Seeking Simple Truth in Complex Materials: Wrestling with Ferroelectrics

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It is not trivial to perform experiments which reveal fundamental aspects of materials' behavior. This is particularly true in nanoscale ferroelectrics, as defect and strain free samples, of quality comparable to those used for semiconductor research for example, are not readily available; yet, the measured properties and behavior of ferroelectrics are often dramatically altered by the presence of defect states. The inevitable result is that physics, due predominantly to defect behavior, can easily be misinterpreted as fundamental to the ferroelectric itself (nicely illustrated in JF Scott's now infamous "Banana" paper [1]).

This talk will attempt to give an overview of two decades of research, performed mostly by the Queen's University Belfast ferroelectrics research team and its collaborators, in which initial frustrations with sample quality drove an alternative fabrication approach, where thin films and nanostructures were made by Focused Ion Beam (FIB) patterning of high purity single crystal bulk material. Studying these new kinds of samples has allowed a number of relatively clean insights into nanoscale ferroelectric properties: statements on the existence and nature of dielectric "dead-layers" in ferroelectric thin film capacitor structures have been possible [2]; flux-closure domains have been observed in simple and complex arrangements [3] which preempted the discovery of genuine dipole vortices [4]; room-temperature magnetoelectric multiferroic effects in single phase-single crystal nanosheets have been seen [5], as have intriguing properties of "superdomains" [6]. Novel methods to control switching and domain wall motion have also been developed in these FIB-machined samples [7].

Having spent so much effort to remove the influence of defects by examining only nanoscale high purity single crystals, it is somewhat ironic that the most recent research performed in Belfast concerns conducting domain walls in bulk ferroelectrics [8], where the existence of defects is extremely important for both maximizing wall conductivity and allowing the creation of domain wall electronic devices. Poetic justice will hence ensure that future research will involve the controlled introduction, rather than attempted removal, of defect states.

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