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Ferroelectrics: Nanoregions team together

Relaxors are materials that shrink or expand when subjected to an applied voltage — an important property for actuators that can convert electrical energy into delicate motion. The prototypical relaxor, lead magnesium niobate ($Pb(Mg_{1/3}Nb_{2/3})O_3$), known as PMN, is widely used in commercial micro-actuator technologies. However, although it was first investigated about fifty years ago, scientists are still trying to identify the structural properties that make PMN such an excellent relaxor.

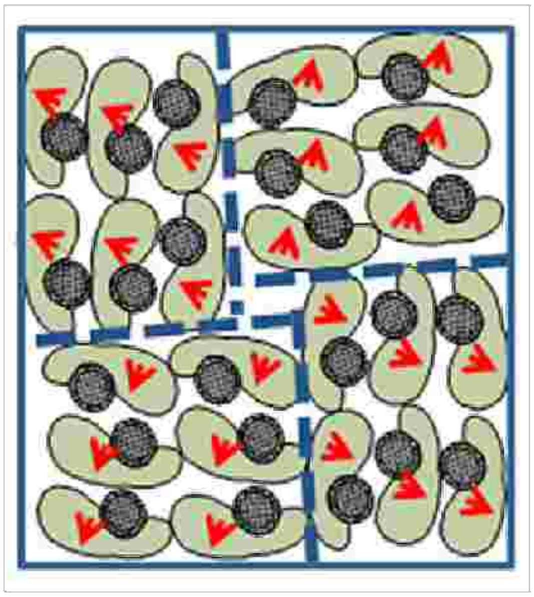

Fig. 1: The relaxor PMN behaves as though it is made up of many nanoscale ferroelectric regions (green), each with a large electric polarization (red arrows) that can rotate easily in an electric field. Non-ferroelectric regions (gray) break up the ferroelectric properties of PMN.

Now, Desheng Fu and colleagues at Shizuoka University in Japan, in collaboration with scientists at several Japanese institutions, are taking advantage of high-resolution imaging, coupled with measurements of the response of PMN crystals to an electric field, to show the role that this material's complex nanostructure plays in its relaxor properties[1].

The researchers performed a series of 'poling' measurements, where they cooled the PMN and measured its electric polarization while applying an electric field. In this way, they determined that PMN exhibits predominantly ferroelectric behavior — developing spontaneous electric polarization when cooled — rather than glass-like properties as expected.

PMN is, however, not a simple ferroelectric material: it is inhomogeneous, consisting of many nano-sized ferroelectric regions. These regions are oriented randomly at room temperature, but team up to align uniformly at temperatures lower than around 225 K. Under an electric field, all of the regions rotate into the same orientation, which is the origin of the large structural distortion of PMN.

Using transmission electron microscopy, the Japanese research team found that the individual ferroelectric regions were oval-shaped and just a few nanometers in size. They also found that many regions with similar polarization alignment cluster together to form a single larger 'domain' (Fig. 1). In between these larger domains, they observed spherical, non-ferroelectric areas, which appear to be what break up PMN into many nanoscale ferroelectric regions.

Explaining the significance of the work, Fu says, "Knowing that PMN has this nano-domain structure, we can design a new material in whic an electric or magnetic field can induce a large elastic deformation. For example, we could tailor the chemistry of PMN so that it has excellent relaxor properties at roo temperature, which would be more practically useful."

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Reference

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