Pyroelectric Activity of Ferroelectric PT/PVDF-TRFE

Bernd Ploss, Beatrix Ploss, F. G. Shin, H. L. W. Chan and C. L. Choy

Department of Applied Physics
The Hong Kong Polytechnic University
Hung Hom, Hong Kong, China

ABSTRACT

This paper studies the pyroelectric coefficient of 0-3 composites consisting of 27%vol lead titanate (PT) powder embedded in a vinylidene fluoride-trifluoroethylene copolymer (PVDF-TRFE) matrix. The constituent phases of the composites have been polarized in four possible ways: only the copolymer polarized; only the ceramic polarized; the copolymer and ceramic phases polarized in the same direction; the two phases polarized in opposite directions. The pyroelectric coefficient was measured by a dynamic method at 5 mHz within the temperature range 20 to 90°C (which covers the ferroelectric to paraelectric phase transition temperature of the copolymer matrix). The composite with the copolymer and ceramic phases polarized in the same direction exhibits strong pyroelectric but relatively weak piezoelectric activity, and *vice versa* when the constituent phases are oppositely polarized. A theoretical model is used to analyze the pyroelectric coefficient of the composites in terms of the pyroelectric and dielectric properties of the copolymer matrix as determined from experiment, and those of the ceramic particles which are assumed to be temperature independent. The pyroelectric coefficient and dielectric permittivity of the ceramic particles are obtained as fitting parameters. The theoretical prediction is found to agree well with the experimental data.

1 INTRODUCTION

COMBINING ferroelectric ceramic particles and a polymer matrix to form composites can give advantages of mechanical flexibility and low acoustic impedance while retaining useful pyroelectric and piezoelectric properties. Such materials have a considerable potential in sensor and transducer applications, due especially to the possibility of tailoring its properties to specifications by a judicious selection of constituent components and of their volume ratio. An additional degree of freedom is made available by employing a polymer matrix that is also ferroelectric, in which case the state of its polarization may be manipulated by poling techniques.

For the present study we choose lead titanate (PT) powder as inclusion and vinylidenefluoride-trifluoroethylene copolymer (PVDF-TRFE) of VDF to TRFE molar ratio 56/44 as the matrix material. Using a special poling method [1, 2] composites in the following four different polarization states have been prepared: only the matrix polarized, only the inclusions polarized, the two phases polarized in parallel directions and the two phases polarized in antiparallel directions. The directions of the polarization vectors of the matrix and the inclusions in these different polarization states are schematically illustrated in Figure 1. The pyroelectric coefficients of these composites and the dielectric permittivity have been measured from 20 to 90°C. These experimental data are used for a theoretical modeling of the pyroelectric coefficient of the composites.

2 THEORY

Compared to the large amount of theoretical work on the dielectric properties of composites, there are relatively few theories describing the effective pyroelectric coefficient of composites consisting of pyroelectric inclusions in a pyroelectric matrix. The pyroelectric coefficient p of composites with a non-pyroelectric matrix is commonly described as a product of the volume fraction of the inclusions v, the local field coefficient L_E with respect to the electric field and the pyroelectric coefficient of the inclusions p_i [3, 4].

$$p = vL_E p_i \tag{1}$$

A similar formula was also proposed by Furukawa *et al.* [5, 6] for the effective piezoelectric coefficient d of a composite of incompressible piezoelectric inclusions in an incompressible non-piezoelectric matrix (*i.e.* both the inclusions and matrix have a Poisson's ratio $\nu = 0.5$)

$$d = vL_T L_E d_i \tag{2}$$

where L_T is the local field coefficient with respect to the stress and d_i is the piezoelectric coefficient of the inclusions. To extend Equation (2) to the case where the matrix is also piezoelectric, transformation rules for v, L_E, L_T and d_i have been suggested to obtain the matrix contribution to d [5]. Applying the same transformation rules for extending