All-inorganic colloidal Si nanocrystals -control of luminescence and surface chemistry by codoping boron and phosphorus

Hiroshi Sugimoto, Shinya Kano, Minoru Fujii,
Department of Electrical and Electronic Engineering, Graduate School of Engineering, Kobe University, Rokkodai, Nada, Kobe 657-8501, Japan
E-mail: h.sugimoto@people.kobe-u.ac.jp

Colloidal semiconductor nanocrystals (NCs) can be used as inks for solution-processed optoelectronic devices, and as nanoprobes fluorescence imaging in biological cells. Silicon (Si) NCs have advantages in their compatibility with biological substances and the Si technology. In contrast to the great advancements in colloidal II−VI and IV−VI semiconductor NCs, it is only recently that the quality (crystallinity, size-distribution and stability in solution) of colloidal Si NCs has been improved. In this talk, we introduce a new type of colloidal Si NCs that are heavily doped with boron (B) and phosphorus (P) simultaneously.[1] By impurity codoping, the structural and optical properties of Si NCs are dramatically modified. First, codoped NCs are dispersible in alcohol and water without organic ligands (see Figure 1(a)). Detailed structural analyses including atom probe tomography demonstrate that heavily B and P doped surface shells are formed. The shell induces negative potential on the surface and provides the colloidal stability in polar solvents. Figure 1(b) shows the photoluminescence (PL) spectra of codoped Si NCs with different diameters. The codoped NCs exhibit size controllable PL in a wide energy range (0.85−1.85 eV).[2] The PL energy below bulk Si bandgap suggests that impurity states are involved in the optical transition. In this presentation, our recent results regarding detailed PL properties, energy level structures[3] and PL study in biological cells of codoped Si NCs will be presented. [1] J. Phys. Chem. C 116, 17969 (2012), [2] J. Phys. Chem. C 117, 11850 (2013), [3] Nano Lett., 16, 2615 (2016).

半導体の最大の利点は不純物ドーピングにより物性を制御できる点であり、半導体ナノ構造にも適応できることが理論的に示されている。シリコンナノ結晶中へのｎ型、ｐ型不純物をドーピングは不純物準位形成によるシリコンナノ結晶の発光制御という新たな光る過程の新たな制御法として有効である。

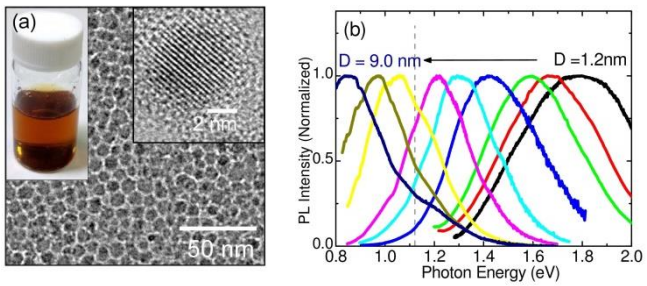

Fig. 1(a) Photograph, TEM and HRTEM images of colloidal codoped Si NCs. (b) PL spectra of codoped NCs with different average diameters (λ_{ex} = 405 nm).