TXQ301

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Interfacial polarization in Piezoelectric Polymers/Composites

Abstract : Piezoelectric properties have been studied for the composite systems of PZT ceramics and polymers using lead zirconate titanate and epoxy that have been fabricated with different ceramic rod widths. The values of the piezoelectric constants and their temperature and frequency dependences were discussed on the basis of the theoretical expressions of the piezoelectric constants for a two−phase system with piezoelectric spherical dispersions. The piezoelectric activity of all the composite systems studied was mainly ascribed to the piezoelectricity of PZT ceramics. The PZT ceramics have shown certain qualities like high electromechanical coupling coefficient k_t, and low planar coupling coefficient k_p, and better acoustic matching to tissue which prove them to find many applications in medical imaging.
Key words : Maxwell Wagner polarization, Ceramics, Composites, Electric Modulus, Acoustic Impedance

1. Introduction :

Translational polarization is usually associated with the presence of migrating charges, by electrons or ions, over macroscopic distances in an applied field. They tend to be trapped and accumulate at physical barriers such as defects, voids, impurities, grain or phase boundaries and also at the electrode interfaces where the material has different charge transport properties, e.g., conductivity. The accumulated charges distort the local electric field and gives rise to permittivity.

Interfacial polarization is particularly important in heterogeneous or multiphase systems such as polymer-ceramic nanocomposites. Interfacial polarization, involving a long range ion movement, is usually observed only at lower frequencies, otherwise known as a space-charge or Maxwell Wagner polarization. In polymers and composite polymeric materials, interfacial polarization is almost always present because of additives, fillers or even impurities which make these systems heterogeneous. Also, making modification in the constituent of piezo material itself then becomes a research topic.

For example, piezo electric ceramic composites are superior to the piezo ceramics alone due to their low acoustic impedance, a parameter which determines the efficient transfer of acoustic energy from the transducer to the investigative medium or vice versa.

2. Methodology :

2.1 Interface polarization coupling in piezoelectric-semiconductor ferroelectric heterostructures

This method uses a dielectric continuum model approach for studying the electrical polarization properties of interface polarization coupled $BaTiO_3$, $BaTiO_3$-ZnO, and ZnO-$BaTiO_3$-ZnO thin-film structures consisting of several hundred nanometer thick layers. Their model augments the effects of electric field driven switchable polarization and depletion layer formation with spontaneous interface polarization coupling. Wurtzite-structure (piezoelectric) *n*-type ZnO and perovskite-structure (ferroelectric) highly insulating $BaTiO_3$ layers were prepared and investigated. The *n*-type ZnO reveals hysteresis-dependent capacitance variations upon formation of depletion layers at the ZnO/BTO interfaces.

2.2 Electric modulus and interfacial polarization in composite polymeric systems

In composite polymeric materials, relaxation phenomena in the low-frequency region are attributed to the heterogeneity of the systems. For the investigation of these processes through electric modulus formalism, hybrid composite systems consisting of epoxy resin-metal powder-aramid fibres were prepared with various filler contents and their dielectric spectra are recorded in the frequency range 10 Hz-10 MHz in the temperature interval 30-150^{o} C.

2.3 Interfacial polarization in piezoelectric fibre-polymer composites

Polymer composites of an epoxy resin matrix filled with PZT fibres were studied by means of dielectric spectroscopy in the frequency range 0.1 Hz to 100 kHz and temperature interval from 80^{o} C to 170^{o} C. An MWS relaxation process was revealed in the frequency range between 0.1 Hz to 10 Hz and temperatures above glass transition.

2.4 PZT/Polymer composites for medical ultrasound

Piezoelectric ceramic polymer composites with l-3 connectivity (i.e., parallel rods in polymer) using lead zirconate titanate and epoxy have been fabricated with different ceramic rod widths. The velocity of sound was measured for these composites using the Time-Delay technique. The values of acoustic impedance obtained by this method are compared with the results determined by the Resonance technique. The electro mechanical coupling coefficient k_t, and planar coupling coefficient k_p, were determined from the thickness mode resonance and planar mode resonance peaks.

