Layer-by-Layer deposition of stable silica coated ZnCuInS nanocrystals for LED application

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Abstract

Ideally, well ordered multi nanocrystals (NCs) layer can prevent the re-absorption and control the energy transfer within different emissive NCs, and increase the color conversion efficiency by minimizing several intermediate energy-loss steps [1]. Layer-by-Layer (LbL) self-assembly is suitable for fabricating a uniformly ordered layer, utilizing electrostatic attractions between oppositely-charged materials, hydrogen bonding, covalent bonding, and other specific interaction [2-4].
In this study, non-toxic and stable silica coated ZnCuInS NCs were synthesized by a reverse microemulsion method using Igepal CO-520, ammonia aqueous solution (28wt%), and TEOS as nonionic surfactant, base catalyst, and silanization precursors, respectively. The NCs were uniformly encapsulated in a silica shell with a diameter of ~30nm. Although hydrolyzed TEOS caused a QY reduction from 63% to 39%, and a 12.5nm red shift occurred after silica coating, the photo and thermal stabilities were extremely improved. For LED application, the silica coated ZnCuInS NCs phosphor layer was arrayed on the 430nm InGaN LED surface by layer-by-layer deposition utilizing electrostatic attraction. GaN surface (1x1 mm) was treated using reactive ion etching with O2 plasma to form a negative charge. The substrate was alternately dipped into an aqueous solution of PDDA (Poly(diallyldimethylammonium chloride), Mw=100,000-200,000, 20wt% in H2O) and ZnCuInS/SiO2 NCs (1 mg/mL) for 20 min, and washed with D.I water. When the ZnCuInS/SiO_2 NCs single monolayer was fabricated, 6.73% high color conversion efficiency was achieved.
These results indicate that the stable silica coated ZnCuInS NCs are promising materials for color converting in solid state light sources. Furthermore, layer-by-layer deposition is suitable for fabricating a uniformly ordered phosphor layer, and for high color conversion efficiency.

References

[1] M. Achermann, M. Petruska, D. Koleske, M. Crawford and V. Klimov, Nano Lett. **6** (2006) 1396-1400
[2] G. Decher, Science **277** (1997) 1232-1237
[3] Y. Lvov, K. Ariga, M. Onda, I. Ichinose and T. Kunitake, Langmuir **13** (1997) 6195-6203
[4] A. Rogach, D. Koktysh, M. Harrison and N. Kotov, Chem. Mater. **12** (2000) 1526-1528

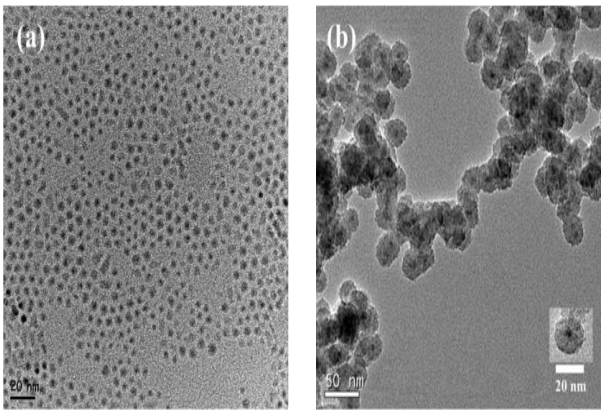

Fig 1. HR-TEM image of (a) ZnCuInS NCs, and (b) silica coated ZnCuInS NCs.

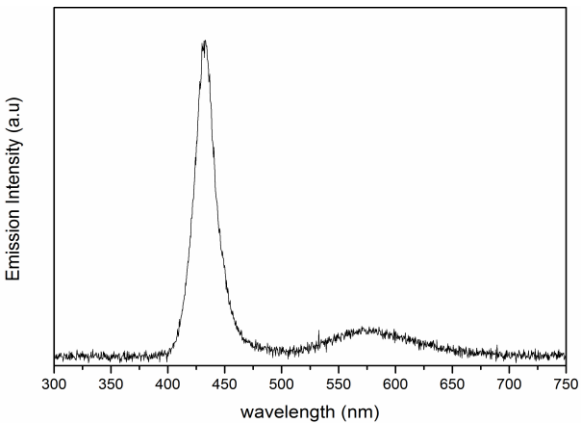

Fig 2. The emission spectrum of fabricated color conversion LEDs. 430nm InGaN LED pumped with ZnCuInS/SiO_2 NCs monolayer phosphor.