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Strain coupling and dynamic relaxation dynamics associated with ferroic and multiferroic phase transition

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Almost any change that occurs in a crystal structure results in some lattice strain and it is inevitable that this will appear also as a change in elastic properties. It follows that one of the most characteristic features of phase transitions, whether driven by structural, magnetic or electronic effects, will be variations of elastic constants. In addition, transformation microstructures such as ferroelastic twins may be mobile under some conditions of temperature and stress and will give characteristic patterns of acoustic loss when measured by dynamical methods. Thanks substantially to the pioneering work of Dr Albert Migliori in developing the technique of Resonant Ultrasound Spectroscopy (RUS), it has been possible to follow the elastic and anelastic behaviour associated with phase transitions quantitatively as a function of temperature through the interval 2-1600 K. It is also possible to add magnetic and electric fields. The frequency window 0.1-2 MHz and inherently small strains of RUS appear to be particularly sensitive for observing the consequences of strain coupling and microstructure relaxation dynamics. Recent collaborative work carried out using the RUS facilities in Cambridge will be presented, relating to phase transitions in multiferroic perovskites, such as $PbZr_{0.53}Ti_{0.47}O_3$-$PbFe_{0.5}Nb_{0.5}O_3$ and Sr_2FeMoO_6, the ferroelectric/improper ferroelastic transition in GeTe, and magnetoelastic behaviour of $EuTiO_3$. A common feature of these is softening of the shear modulus ahead of the transition that is not expected on the basis of linear/quadratic coupling between strain and the driving order parameter (improper ferroelastic). This appears to be due to coupling of acoustic modes with unseen central modes which are related to collective motions of domains with short range order. In some cases the ferroelastic twin walls have a well defined freezing interval (GeTe) whereas anelastic loss and stiffening over a wide temperature interval appears to be diagnostic of a microstructure with heterogeneous strain variations. Elastic softening by 10's of percent is typical of the effect of shear strains in the range 0.005-0.03.