Russell Berrie Nanotechnology Institute
Technion - Israel Institute of Technology

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"Understanding Hybrid Lead-halide Perovskites"

Wednesday,
02 November, 2016

12:00 refreshments
12:30 lecture

Wang Auditorium
The Dalia Maydan Building
Faculty of Materials Science and Engineering

RBNI Monthly Seminar Series 2016

TECHNION
Israel Institute of Technology

Understanding Hybrid Lead-halide Perovskites

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Hybrid lead halide perovskites exhibit carrier properties that resemble those of pristine nonpolar semiconductors despite static and dynamic disorder, but how carriers are protected from efficient scattering with charged defects and optical phonons is unknown. Here, we probe the mechanism of charge carrier protection in hybrid perovskites using femtosecond time-resolved photoemission, time-resolved photoluminescence, and nonlinear optical spectroscopies. We find that nascent charge carriers are screened by "solvation" or large-polaron formation on time scales $\leq$ 250 fs, leading to protected carriers with dramatic suppression of electron- LO phonon scattering. This results in long-lived energetic electrons with excess energy ~ 0.25 eV above the conduction band minimum and with lifetime on the order of 100 ps, which is $\geq 10^3$ time longer than those in conventional semiconductors. The exceptionally long-lived energetic carriers lead to hot fluorescence emission on the ~100-200 ps time scale. The protection of energetic carriers is directly correlated with the liquid-like reorientational motion of organic cations, as revealed in nonlinear optical spectroscopy. The formation of protected energetic carriers requires the competitive ultrafast dynamics of large-polaron formation in the dynamically disordered hybrid perovskite structure. In contrast to that of energetic carriers, the protection of long-lived bandedge carriers do not require the presence of organic cations and is an intrinsic property of the soft perovskite lattice.

[1] Haiming Zhu, Kiyoshi Miyata, Yongping Fu, Jue Wang, Prakriti P. Joshi, Daniel Niesner, Kristopher K. Williams, Song Jin, X.-Y. Zhu, "Screening in crystalline liquids protects energetic carriers in hybrid perovskites," *Science*, **2016***, 353*, 1409-1413.

[2] X.-Y. Zhu, V. Podzorov, "Charge carriers in hybrid organic-inorganic lead halide perovskites might be protected as large polarons," *J. Phys. Chem. Lett.* **2015**, *6*, 4758-4761.

[3] Haiming Zhu, M. Tuan Trinh, Yongping Fu, Jue Wang, Prakriti P. Joshi, Kiyoshi Miyata, Song Jin, X.-Y. Zhu, "Organic cations might not be essential for the exceptional properties of bandedge carriers in lead halide perovskites," *Adv. Mater.* **2016**, *28,* in press.