Tweed, Twins and Holes: a link between Mineralogy and Materials Science

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Abstract

The paper on “Tweed, Twins, and Holes”, recently published by Ekhard K.H. Salje (2014a) gives a comprehensive overview on experiments, theory and computer simulations of microstructures in ferroelastic and multiferroic minerals and synthetic crystals, with special emphasis on domain wall properties. Such materials are highly interesting for technological applications as well as from a more fundamental point of view, bearing a lot of open questions. Domain boundaries are nanometre sized objects which very often exhibit physical properties quite different from the bulk. This can lead to completely new functionalities as compared to single domain crystals.
Ekhard Salje draws a bow from Geophysics to Materials Science. He shows how materials scientists can make use of geo-materials and mineralogists can profit from theoretical understanding proposed by physicists. There is justified hope that both communities will intensify collaboration to the benefit of both.

In materials science there is a long tradition in studying the bulk properties of samples. Structural defects caused by impurities, vacancies, dislocations, and twin walls, etc. were labelled as disruptive to work. Historically, in most cases the intent was to grow, investigate and use single crystals of extremely high purity. This was and is quite different today in mineral science. Nanostructures have been a major research topic in mineralogy for many decades because they are common in minerals and they may be used to reconstruct the thermal history of a sample.
The situation changed fundamentally when it became possible to measure the functional properties of micro- and nanostructures by various experimental techniques like AFM, and piezoforce microscopy (PFM), etc. which have opened new research fields in physics and materials science. It turns out that domain walls can host properties that do not exist in the bulk solid (Catalan, et al. 2012). Typical examples are electrical or ionic conductivity, polarity or magnetism of domain walls embedded in a non-conducting paraelectric or paramagnetic matrix. An impressive example concerns the discovery of superconductivity of domain walls in an isolating WO_3 matrix (Aird and Salje 1998). Another breakthrough was the observation that ferroelastic domain walls in $SrTiO_3$ become polar below 80 K (Salje 2013), which was revealed by a clever modification of Resonant Ultrasound Spectroscopy (RUS) technique. “Domain engineering” (Fousek, Litvin and Cross 2001) or “Domain boundary engineering” (Salje and Zhang 2009) is nowadays systematically used to tailor

the properties of crystals, ceramics or thin films (Feigl 2014). But it is not just the static properties of a material that can strongly depend on microstructure (Waitz, Schranz and Tröster 2014), also the dynamic properties under external stress, electric- or magnetic fields are an important issue (Salje 2014b), and there are many open questions concerning the existence or non-existence of strain glasses (Kustov 2014), the role of polar nanoregions in relaxor ferroelectrics (Kleemann 2014) or the origin of domain freezing as well as its possible relation to glass freezing (Salje, Ding and Aktas 2014) in ferroelastic crystals.

It turns out, that the behaviour of inhomogeneous microstructured materials, especially those where long-range interactions are predominant, provides one of the most challenging problems in physics. It is the interplay of various material properties that operate over a range of length scales and a broad range of time scales which makes the problem so difficult; complete understanding can only be reached if experiments, computer simulations and theory go hand in hand.

In his recent American Mineralogist paper, Salje (2014a) demonstrates using several examples (including earthquake dynamics in collapsing nanoporous minerals) how minerals can inspire materials scientists and physicists can assist mineralogists to understand natural and synthetic materials in a much better way.

I am confident that the paper will contribute in closing the ranks between mineralogists and materials scientists, ultimately generating a long-term impact in the exciting field of nanostructured materials.

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