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ABSTRACT:

Strain-Induced Modulation of Electronic and Magnetic Properties in Fe_3O_4

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Electronic order in strongly correlated materials is highly sensitive to lattice geometry, as small variations in bond lengths and angles modify orbital overlap and interaction strengths. An effective tuning parameter must therefore change lattice symmetry without introducing disorder. Uniaxial stress fulfills this requirement by providing a direction-selective, symmetry-breaking distortion, unlike hydrostatic pressure or chemical substitution [1]. Here, uniaxial compression is employed to investigate the Verwey transition in stoichiometric magnetite (Fe3O4), a prototypical correlated oxide exhibiting coupled charge, orbital, and structural ordering at TV ≈ 123 K [2]. A compact, quantitatively calibrated uniaxial-pressure platform (SOL cell) was developed to enable reproducible in situ electrical transport and AC magnetic susceptibility measurements under directional stress, with calibration ensuring a reliable relationship between displacement and applied stress.
Transport and magnetic measurements reveal a pronounced anisotropic response for compression along the ⟨100⟩ and ⟨110⟩ directions. In both cases, TV increases with stress, indicating stabilization of the monoclinic phase, with the enhancement under ⟨110⟩ nearly an order of magnitude larger. AC susceptibility further shows a progressive suppression of the transition step and significant hysteresis broadening under ⟨110⟩ compression, consistent with strain-driven reorganization of magnetic and structural domains. These results demonstrate that strain symmetry critically governs the stability and evolution of the Verwey phase and establish directional lattice control as a quantitative tool for engineering correlated electronic states in magnetite.

[1] H. Elnaggar, ..., W. Tabiś, Phys. Rev. Lett., 127, 186402 (2021).
[2] K. Podgórska, …, W. Tabiś, Phys. Rev. B, 111, 051161 (2025).