Synthesis Strategy of Ag-Based Multinary Quantum Dots from the Perspective of Controlling Emission Properties

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The synthesis and application of semiconductor quantum dots (QDs) have recently become one of the main topics of nano-colloidal chemistry. Conventional QDs such as CdSe, CdTe and PbSe have (1) a wide absorption band, (2) a high photoluminescence quantum yield (PL QY), and (3) a controllable energy gap (E_g) due to the quantum size effect. Because of these attractive optical properties, QDs have become key materials for optical and optoelectronic applications such as biological markers, light emitting devices, and solar cells. However, one of the biggest problems of CdSe and PbSe were that they contain highly toxic elements and therefore have limitations for commercial QD-based applications.

To overcome this disadvantage, efforts have been focused on the preparation of multinary semiconductor QDs consisting of a group I-III-VI semiconductor, such as $CuInS_2$ and $AgInS_2$. These low-toxic semiconductor QDs having a direct band gap and a large absorption coefficient have been extensively studied as luminescent and absorbing materials. Due to many efforts, these multinary QDs have been developed to show sufficiently strong emission (PL QY > 80%) in visible and the near-infrared (NIR) light regions. Unlike conventional binary QDs, the E_g of I-III-VI-based multinary QDs can be conveniently altered by changing the particle size as well as their chemical composition. Group I-III-VI semiconductors can easily form a solid solution with a group II-VI semiconductor having a similar crystal structure, and the particle composition greatly influences the E_g of QDs.

So far, we have developed I-III-VI-based semiconductor QDs of ZnS-$AgInS_2$ (ZAIS) solid solution with good PL properties and have been working on the control of their PL wavelength in the visible wavelength region by tuning in their size and chemical composition of the solid solution.[1-3] Furthermore, we have found that ZAIS QDs precisely synthesized in this manner are useful not only as light-emitting materials but also as energy conversion materials such as photocatalysts and sensitizers in solar cells. However, further improvements in the optical and photoelectrochemical properties are needed to replace high-quality conventional QDs with these multinary QDs. Recent advances in I-III-VI-based semiconductor QDs and their solid solutions for photoluminescence and photoelectrochemical applications will be present in this presentation.

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