The Pyroelectric Coefficient of Composites

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Abstract - **The effective physical properties of composites are generally depending on the properties of the constituents, the volume ratio, and the shape and spatial arrangement of the components (e.g. the connectivity) in a quite complex way. This is the reason why problems like the dielectric constant of composites have kept scientists busy over more than a century. In the case of properties like the pyroelectric coefficient we have derived a simple relation which is of universal validity if only the following assumption is accepted: the dielectric constants of the constituents do not change under the influence of the electric field generated by the pyroelectric activity. This assumption holds usually very well in pyroelectric materials, as the electric field which results from the pyroelectric activity is much smaller than the electric field required to induce a significant variation of the dielectric constant. In this general relation, the pyroelectric coefficient of the composite is written as a function of the pyroelectric coefficients and dielectric constants of the constituents, the volume ratio and the effective dielectric constant of the composite material. Shape and spatial arrangement of the components are not directly involved in the relation, the influence of these is all included in the effective dielectric constant of the composite. Therefore, this relation gives a correct description for all kinds of connectivities and gives an easy access to the optimization of pyroelectric composites, e.g. by the specific introduction of some conductivity into the materials.**

I. 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 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.

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 [1, 2].

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

A similar formula was also proposed by Furukawa et al. [3, 4] 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 of 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 Eq. (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 [3]. Applying the same transformation rules for extending to the case of a pyroelectric matrix, Eq. (1) becomes:

$$p = vL_E p_i + (1 - vL_E)p_m \tag{3}$$

where p_m is the pyroelectric coeffcicient of the matrix. The following expression for L_E was derived by Furukawa