

Poling study of PZT/P(VDF–TrFE) composites

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Abstract

Thick-film composites with 0.2 and 0.6 volume fractions of lead zirconate titanate (PZT) powder dispersed in a vinylidene-fluoride–trifluoroethylene copolymer [P(VDF–TrFE)] matrix were prepared by solvent casting followed by compression moulding. The composites were poled by various procedures to produce samples with only the ceramic phase poled, only the copolymer phase poled, or both the ceramic and copolymer poled. The polarization profiles of the poled composites have also been obtained using the laser intensity modulation method (LIMM). © 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Poling the inclusions in a 0–3 composite ferroelectric is not trivial when the spontaneous polarization of the inclusions is much higher than the surrounding matrix like in a system of lead titanate (PT) or lead zirconate titanate (PZT) in polyvinylidene fluoride–trifluoroethylene [P(VDF–TrFE)]. The starting point is the state of the composite with the matrix and inclusions unpoled. Poling the inclusions to their spontaneous polarization means the generation of an electric displacement in the inclusions which is substantially higher than the maximum electric displacement of the surrounding matrix material. This can only be achieved by a considerable rearrangement of charge as the divergence of the electric displacement is equal to the charge density. When, for example, a stack of different ferroelectric layers is poled in a temperature and time regime where the electric conductivity of the materials is low, then the layer with the smallest maximum polarization limits the polarization of the whole stack [1]. We have, however, demonstrated that lead titanate inclusions in P(VDF–TrFE) can be polarized to a high degree at elevated temperature making use of the conductivity of the polymer, while the matrix can be polarized at low temperature without changing the polarization of the inclusions [2].

The pyroelectric coefficients of both components have the same sign, but the piezoelectric coefficients have opposite signs. If the matrix and inclusions of a composite of PT or PZT in PVDF–TrFE are polarized in the same direction, then the pyroelectric responses of both components are reinforced while the piezoelectric responses are partially cancelled. On the other hand, by poling the two phases in opposite directions, a material with reduced pyroelectric but increased piezoelectric sensitivity is produced. A 30 μm thick composite film of lead titanate in P(VDF–TrFE) matrix can be poled in a very controlled way. Compensation of the piezoelectric or of the pyroelectric activity is achieved in a material with 27% volume fraction of the ceramic phase [3]. These materials are of high interest for the application in sensors. The sensitivity of a piezoelectric sensor to temperature changes which is an inherent problem of the usual piezoelectric materials and which often requires a complex compensation circuit is completely avoided by the use of these internally compensated composites.

The situation becomes more difficult, however, when thick film material is poled. The breakdown voltage of P(VDF–TrFE) film with a thickness above 0.5 mm is typically lower than the coercive voltage of the material at room temperature. Thick film material is usually either poled at elevated temperature, e.g. by cooling the material slowly from the paraelectric to the ferroelectric state under an applied voltage or at room temperature

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