CMP Seminar
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Heat Trap and Nano Thermionics/Thermoelectrics

Abstract: When a beam of light strikes a bulk conductor, the heat generated at the point of incidence dissipates into a wide area; no significant temperature increase takes place unless a very high optical intensity is used. I will discuss how the situation is drastically different in carbon nanotube forests: although they are understood to be good conductors, surprisingly, the heat generated in them can remain localized to the illuminated spot. We explain this "Heat Trap" effect based on the quasi-one-dimensional nature of heat transfer and the strong temperature dependence of thermal conductivity in these materials, and we have seen that this could, in fact, be not limited to nanotubes, but a property of one-dimensional systems in general.

Why does this matter? Consider the conversion of light or heat to electricity, where the absorption of photons, the blockade of phonons, and the release of electrons are of fundamental importance. We will see that carbon nanotubes seem to have much to offer on all these fronts. For example, one way to harvest solar energy is through the photovoltaic effect. But another mechanism, that of thermionic emission of electrons from a hot cathode and their collection by a cold anode in vacuum, has also been known for decades, with advantages such as inherent simplicity, robustness, and high current/power density. However, heating a bulk cathode to thermionic emission temperatures using sunlight is a fundamental challenge, requiring impractically high intensities, achievable only by using large sunlight collection/focusing and complex thermal isolation infrastructure. On the other hand, the Heat Trap effect allows the efficient heating of nanotube cathodes to very high temperatures using a low-power beam of light, thus enabling simple and compact solar thermionic devices, examples of which I will present. We will also see that the implications of this effect go beyond simple thermionic conversion and involve multi-photon photo-thermionics, thermoelectrics, vacuum electronics and phononics.

Speaker biography: Alireza Nojeh received his BS and MS degrees in electrical engineering from Sharif University of Technology. His work there focused on optoelectronic modulators based on interface charge layers. He then obtained a DEA in electronics/optoelectronics at the University of Paris XI - Orsay, where he worked on high electron mobility transistors, and a PhD in electrical engineering at Stanford University (2006), where he worked on carbon nanotubes, focusing on nanoscale electron emitters. He then joined the University of British Columbia, where he is currently an associate professor of electrical and computer engineering. This year, he is also a Wall Scholar at the Peter Wall Institute for Advanced Studies at UBC. His research interests are still in nanotechnology, in particular in carbon nanotube devices; interaction of light with nanostructures; energy conversion; electron sources, vacuum electronics and electron microscopy; solid-state electronics; micro/nanofabrication; and modeling and simulation of nanoscale structures.

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