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Optical probes of symmetry breaking in magnetic and superconducting $BaFe_2(As_{1-x}P_x)_2$[1]

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The discovery of iron pnictide superconductors has opened promising new directions in the effort to fully understand the phenomenon of high-T_c, with a focus on the connections between superconductivity, magnetism, and electronic nematicity. The $BaFe_2(As_{1-x}P_x)_2$ (P:Ba122) system in particular has received attention because isovalent substitution of As for P generates less disorder than doping on the Fe site. The phase diagram of P:Ba122 is characterized by a line of simultaneous antiferromagnetic (AF) and tetragonal-to-orthorhombic transitions, $T_s(x)$, that penetrates the superconducting dome at x=0.28, just below optimal doping (x_{opt} =0.30). In this work, we use spatially-resolved optical polarimetry and photomodulated reflectance to detect linear birefringence and therefore breaking of 4-fold rotational (C_4) symmetry. In underdoped ($x<0.28$) samples, birefringence appears at $T>T_s$and grows continuously with decreasing T . The birefringence is unidirectional in a large (300 μm x300 μm) field of view, suggesting that C_4 breaking in this range of T is caused by residual strain that couples to a diverging nematic susceptibility. Birefringence maps just below $T_s(x)$ show the appearance of domains, indicating the onset of spontaneous symmetry breaking to an AF ground state. Surprisingly, in samples with $x>0.28$, in which the low T phase is superconducting/ tetragonal rather than AF/orthorhombic, C_4 breaking is observed as well, with an abrupt onset and domain formation at 55 K. We tentatively associate these features with a transition to an AF phase induced by residual strain, as previously proposed [H.-H. Kuo et al. Phys. Rev. B86, 134507 (2012)] to account for structure in resistivity vs. T. Time-resolved photomodulation allow us to follow the amplitude of the AF order with time following pulsed photoexcitation. Below T_c the AF order at first weakens , but then strengthens in response to the photoinduced weakening of superconductivity. This complex time evolution is accounted for quantitatively by a model based on the coexistence and competition of AF and superconducting order.

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