741.

7.A.K.Jonscher, *"Dielectric Relaxation in solids"*, Chelsea Dielectric Press,London,1999.

8.T.Furukawa, Piezoelectricity and Pyroelectricity in Polymers, IEEE Trans.Electr.Insul **24**(1989)375-394.