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Nanoscale Structure and the Two-timescale Dynamics of Relaxor Ferroelectrics[1]

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The structural basis for the original dynamics of relaxor ferroelectrics lies in the development of mesoscopic or intermediate range order, the polar nanoregions (PNR). The formation of these PNRs can itself be related to the atomic site disorder that is characteristic of ferroelectric relaxors. For example, in $KTa_{1-x}Nb_xO_3$ (KTN), the niobium ions are off-centered in a [111] direction, and in $PbMg_{1/3}Nb_{2/3}O_3$ (PMN) both Nb and Pb are off-centered, the latter in either a [110] or a [111] direction. These off-center ions can hop or tunnel between different symmetry-related positions and, with decreasing temperature, their motion can become correlated. In PMN, it is obvious that the hopping times of Pb and Nb will be very different because of the large difference in their masses as well as in their off-centering distances. It should therefore not be surprising to observe dynamics on two different timescales, and possibly also on two different length scales, simultaneously. This has a decisive influence on the physical properties of these systems, which are no longer simply a statistical average of the microscopic properties, but are determined at the mesoscopic level. A variety of experimental results suggest the existence of a two-timescale dynamics, which appears to be characteristic of the relaxor behavior. In this talk, we present a selection of the most meaningful results that support this assumption in several relaxor systems (KTN, PMN, PZN): these include Raman and neutron scattering, NMR, dielectric and ultrasonic results. We describe the evolution of the nanoscale structure with temperature and the corresponding evolution of the relaxor dynamics. We show that this evolution is characterized by four stages, a purely dynamic stage, a quasi-dynamic stage, a quasi-static stage and a static or frozen stage, which are also apparent in the macroscopic properties of relaxors. Finally, we point to intriguing similarities between the dynamics of relaxors and that of structural glasses.

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