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Emerging Strategies for the Rational Synthesis of Copper-Chalcogenide Based Hetero-Nanorods

Celso de Mello Donegá

Condensed Matter and Interfaces, Debye Institute for Nanomaterials Science, Utrecht University, P.O. Box 80000, 3508 TA Utrecht, The Netherlands.

Colloidal semiconductor heteronanocrystals (HNCs) exhibit unique optoelectronic properties that are inaccessible to single-component NCs, making them promising materials for a wide range of applications. The optoelectronic properties of HNCs are determined not only by the bandgap and band alignment of its constituent materials but also by their morphology and heteroarchitecture. Applications requiring efficient charge separation (*e.g.*, photovoltaics and photocatalysis) greatly benefit from anisotropic morphologies, such as heteronanorods. Most of the work on heteronanorods has focused on Cd-chalcogenide-based HNCs. However, given the toxicity of Cd, the potential of these materials for large scale applications is limited.
Copper-chalcogenide based NCs have attracted increasing attention as promising alternatives for Cd- and Pb-chalcogenide NCs due to their low toxicity, large absorption cross-sections across a broad spectral range, composition-dependent band gaps in the 1 to 2.5 eV range, and photoluminescence tunability, spanning a spectral window that extends from the UV to the NIR depending on the NC size and composition.
Several synthetic strategies have been used in the quest for high-quality colloidal copper chalcogenide based HNCs. The most promising ones are based on the multistage approach, which allows the combination of different synthesis techniques (e.g., cation exchange or seeded growth) in a sequential manner in order to achieve the targeted preparation of colloidal HNCs. In this talk, I will discuss a selection of recent examples, chosen in order to provide an overview of the current status of the quest for Cd- and Pb-free HNCs and to illustrate specific synthesis strategies: $CuInSe_2/CuInS_2$ dot core/rod shell heteronanorods, $Cu_{1.8}S$-based multicomponent axially segmented heteronanorods, $CuInS_2/ZnS$ dot core/rod shell heteronanorods, and Janus-type $Cu_{2-x}S/CuInS_2$ and $Cu_{2-x}S/ZnS$ heteronanorods. I will show that by combining the design principles of post-synthetic heteroepitaxial seeded growth and nanoscale cation exchange into multistage synthesis strategies one can potentially gain access to a plethora of Cu-chalcogenide-based multicomponent heteronanorods with diameters in the quantum confinement regime.