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Superdomains and Flux Closure Patterns in Ferroelectrics[1]

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Microstructural complexity has been a recognized feature of ferroelectric materials since the earliest optical microscopy studies on $BaTiO_3$ over 60 years ago,[2,3] in which rich patterns of domain states were observed. Arlt and Sasko[4] famously highlighted the existence of bands of domain structures forming herringbone patterns and, in so doing, helped to establish the notion that domain architectures exist over a number of different length scales: hierarchies naturally develop in which coarse-scale "superdomains" are themselves composed of sets of finer-scale "subdomains." What was not widely recognised, was that these "superdomains" could act as functional entities in their own right, with net polarisation and spontaneous strain being the vector sum of these quantities from constituent "subdomains". In this talk, we will explore the dominant role that superdomain functionality can have on the behaviour of ferroelectrics, at least at the meso and nanoscales. Observations made on single crystal thin film sheets and nanodots of $BaTiO_3$ (machined using a Focused Ion Beam Microscope) will be presented and several key points will be made: (i) that boundaries between superdomains generally adhere to the same constraints as those seen in subdomains (for example, that the divergence in the net superdomain polarisation across boundaries is zero); (ii) that superdomains demonstrate the same scaling laws (Landau-Kittel scaling) as were originally developed for simple subdomains; (iii) that ferroelectric switching can be entirely mediated by superdomains rather than subdomains; (iv) that flux closure objects, which extend beyond the nanoscale, require the existence of superdomains. The dynamics of flux closure formation, due to depolarising fields, has also been mapped and will be presented.

[1]The EPSRC is acknowledged for financial support.

[2]P. W. Forsbergh, Phys. Rev. 76, 1187 (1949).
[3]W. Merz, Phys. Rev. 95, 690 (1954).
[4]G. Arlt and P. Sasko, J. Appl. Phys. 51, 4956 (1980).