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Modelling Porous Ferroelectrics to Assess Piezoelectric Energy Harvesting Capabilities

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UNIVERSITY OF BATH

NEMESIS — Novel Energy Materials: Engineering Science and Integrated Systems

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, ε_{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

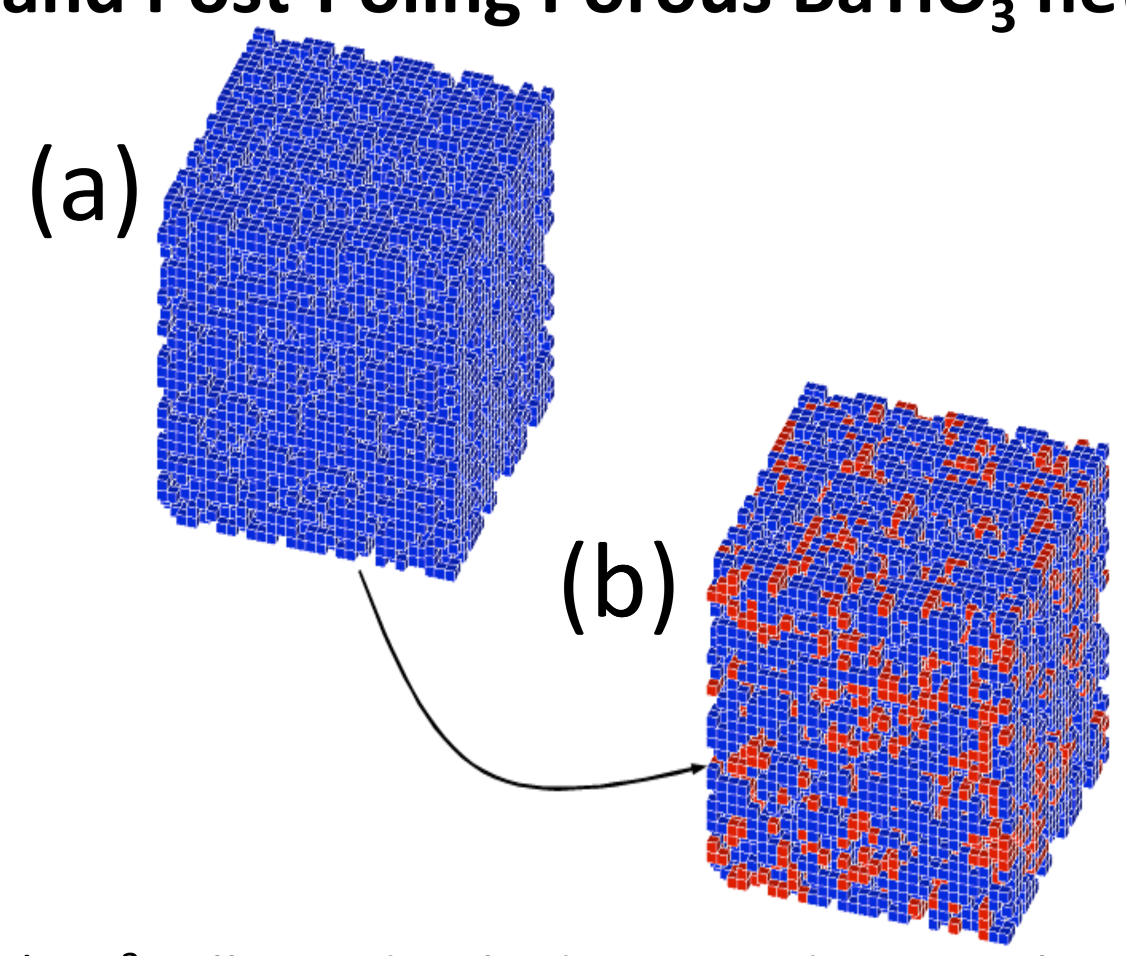

Fig. 1: (a) 30^3 cells randomly designated material properties of either unpoled $BaTiO_3$ (blue) or air (empty), depending of density defined for run and (b) post-poling procedure with poled (red) and unpoled $BaTiO_3$ (blue) and air (empty). $BaTiO_3$ elements are poled when local E-field exceeds coercive field.

