Condensed Matter Seminar

Making compound semiconductor nano-dots, -rings, and -spikes

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The formation of nanoscale structures continues to be an important topic of research for a variety of applications, including solar cells, thermoelectrics, and quantum information processing. Our group examines the fundamental physics behind the formation mechanisms of III-V compound semiconductor nanostructures produced from both a "top-down" and self assembled point of view. In this talk I will concentrate on three different approaches for nanostructure formation, each having significantly different governing mechanisms and result in different shapes. The first is the well studied strain driven self assembly of quantum dots, which has important applications in intermediate band solar cells. One aspect of this mechanism that hasn't been examined is the importance of the initial surface reconstruction in the formation of the dots. We show that it directly affects the microstructure, optical and transport properties of these dots. Furthermore, capping these structures significantly alter their shape. The second formation method of nanostructures is droplet epitaxy, in which liquid metal is first deposited on a surface, followed by exposure to a group V flux and subsequent crystallization. Droplet epitaxy is particularly attractive because nanostructure formation is not strain-driven, enabling the fabrication of dots in lattice matched systems. Furthermore, several different shapes may be obtained, including compact islands, rings, and extended discs. Kinetic Monte Carlo simulations that explicitly take the group III and group V species into account elucidate the kinetic processes responsible for these shapes, and predict new structures that have yet to be reported experimentally. The third method is focused ion beam erosion for creating nanospikes, which proceeds via an ion-induced droplet masking process. Metallic droplets form on the surface due to preferential sputtering of the group V such that nanospikes form under the droplets as the surrounding material is etched away. The nanospikes possess a metallic indium cap, an ion damaged outer layer, and a core with varying crystalline perfection. Their electrical properties have been characterized using a combined *in-situ* TEM/nanoprobe technique, which allows for simultaneous TEM imaging and current-voltage measurements. The nanospikes are conductive and show non-Ohmic current-voltage behavior that depends on the details of the microstructure of each spike. The ion-disrupted yet still conductive nature of the nanospikes may make them useful for nanoscale thermoelectric applications.

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