Revisiting old questions in new materials  
By  
Dr Shaffique Adam  
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Date: 5 September 2013, Thursday  
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Venue: Hilbert Space (SPMS-PAP-02-02)  
Host: Asst. Prof. Pinaki Sengupta

Abstract

From the hard-drives that harness giant magneto-resistance to the transistors that drive modern processors, solid state physics is at the very heart of the technological revolution. Implied in this effort is a thorough understanding of electronic systems in nanoscale geometries. In this context, the complex interplay between disorder, electron-electron interactions and quantum interference is an interesting backdrop to many of the unsolved mysteries in condensed matter physics. About seven years ago, a new electronic material appeared – notable not only for its ease of preparation and theoretical simplicity, but also by its promise for future electronic devices [1]. Single monatomic sheets of carbon, known as graphene, have an electronic dispersion that is reminiscent of light, in that they can be described as a massless Dirac particle. In many ways, graphene is a textbook system to test physical models – for instance, similar to field-effect transistors, the electron density in graphene sheets can be modulated by a backgate. However, unlike conventional semiconductors, the carrier density can be continuously tuned from electron-like carriers for large positive gate bias to hole-like carriers for negative bias, with the Dirac point defined as the singularity that marks the transition from electrons to holes. When graphene is close to charge neutrality, its energy landscape becomes highly inhomogeneous, forming a sea of electron-like and hole-like puddles, which determine the properties of graphene at low carrier density. In this talk, I will discuss how the electronic properties of the Dirac point provide an intriguing example of how the competing effects of disorder, electron-electron interactions, and quantum interference conspire together to give a surprisingly robust state whose properties can be described using semi-classical methods. Armed with this success, I will discuss how future graphene experiments could shed light on some long-standing open questions in condensed matter physics.

References

Short Biography

Shaffique Adam is a theoretical physicist excited about understanding the complex and surprising ways electrons behave when they are subject to the interplay of quantum mechanics, material imperfections, confined geometries and interactions with other electrons. This love of discovery and passion to share it with others was kindled as an undergraduate at Stanford (BS, 2000) and reinforced as a graduate student at Cornell (PhD, 2006). After spending three years as a post-doctoral researcher at the Condensed Matter Theory Center at the University of Maryland, he later joined the Center for Nanoscale Science and Technology at the United States National Institute of Standards and Technology as a Fellow of the National Research Council of the United States National Academy of Sciences. He is currently an Assistant Professor jointly at Yale-NUS College and at the Graphene Research Centre with the Department of Physics at the National University of Singapore and a 2012 recipient of the Singaporean National Research Foundation Fellowship, which provides S$3 million in research funding over five years to study the effects of interactions in new materials like graphene and topological insulators. Shaffique has published over 30 papers in prominent journals including Nature, Nature Physics, the Proceedings of the National Academy of Sciences (USA) and Physical Review Letters trying to understand the physical mechanisms at play in a variety of technologically important advanced materials such as semiconductor quantum dots, magnetic nanoparticles, and graphene.

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