

# PHYSICS DEPARTMENT COLLOQUIUM

## “Complex Materials: Dynamics of the Drude Response”

BY

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The Drude model is the simplest description of charge transport in materials such as metals and semiconductors. In essence, this model describes the response of a charge distribution to an applied electric field in terms of the carrier density, effective mass, and transport scattering time. Simple textbook derivations of the Drude model often imply that it is of limited utility when, in reality, the intuition it provides and its breadth of applicability is impressive. Measuring changes in the Drude response of a given material as a function of temperature or magnetic field provides a powerful probe of interactions that drive functional behavior such as metal-to-insulator transitions. Even in materials where there is a clear deviation from the Drude model, it serves as the starting point for advancing our understanding. A related issue is if dynamic measurements of the Drude response can provide insight into the functional properties of complex materials. I will answer this in the affirmative by providing three recent examples using time-resolved far-infrared and mid-infrared spectroscopy.

First, erbium arsenide nanoislands grown in GaAs in a superlattice structure using molecular beam epitaxy offer the means to tune the recombination time of photoexcited carriers. The short-lived (<1 picosecond) Drude response in ErAs:GaAs superlattices is superior to other materials enhancing the performance of photoconductive terahertz detectors [1]. Second, split ring resonators (SRRs) are an exciting new metamaterial exhibiting electric and magnetic resonances enabling new designer materials such as negative index of refraction lenses. I will present recent time-integrated and dynamic measurements of SRRs at far-infrared frequencies. Photoexcitation of carriers in the GaAs substrate upon which the SRR array is fabricated short the resonant response leading to an ultrafast narrowband switch [2]. Third,  $\text{Ti}_2\text{Mn}_2\text{O}_7$  is a recently discovered material that exhibits negative magnetoresistance – that is, an increase of the conductivity upon application of a magnetic field. Time-resolved mid-infrared measurements of the Drude plasma edge in  $\text{Ti}_2\text{Mn}_2\text{O}_7$  reveal that, in both the ferromagnetic and paramagnetic phases, carrier recombination is strongly influenced by spin fluctuations [3]. This suggests that in  $\text{Ti}_2\text{Mn}_2\text{O}_7$  spin disorder alone may be the primary driver for negative magnetoresistance in contrast to other materials where lattice polarons cannot be neglected.

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