THE MATERIALS SCIENCE AND ENGINEERING DEPARTMENT
SPRING COLLOQUIUM SERIES PRESENTS:

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Small Defects, Big Deal: Using point defects to control giant opto-mechanics and to engineer new resistive switches

My Semiconductor point defects that create deep charge traps are often to be avoided, because they speed up bad things (non-radiative recombination) and slow down good things (photodetector response). Nevertheless, deep traps often feature large charge-lattice coupling phenomena that are fundamentally interesting and could be put to good use. Here we present two studies and several potential applications of charge-lattice coupling at deep traps in II-VI semiconductors. We find that deep traps are correlated with giant opto-mechanical effects, such as changes in hardness and elastic modulus greater than 50% under relatively mild illumination (*e.g.* blue light at 1.5 mW/cm^2) during nanoindentation, and that these giant effects can be tuned by materials processing. We understand the giant photo-elastic effect as arising from strong charge-lattice coupling at point defects, which we model in atomistic detail using density functional theory. We also find that deep traps can be engineered as functional elements for two-terminal resistive switches, that operate by the same mechanism responsible for persistent photoconductivity, but without light (*i.e*. photoconductivity without photons). We illustrate how giant Stark effects (or giant Hung-Rhys factors) can be incorporated in semiconductor device band diagrams for predictive design of resistive switches with qualitatively new behavior. We will conclude with discussions of how these opto-mechanical and resistive switching effects may become useful for application.
As time allows, we may also discuss recent results in chalcogenide perovskites, including first-of-a-kind epitaxial film growth by gas-source molecular beam epitaxy (MBE), band gap tuning by alloy and phase control, and physical properties measurements that point to the importance of strong lattice fluctuations for the functional properties of these emerging semiconductor materials.

Rafael Jaramillo is the Thomas Lord Associate Professor of Materials Science and Engineering at MIT. His research sits in the big, fun space between materials science, solid state physics, and opto-electronic technologies. His current interests can be characterized as defect and phase engineering of chalcogenide semiconductors, with emphasis on developing processing methods to control sulfide and selenide thin films. Prior to joining the faculty at MIT, he worked as a postdoc at Harvard and at MIT on topics in oxide electronic materials and chalcogenide thin-film solar cells. He earned his PhD from The University of Chicago for work on antiferromagnetism and quantum phase transitions in chromium. Dr. Jaramillo is the recipient of numerous awards including the Rosalind Franklin Young Investigator Award from the Advanced Photon Source at Argonne National Laboratory, the Department of Energy SunShot Potdoctoral Fellowship, and the National Science Foundation Faculty Early Career Development Award (CAREER). He lives in Cambridge, MA with his wife and kids.

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