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 $\text{FOM}_{33} = d_{33}^2/\varepsilon_{33}$ [1]. The development of an FE Model will allow different porous structures to be evaluated for their energy harvesting capabilities.

FE Modelling Process

1. Generate network model geometry
2. Determine random two phase distribution (unpoled BaTiO$_3$ and air) for given volume fraction of porosity
3. Apply poling voltage to ‘electroded’ surfaces
4. Establish distribution of polarised material
5. Characterise porous piezoceramic performance in terms of $d_{33}$, $\varepsilon_{33}$, and energy harvesting FOM
6. Record results
7. Clear model

Initial Results

Fig. 1: (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.

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

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 $\mu_{33}$ (elastic compliance)

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References