Trions at a Trapping Defect

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Trions—or charged excitons— are quasi-particles composed of two electrons and one hole (or vice versa). Particularly a negative trion may be seen as an analog to the anions of hydrogen and positronium. In contrast to excitons, a trion features a net charge and half integer spin, which allow for the manipulation of electron spin and optically probing local electrostatic fluctuations. Governed by optical selection rules different from those of excitons, trions can also significantly impact the dynamics of optically forbidden dark excitons. Because of their unique properties, trions have been intensively explored for a broad range of potential applications, including quantum information, sensing, energy harvesting, lasing, and light-emitting devices. The existence of trions was experimentally confirmed only recently, first in quantum wells and more recently in carbon nanotubes. In SWCNTs, trions have been generated by high power laser excitation [1, 2] and doping [3-6] of the host material. However, in the few previous cases in which trions have been observed, trion PL is rather weak. One of the key factors that fundamentally limits trions to rise as a dominant species is their low binding energy.

In this talk, we will discuss experimental evidence of trions that are trapped at chemical defects synthetically introduced into semiconducting SWCNT hosts. [7, 8] By co-localizing charges with excitons at these emissive defect centers we show that it is possible to produce ultrabright trions. The trap-localized trions fluoresce brightly at room temperature, even with weak excitation. We experimentally determined the binding energy of the defect-localized trions to be as large as 119 meV in (6,5)-SWCNT, which are significantly larger than that of mobile trions in the same host (54 meV), 0D quantum dots (2–25 meV), and also 2D materials (15–45 meV), and can even be compared to the 327 meV binding energy of positronium anions. The trapped trions have a photoluminescence lifetime that is more than two-order of magnitude larger than “free” trions in the same host material. Our defect dependence studies and magnetoluminescence spectroscopy suggest that unlike native excitons and free trions, these trapped trions are intrinsically bright.

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