Effective properties of composites containing relaxor-ferroelectric single-crystalline and ferroelectric ceramic components

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Abstract

The aim of this work is to determine and analyze effective electromechanical properties of novel 0-3 "relaxor-ferroelectric single crystal (RFSC) - ferroelectric ceramic (FC)" composites and 0-1-3 "RFSC - FC - polymer" composites being suitable for transducer technology, hydroacoustic and medical devices. Spheroidal RFSC inclusions are assumed to be aligned in a FC matrix, thus, constituting a 0-3 composite. In 0-1-3 composites, extended RFSC-FC rods are surrounded by a polymer matrix. The RSFC components are perovskite-type solid solutions of lead magnesium niobate - lead titanate or lead zinc niobate - lead titanate near the morphotropic phase boundary. The FC components are perovskite-type modified lead titanate compositions. Piezoelectric coefficients e_{ij*} and d_{ij*} of these composites are determined in dependence on the volume concentration of the components and the shape of the RFSC inclusions by using the self-consistent method [1] and Eshelby factors [2]. Of particular interest are, first, non-monotonic concentration dependences of e_{3j*} and d_{3j*} and, second, large anisotropy of these piezoelectric coefficients and of the electromechanical coupling factors k_{3j*} . It is found that the shape and composition of the RSFC inclusions can considerably influence the hydrostatic piezoelectric coefficient $e_{h*} = e_{33*} + 2e_{31*}$ in the 0-3 composite with the volume concentration of the inclusions under 50%. In this case we deal with original materials where the electromechanical interaction between the highly piezo-active (RFSC) and highly anisotropic (FC) components plays the leading role. Empirical links between electromechanical constants of the RSFC and FC components have been established which guarantee optimum composite coefficients e_{3j*} and d_{3j*} . An evolution of concentration dependence of the effective electromechanical properties at the transition from the 0-3 composite to the 0-1-3 composite with the same piezo-active components is considered. [1] M. Dunn, J. Appl. Phys., 73, 5131 (1993). [2] J.H. Huang and J.S. Yu, Comp. Eng., 4, 1169 (1994).