Modelling the effect of Porous structure on Poling Behavior of Ferroelectric Ceramics

J.I. Roscow[1,*], Y. Zhang[1], R.W.C. Lewis[2], J. Taylor[3] and C.R. Bowen[1]
[1]Department of Mechanical Engineering, University of Bath
Claverton Down, Bath, BA2 7AY, UK
[2]Renishaw Plc.
Wooton Road, Wooton-under-Edge, GL12 8SP, UK
[3]Department of Electronic and Electrical Engineering, University of Bath
Claverton Down, Bath, BA2 7AY, UK
*J.I. Roscow: J.I.Roscow@Bath.ac.uk

Porous ferroelectric ceramics (barium titanate and lead zirconate titanate (PZT)) have been modelled using a finite element approach to investigate the effect of porous structure on the electric field distribution within the two phase composite during the poling process required to induce piezoelectric and pyroelectric behavior. Three types of porous structures were investigated across a range of porosities: uniformly distributed porosity (3-0/3-3 connectivity); sandwich layer structures, whereby a porous layer with 3-3 connectivity is sandwiched between two dense outer layers; and aligned porous structures (2-2/3-1 connectivity). Porous networks were initially generated with elements either assigned the properties of unpoled ferroelectric ceramic or air. A poling field was then simulated to establish the distribution of poled material within the structure. The composites were then characterized in terms of effective piezoelectric charge coefficients, d_{33} and d_{31}, and relative permittivity, ε_r, so as to assess their capabilities for applications such as sensors and energy harvesting devices using relevant figures of merit. The porous structure is found to be closely linked to the ease with which the material can be poled and therefore has a significant effect on the piezoelectric properties of the composite. The results indicate aligned porous structures, such as those achieved using the freeze casting process, are best suited for applications that require high d_{33} coefficients and low ε_r, such as energy harvesting where the relevant figure of merit is d_{ij}^2/ε_r.