3. Results and Discussion :

3.1 PZT/Polymer composites for medical ultrasound

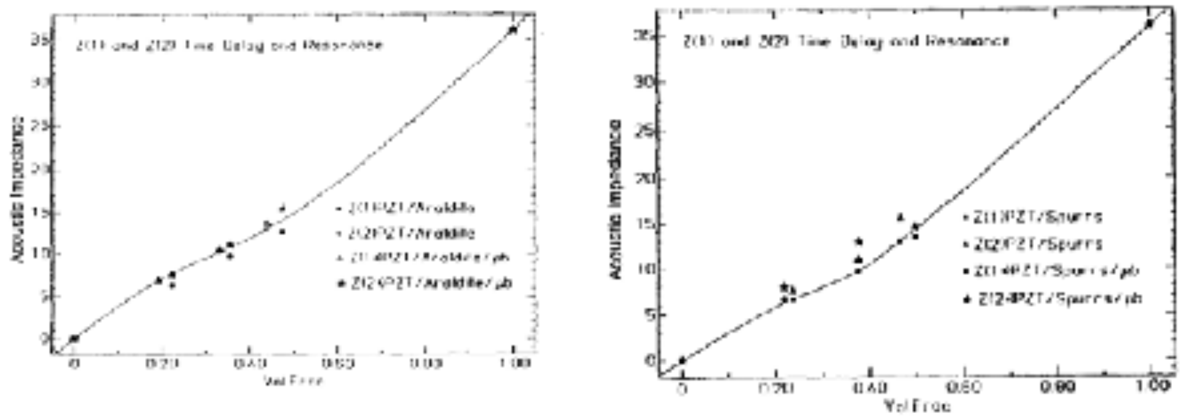


Fig 1; - Variation of acoustic impedance with volume fraction

3.2 Electric modulus and interfacial polarization in composite polymeric systems

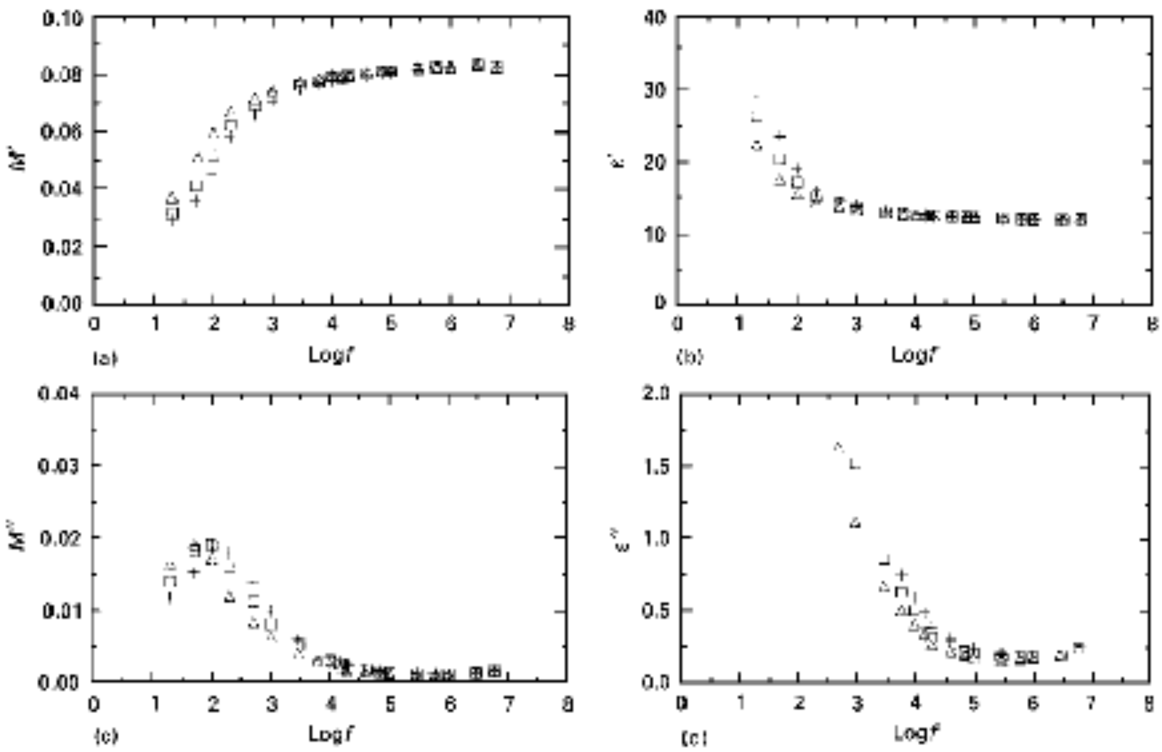


Figure 2 (a, b) Real M', ε' and (c,d) imaginary M'', ε'' parts of electric modulus and dielectric permittivity versus frequency for various temperatures of the composite with 25 p.h.r. in Al and 0.5 p.h.r. in Kevlar fibres. (△) 140 °C, (□) 145 °C (+) 150 °C.

