Preformed, Nanoscale Ferromagnetism in Manganites

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Conventional second-order phase transitions such as the superconducting or ferromagnetic (FM) transition take place as the correlation length diverges with critical fluctuations as the temperature is lowered towards the transition point. However, there are intriguing situations where distinct intermediate states are involved in phase transitions. For example, the superconducting transition in the high-T_C cuprates is believed to be preceded by the appearance of preformed superconducting Cooper pairs, argued to exist in a broad temperature range below the so-called psuedogap temperature, T*. Similarly, ferroelectric relaxors are another important example, in that it has been observed that before the onset of long-range ferroelectric order, polar nano-regions (PNR) begin to appear below a certain temperature (the so-called Burns temperature), which is much greater than the ferroelectric transition temperature. From our Lorentz microscopy investigation, combined with conventional magnetic and thermodynamic studies, we have discovered the presence of a new thermodynamic FM phase characterized by the emergence of nano-scale (20-30 nm) magnetic regions (magnetic PNR) which in fact precede the onset of ferromagnetic long range order in the colossal magnetoresistive (La,Pr,Ca)MnO_3. Interestingly, we have also found two types of FM domain structures in the low-temperature, long-range FM state; typical micrometer-scale 180 ° FM domains with Bloch-type walls and 100 nanometer-scale 90 ° FM domains with wavy stripe patterns.

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