IBS CINAP Special Lecture

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Interlayer Excitons and Magneto-Exciton Condensation In van der Waals Heterostructures

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Abstract

A pair of electron and hole across the interface of semiconductor heterostructure can form a bound quantum state of the interlayer exciton. In a coupled interface between atomically thin van der Waals layers, the Coulomb interaction of the interlayer exciton increases further. Coulomb drag effect is a mesoscopic effect which manifests many-body interactions between two low-dimensional systems, which has served an extremely useful probe the strong correlation in quantum systems. In this presentation, we will first discuss observing interlayer exciton formation in semiconducting transition metal dichalcogenide (TMDC) layers. Unlike conventional semiconductor heterostructures, charge transport in of the devices is found to critically depend on the interlayer charge transport, electron-hole recombination process mediated by tunneling across the interface. We demonstrate the enhanced electronic, optoelectronic performances in the vdW heterostructures, tuned by applying gate voltages, suggesting that these a few atom thick interfaces may provide a fundamental platform to realize novel physical phenomena. In addition, spatially confined quantum structures in TMDC can offer unique valley-spin features, holding the promises for novel mesoscopic systems, such as valley-spin qubits. In the second part of the presentation, we will discuss magneto-exciton condensation. In this electronic double layer subject to strong magnetic fields, filled Landau states in one layer bind with empty states of the other layer to form an exciton condensate. Driving current in one graphene layer generates a near-quantized Hall voltage in the other layer, resulting in coherent exciton transport. In our experiment, capitalizing strong Coulomb interaction across the atomically thin hBN separation layer, we realize a superfluid condensation of magnetic-field-induced excitons. For small magnetic fields (the BEC limit), the counter-flow resistance shows an activation behavior. On the contrary, for large magnetic fields limit where the inter-exciton separation decreases (the BCS limit), the counter-flow resistance exhibits sharp transitions in temperature showing characters of Berezinskii-Kosterlitz-Thouless (BKT) transition. Furthermore, complete experimental control of density, displacement and magnetic fields in our graphene double layer system enables us to explore the rich phase diagram of several superfluid exciton phases with the different internal quantum degrees of freedom.

Brief Bio

Professor Philip Kim received his B.S in physics at Seoul National University in 1990 and received his Ph. D. in Applied Physics from Harvard University in 1999. He was Miller Postdoctoral Fellow in Physics from University of California, Berkeley during 1999-2001. He then joined in Department of Physics at Columbia University as a faculty member during 2002-2014. Since 2014, he moves to Harvard University, where he is Professor of Physics and Professor Applied Physics.

The focus of Prof. Kim's group research is the mesoscopic investigation of transport phenomena, particularly, electric, thermal and thermoelectrical properties of low dimensional nanoscale materials. These materials include carbon nanotubes, organic and inorganic nanowires, 2-dimensional mesoscopic single crystals, and single organic molecules.

Professor Kim also received numerous honors and award including Oliver E. Buckley Prize (2014) from American Physical Society.

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