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Effect of Phase Change in Piezoelectric Ceramic-Polymer Composites and their Applications

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ABSTRACT

The hot press method is one of the best suited method for the preparation of piezoelectric ceramic-polymer composites with 0-3 connectivity. The composite samples are prepared by using two different phases of the polymer matrix.The dielectric phenomenon of the PZT-PVDF composite has been investigated with respect to the poling field. The piezoelectric strain coefficient (d_{33}) of the composite samples is measured and compared.The piezoelectric voltage coefficient (g_{33}) values were established from dielectric constant and d_{33} values of the composite.

Keywords: Dielectric constant; Piezoelectric composite; Piezoelectric strain coefficient; PZT-PVDF; Voltage coefficient.

1. INTRODUCTION

Development and investigation of smart materials become the centre of attraction among the most of the researchers around the globe due to its wide range of applications. Piezoelectric materials are one such kind of material which has paid more attention due to its diverse application in industry, space science, energy harvesting devices, memory storage units, sensing devices and transducer applications (Gowdhaman *et al.* 2015a; Jain *et al.* 2015). Among several piezoelectric materials Lead Zirconate Titanate (PZT) has been found to be a prominent material due to its significant dielectric and piezoelectric properties (Gowdhaman *et al.* 2015b). However, its mechanical stability limits their use as a single phase PZT and hence it has been often mixed with a polymer phase in order to increase its flexibility (Tiwari and Srivastava 2015).

There are many PZT-polymer composites have been examined by researchers around the world (Sampathkumar *et al.* 2013; Sundaram *et al.* 2014). Based on that Polyvinylidene fluoride (PVDF) has been identified to be one of the suitable polymer for making composite.PVDF has strong piezoelectric properties over other polymers which makes them useful for the preparation of biphasic piezoelectric ceramic-polymer composites Biphasic solid materials have ten different connectivity pattern (Gowdhaman *et al.* 2016a) among which 0-3 connected ceramic-polymer composites are the major materials which are under study because of its reliability for practical applications as well as ease of fabrication. The ceramic and polymer phases are combined together to form composite using a suitable solvent. The phase of the PVDF can be altered with respect to the solvent (Gowdhaman *et al.* 2016b).

In this present study two different phases of PVDF have been used for the composite preparation. The hot press method has been adopted for sample preparation. The effect of dielectric and piezoelectric properties on different polymer phase has been studied by comparison of the obtained results. The γ and β phase of PVDF has been achieved by using dimethyl sulfoxide (DMSO) and cyclohexanone as solvent respectively (Senthilkumar *et al.* 2005). In one of our earlier studies we have compared the dielectric and piezoelectric behavior of the PZT-PVDF composites which are poled for one hour (Gowdhaman *et al.* 2015c). In this study an attempt has been made to pole the samples for about 1.30 hr and the above mentioned properties of those samples were analysed.

2. EXPERIMENTAL METHODS

The ferroelectric ceramic, polymer composites were prepared at 0.5 volume fraction of PZT. The APC 855 PZT powder from American Piezoceramics and the PVDF pellets (Sigma Aldrich Chemicals) has been used as ceramic and polymer phase respectively for composite preparation.The polymer PVDF is heated at 170 °C using a solvent cyclohexanone. PZT has been added in the molten form of PVDF which results the formation of composites. Further the above procedure has been repeated for the preparation of composite using DMSO as a solvent to vary the phase of the polymer phase. The prepared composites were made into pellets of fixed dimension using a hot press apparatus. The samples were electroded on both sides using conductive silver paste obtained from Sigma Aldrich chemicals. The polarization on the composite samples has been performed in a silicone oil bath by using a high voltage power supply. All the samples were poled at 120 °C for about 1.30 hr under different poling fields.

3. RESULTS & DISCUSSION

3.1 Dielectric Constant

The variation of dielectric constant at different poling fields has been plotted in fig. 1. It is found that the dielectric constant of the composite prepared using DMSO possess better dielectric constant values over the different poling fields (fig.1). This may be due to the fact that the composites prepared using DMSO might be more relaxed than the composites prepared using cyclohexanone.

