Collective dynamics underpins Rayleigh behavior in disordered polycrystalline ferroelectrics

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Abstract: Nanoscale and mesoscopic disorder and associated local hysteretic responses underpin the unique properties of spin and cluster glasses, phase-separated oxides, polycrystalline ferroelectrics, and ferromagnets alike. Despite the rich history of the field, the relationship between the statistical descriptors of hysteresis behavior such as Preisach density, and micro and nanostructure has remained elusive. By using polycrystalline ferroelectric capacitors as a model system, we now report quantitative nonlinearity measurements in 0.025-1 μm^3 volumes, approximately 10^6 times smaller than previously possible. We discover that the onset of nonlinear behavior with thickness proceeds through formation and increase of areal density of micron-scale regions with large nonlinear response embedded in a more weakly nonlinear matrix. This observation indicates that large-scale collective domain wall dynamics, as opposed to motion of noninteracting walls, underpins Rayleigh behavior in disordered ferroelectrics. The measurements provide evidence for the existence and extent of the domain avalanches in ferroelectric materials, forcing us to rethink 100-year old paradigms.