Modelling Porous Ferroelectrics to Assess Piezoelectric Energy Harvesting Capabilities

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Aim: To evaluate the effect of porosity and porous structure on the energy harvesting capabilities of ferroelectric ceramics using a Finite Element Modelling approach.

Context
Porous piezoelectric ceramics are of interest for energy harvesting applications due to porosity causing significant reductions in permittivity, $\varepsilon_{33}$, compared with relatively small reductions in longitudinal strain coefficient, $d_{33}$, leading to increases in energy harvesting figures of merit, where $FOM_{33} = d_{33}^2 / \varepsilon_{33}$ [1]. The development of an FE Model will allow different porous structures to be evaluated for their energy harvesting capabilities.

Pre- and Post-Poling Porous BaTiO$_3$ network

(a) 30$^3$ cells randomly designated material properties of either unpoled BaTiO$_3$ (blue) or air (empty), depending on density defined for run and (b) post-poling procedure with poled (red) and unpoled BaTiO$_3$ (blue) and air (empty). BaTiO$_3$ elements are poled when local E-field exceeds coercive field.

![Pre- and Post-Poling Porous BaTiO$_3$ network](image)

Fig. 1: Flow diagram of modelling process used to generate randomly distributed porosity with piezoelectric ceramic (adapted from [2])

Initial Results

![Initial Results](image)

Fig. 3: FE model data (blue) compared to experimental data BaTiO$_3$ (red) for (a) $d_{33}$, (b) relative permittivity and (c) $FOM_{33}$, all plotted as a function of relative density. Experimental data measured from BaTiO$_3$ ceramics with range of porosities obtained using the burned out polymer spheres (BURPS) process.

Discussion & Outlook
- Want to bring model and experimental data closer together
  - More accurate input data required
- Use model to investigate EH capabilities of different structures/ connectivities
  - Currently, only randomly distributed porosity (3-0/3-3) generated
  - Structure has effect on key properties, i.e. $d_{33}$, $\varepsilon_{33}$ and $S^0_{33}$ (elastic compliance)

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References