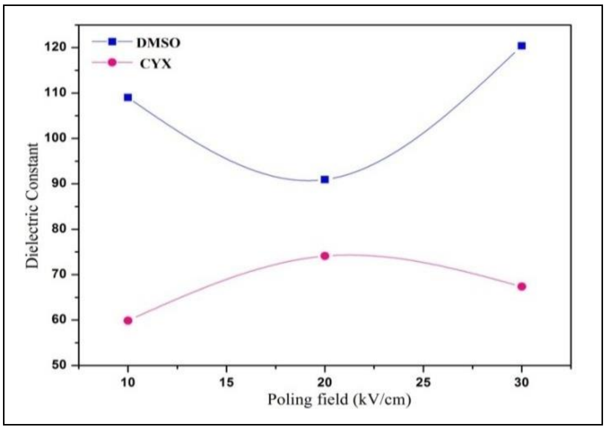

Fig. 1: Variation of dielectric constant at different poling fields

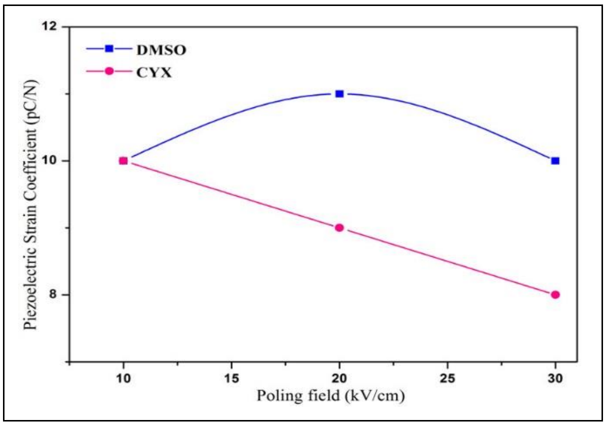

Fig. 2: Variation of piezoelectric strain coefficient with poling field

3.2 Piezoelectric Properties

3.2.1 Piezoelectric Strain Coefficient (d_{33})

The fig. 2 demonstrates the variation of the piezoelectric strain coefficient (d_{33}) values of different poling fields. It is observed that the composite samples prepared using DMSO as a solvent have a small increase in d_{33} values which tends to decrease at higher poling fields, whereas d_{33} values linearly decreases for the samples prepared using cyclohexanone as solvent. The decrease in d_{33} values might have occurred due to the space charge effect at higher poling fields.

3.2.2 Piezoelectric Voltage Coefficicent (g_{33})

The piezoelectric voltage coefficient values of the PZT-PVDF composite samples were established from the dielectric constant and d_{33} values of the composites that is $g_{33}=d_{33}/\varepsilon_0\varepsilon_r$ (Gowdhaman *et al.* 2015b). It is observed that the piezoelectric voltage coefficient values start to decrease beyond the poling field of 20 kV/cm irrespective of the phase of the polymer phase (fig. 3).

In comparison with g_{33} values, the samples prepared using cyclohexanone has better values than compared to samples prepared by DMSO as solvent.The decrease in g_{33} values at higher poling fields may be caused by the depolarization effect (Damjanovic, 2006; Gowdhaman *et al.* 2015c).

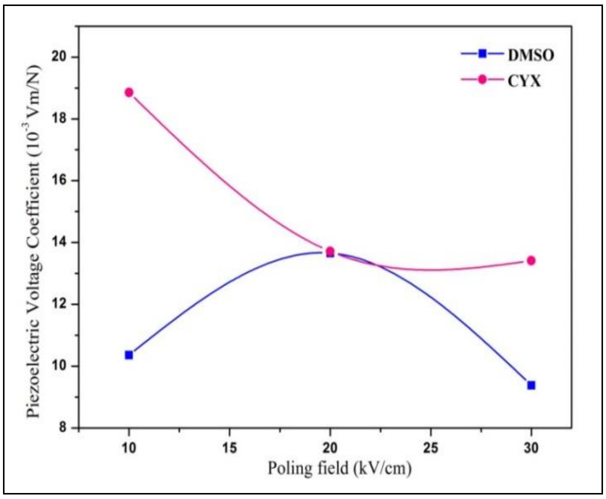

Fig. 3: Plot betweenpiezoelectric voltage coefficient and the poling field

4. CONCLUSION

The successful fabrication of 0-3 connected piezoelectric ceramic-polymer composites have been done by using the hot press method.The dielectric constant of the composites made by using DMSO as solvent retain better dielectric constant and piezoelectric strain coefficient values when compared to one which was made by cyclohexanone.The piezoelectric voltage coefficient of the composites tends to decrease with increase in poling fields. In a nutshell, it can be concluded that this work could be further optimized by repeating it over a wide range of poling fields.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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