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Donor doped cadmium oxide: An extreme-mobility oxide conductor

JON PAUL MARIA, North Carolina State University

The widespread interest in plasmonic technologies surrounds a wealth of emergent optoelectronic applications, such as plasmon lasers, transistors, sensors, and information storage. While materials for UV-VIS and near infrared wavelengths applications have been found, the mid-infrared range remains a formidable challenge to address: only a few known systems can achieve sub-wavelength optical confinement with low loss. Here, we undertake this challenge. A combination of experiments and *ab-initio* modeling demonstrate and understand an extreme peak of electron mobility in Dy-doped CdO that is achieved through "*defect equilibrium engineering*". In so doing, we create a tunable plasmon host that satisfies the demanding criteria for mid-infrared spectrum plasmonics, and overcomes the losses seen in conventional plasmonic materials like Ag and Au. Extrinsic doping pins the CdO Fermi level above the conduction band minimum. It increases the formation energy of native oxygen vacancies, thus reducing their populations by several orders of magnitude. The substitutional lattice strain induced by Dy-doping is sufficiently small, allowing mobility values around 500 $cm^2/V{\bullet}s$ for carrier densities above $10^{20}/\ cm^3$. CdO:Dy resembles the ideal "lossless metal", a potentially new material for exploring integrated mid-IR plasmonic applications. Our claim is based on temperature dependent transport, mid-IR spectroscopy, thermal transport, and *ab-initio* characterizations showing that 1) CdO:Dy is a model system for intrinsic and extrinsic manipulation of defects affecting electrical, optical, and thermal properties; 2) oxide conductors so prepared are ideal candidates for plasmonic devices; and 3) the defect engineering approach for property optimization is generally applicable to other conducting metal oxides.