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Exploring Dynamic Phase Transitions in the Vanadates using Terahertz Spectroscopy

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Richard D. Averitt, Boston University

In this presentation, I will discuss our recent work using transient strain and transient electric fields to drive phase transitions in complex materials. The goal of such studies is to investigate nonequilibrium phenomena in materials with strongly coupled charge, orbital, lattice, and spin interactions to explore myriad pathways in driving phase transitions with the ultimate goal of accessing new metastable states that, in a given material, are not thermally accessible.

Specifically, I will discuss our results on the vanadates VO2 and V2O3. V2O3 undergoes a transition from antiferromagnetic insulator at low temperatures to a strongly correlated metal above ~160K and VO2 exhibits an insulator to metal transition at 340K. Optical-pump THz-probe studies on V2O3 thin films reveal metallic-state coherent oscillations in the far-infrared conductivity. The 100 ps conductivity oscillations result from optically induced strain that drives V2O3 from the correlated metallic state towards a paramagnetic insulating phase. In addition, I will discuss experiments using metamaterial enhanced high field terahertz (THz) pulses (up to ~4MV/cm) to induce the insulator-to-metal transition in vanadium dioxide (VO2) thin films. Ultrafast THz field enhancement in the gaps of metamaterial split ring resonators releases free electrons in VO2 via the Poole-Frenkel effect. The accelerated hot electrons transfer energy to lattice via electron phonon coupling inducing the persistent VO2 phase transition. This electric-field induced phase transition occurs on a picosecond time scale.

Primary author: AVERITT, Richard (Boston University)

Presenter: AVERITT, Richard (Boston University)

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