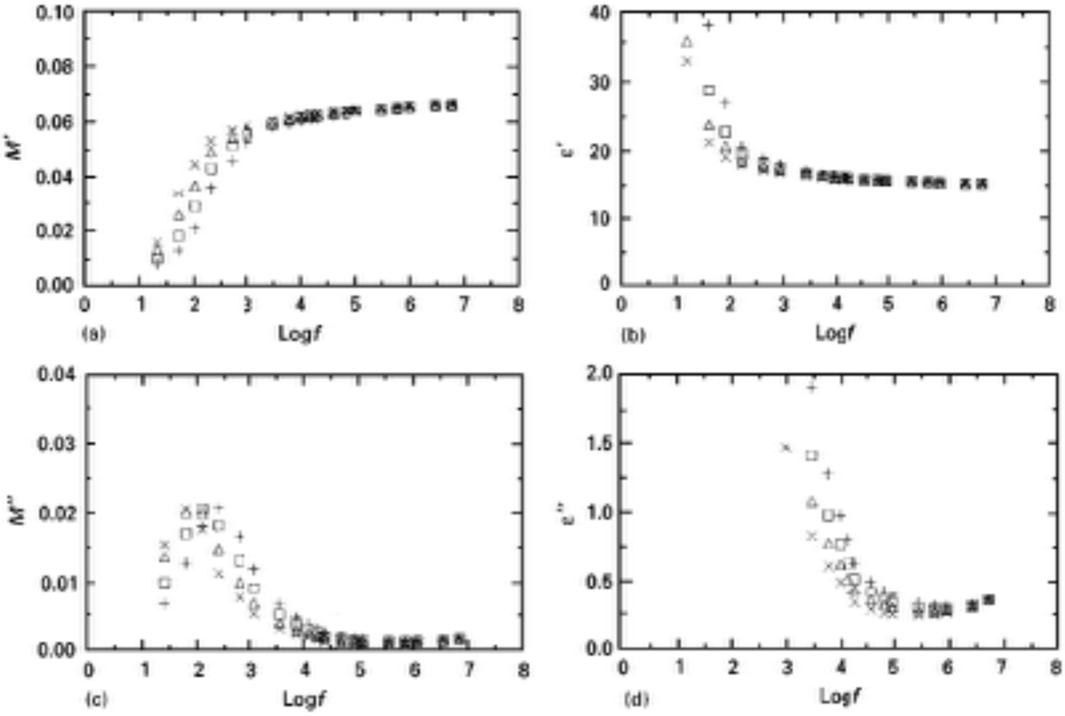
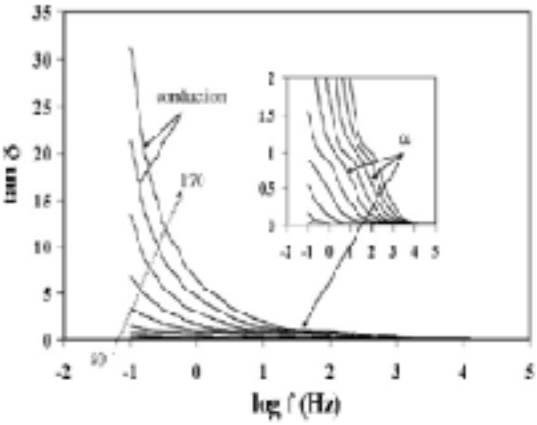
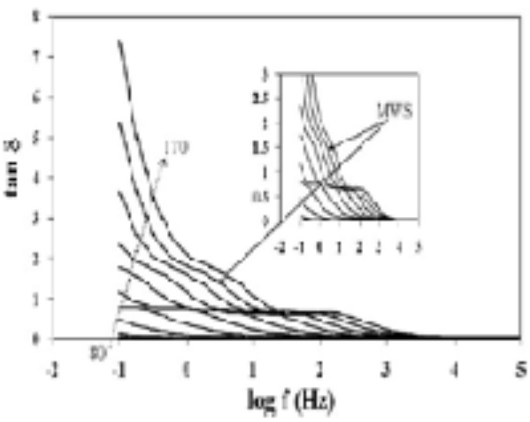


Figure 3 (a, b) Real M', ε' and (c, d) imaginary M'', ε'' parts of electric modulus and dielectric permittivity versus frequency for various temperatures of the composite with 25 p.h.r. in Al and 1.5 p.h.r. in Kevlar fibres. (×) 135 °C, (△) 140 °C, (□) 145 °C, (+) 150 °C.

3.3 Interfacial polarization in piezoelectric fibre-polymer composites



(a)



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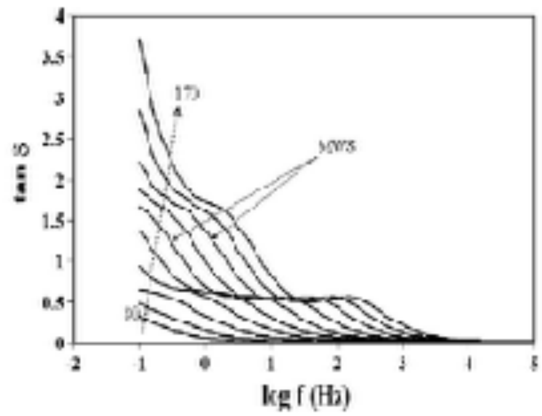

(c)

Fig 5. - Dielectric loss factor tan δ versus frequency in the piezocomposite with 8 % (a), 20 % (b) and 26 % (c) of PZT fibre volume ratio at different temperatures (°C).

Outcomes and analysis :

Both PZT/Araldite and PZT/Spurrs Epoxy with a ceramic width of 80 µm and polymer width of 75 µm appear to have a low acoustic impedance, a lower planar coupling coefficient, and a high electromechanical coupling factor. An interfacial relaxation in evident in the dielectric spectra of examined systems, due to interfaces by the PZT fibres.

Epilogue :

With the properties determined, I think piezo ceramics/polymers can find immense applications like in medical ultrasound transducers that are superior to those conventionally made using PZT only.

Also, as the materials are developing at nano scale due to the advent of advanced technologies peizoelectric property can be harnessed to shape our future.

References :

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Appendix :