Two Dimensional Materials: New Physics and New Applications

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Abstract

As the research in atomically thin two dimensional (2D) is maturing, a good question to ask now is what new science has been discovered and what new technologies have been realized. While it is becoming increasingly clear that two dimensional materials studied thus far will likely not be able to compete with mature electronic and photonic technologies like silicon transistors and III-V semiconductor lasers and detectors, 2D materials do offer opportunities to realize novel devices and technologies that, i) cannot be realized easily by traditional materials, and ii) are in fact useful. In this presentation, we will discuss a few of these new technologies, in the electrical, mechanical and optical arenas, that have been made possible as result of the research on 2D materials conducted in our group at Cornell and also by other groups. The high mobility of carriers in graphene allow plasmons to propagate with lower losses compared to all other materials. Our experimental and theoretical work shows that graphene plasmonic structures can be used to realize VLSI electrical interconnects that have much lower propagation delays, much lower losses, and much reduced signal distortion compared to state of the art copper interconnects (i.e. a beyond-copper technology!). Our work in transition metal dichalcogenides has shown that multilayer stacks of these 2D atomic layers support mechanical oscillation modes with frequencies approaching one terahertz and with high quality factors. These high frequencies are unmatched by any other MEMs material and the frequency-quality factor products of these modes, a figure of merit of MEMs oscillators, exceed that of any other known MEMs material even at much lower frequencies. Finally, our recent work has shown that bilayer graphene supports excitons whose optical transition energies can be electrically tuned all the way from zero to mid-IR values. This enormous tunability is unmatched by any other known material and offers opportunities for hyperspectral detection and imaging. The presentation will also discuss the new science discovered in each case.

Bio Note:
Farhan Rana is the Joseph P. Ripley Professor of Engineering and the Associate Director of the School of Electrical and Computer Engineering at Cornell University. He received the B.S., M.S. (1997), and Ph.D. (2003) degrees all in Electrical Engineering from the Massachusetts Institute of

Technology (MIT). Before starting the Ph.D., he worked at IBM's T. J.Watson Research Center on Silicon nanocrystal and quantum dot flash memory devices. He joined the faculty of Electrical and Computer Engineering at Cornell University, Ithaca, NY, in 2003 and started the semiconductor nanostructures and optoelectronics research group. He has more than 200 publications in refereed journals and conferences. He received the US DefenseAdvanced Research Projects Agency (DARPA) Young Faculty Award in 2008, the US National Science Foundation (NSF) CAREER Award in 2004, the ILX Lightwave Faculty Award in 2005, Cornell's Michael A. Tien Excellence in Teaching Award in 2006 and in 2017, and the College of Engineering Teaching Award in 2010. He has also received several best paper awards including the "Most Downloaded Paper" title in 2008 by the IEEE Transactions on Nanotechnology and he was included in the list of the top 50 most cited authors published by the Applied Physics Letters. In 2013, he was ranked among the top 10 professors at Cornell University by the Business Insider magazine. He was awarded the Cornell's College of Engineering Outstanding Research Award in 2016.