Ferroelectrics in Multilayer Ceramic Capacitor Structures (Scarce Skills Project in Collaboration with Kyocera AVX and the University of Sheffield)

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Research Centre: CQMT
Suitable for: Students interested in functional materials and microscopy
Type of Project: Mainly experimental but also perhaps some modelling components
Skills required: Reasonable laboratory skills and common sense
Skills gained: High-end microscopy techniques and data analysis

Background

Periods of human history are often defined in terms of the materials that are technologically most important at the time (stone, bronze, iron etc.). Currently, we live in the silicon age, as our devices are almost entirely reliant on silicon technology. Yet, ferroelectric ceramics are equally key – they are used as the dielectrics in the vast majority of surface mount capacitors (Multi-Layer Ceramic Capacitors, or MLCC's) that are ubiquitous in modern electronic systems.

MLCC's usually contain doped barium titanate ($BaTiO_3$). This dielectric allows for a high permittivity which can be designed to be stable with respect to temperature and operating voltage variations. Over recent decades, research teams have been progressively optimising the properties of $BaTiO_3$ by changing the ceramic microstructure and the distributions of dopants. However, the endeavour is one of diminishing returns and so progressively industry is looking away from $BaTiO_3$ and towards alternative ferroelectric systems.

This Project

Kyocera/AVX has been collaborating with the University of Sheffield for a number of years and is seeking to sponsor a new programme, with the aim of exploring alternative ferroelectrics for MLCC's, based on the functional ceramics expertise of the academic team there. They are also keen to involve the ferroelectrics research team at Queen's University Belfast, primarily because of its expertise in characterisation using high-end (and often bespoke) microscopy techniques [1-4] and linking insights gained through microscopy to the functional behaviour of the materials.

This PhD project will therefore be mainly concerned with ferroelectric investigations based on microscopy, involving imaging, functional characterisation and chemical mapping to understand the origin of properties displayed that will help discover and optimise the dielectrics of the future for MLCC technology. The key techniques to be employed will be: scanning probe microscopy (mostly piezoresponse force microscopy), focused ion beam microscopy and transmission electron microscopy [1-4].

References

[1] J. R. Maguire *et al.* Ferroelectric domain wall p-n junctions. Nano Lett. **23** 10360 (2023); [2] Y. Tikhonov *et al.* Polarization topology at the nominally charged domain walls in uniaxial ferroelectrics. Adv. Mater. **34** 2203028 (2022); [3] L. J. McGilly and J. M. Gregg. Polarization Closure in $PbZr_{0.42}Ti_{0.58}O_3$ Nanodots. Nano Lett. **11** 4490 (2011); [4] J. McCartan *et al.* Fundamental Aspects of Conduction in Charged $ErMnO_3$ Domain Walls. Adv. Elec. Mater. **10** 2400091 (2024).