FE Modelling Process

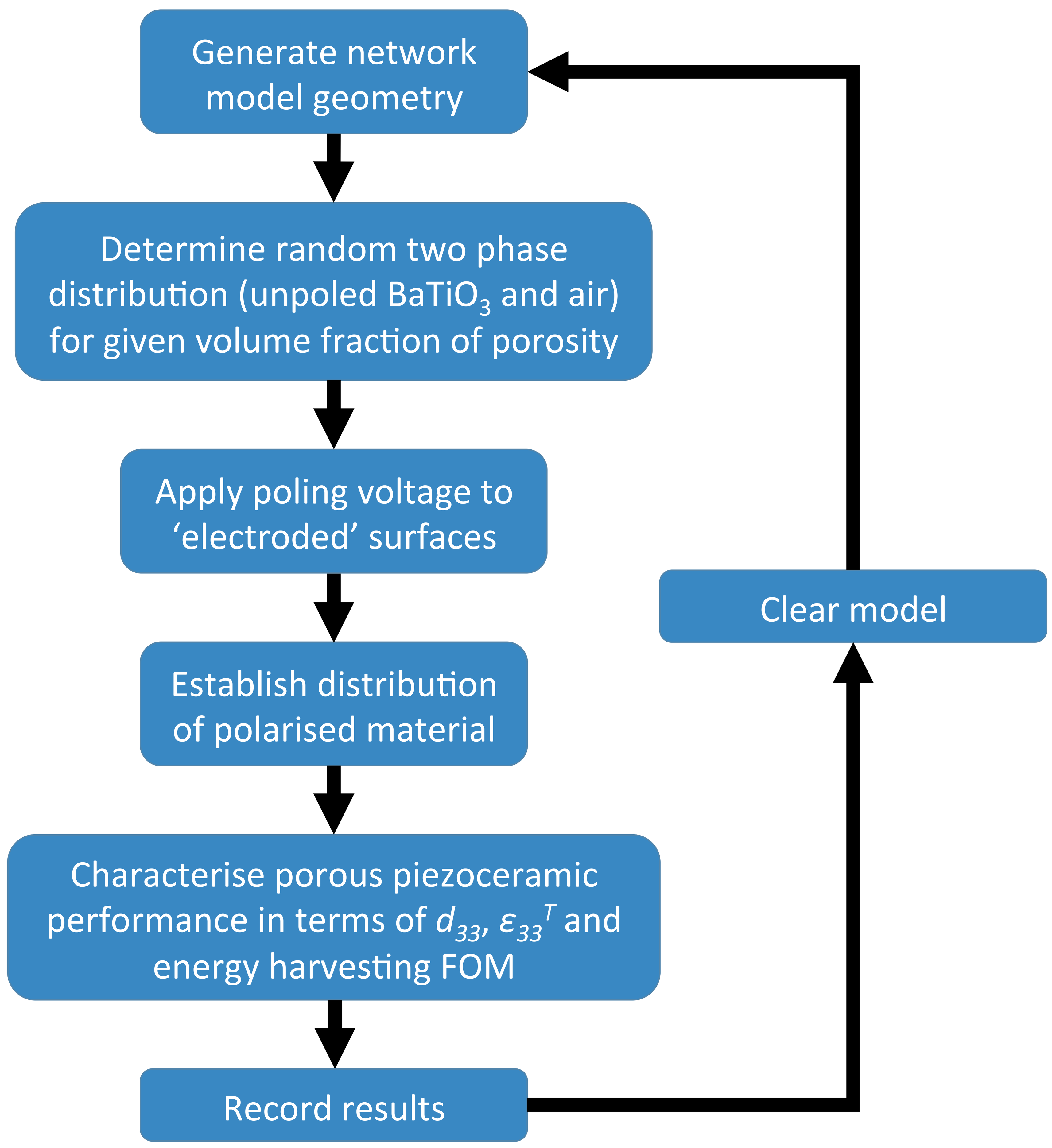

Fig. 2: Flow diagram of modelling process used to generate randomly distributed porosity with piezoelectric ceramic (adapted from [2])

Initial Results

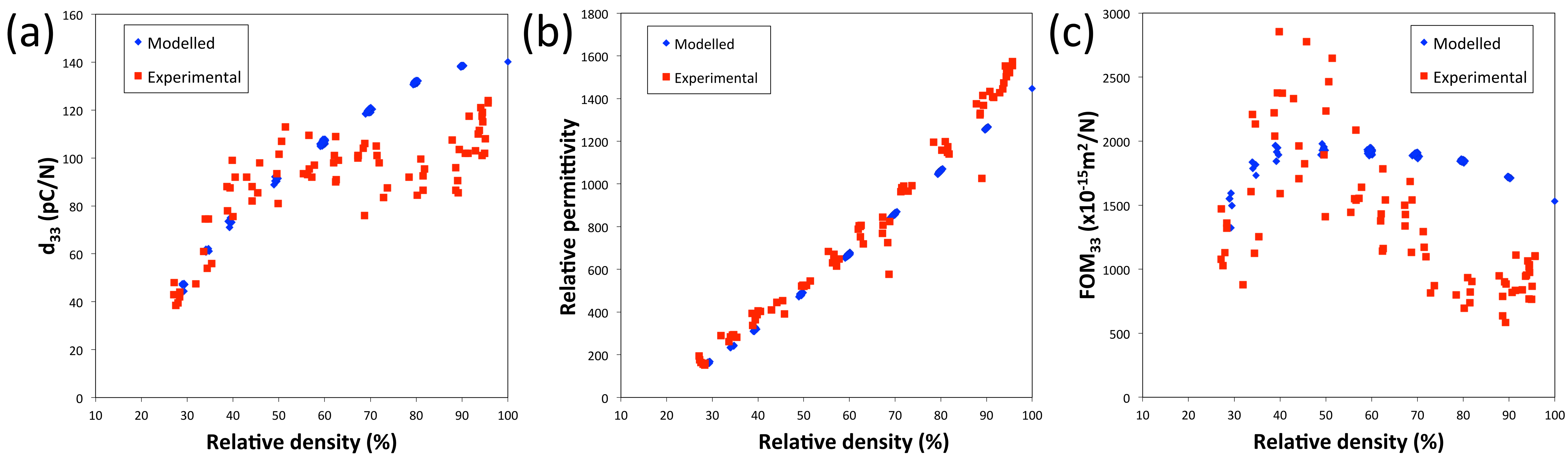

Fig. 3: FE model data (blue) compared to experimental data $BaTiO_3$ (red) for (a) d_{33}, (b) relative permittivity and (c) FOM_{33}, all plotted as a function of relative density. Experimental data measured from $BaTiO_3$ ceramics with range of porosities obtained using the burned out polymer spheres (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}, ε_{33} and S^E_{33} (elastic compliance)

Acknowledgement

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[2] Lewis, R. W. C., Dent, A. C. E., Stevens, R., & Bowen, C. R. (2011). *Smart Mater. and Struct.*, 2011, ***20***, 085002.