Color Converter Based on Giant Shell Quantum Dots and Their Composites

Sören Becker¹, Jan Niehaus¹
soeren.becker@iap.fraunhofer.de
¹Fraunhofer IAP-CAN, Grindelallee 117, 20146 Hamburg, Germany
Keywords: giant shell quantum dot, polymer composite, color conversion

ABSTRACT
We present an automated and up-scaled synthesis of giant shell QDs (GSQDs). For color conversion, the ligand shell of these particles will be adjusted. The modified QDs will be incorporated in suitable matrices with high QD content and transferred onto a blue light LED.

1 Introduction
In 2013 Sony released the first quantum dot TV (QDTV) based on zero-dimensional, spherical semiconducting nanocrystals (QDs) with improved color gamut. Today especially Samsung is pushing the technology within their QLED TV range. Despite their naming these displays still use QD sheets in the back light unit to produce white light suitable for a wider color gamut. In fig. 1 the stacked composition of an established QDTV is schematically shown. The blue light (~ 450 nm) of the back light unit (BLU) interacts with the QDs in polymer film leading to white light. As in traditional TV panels this light is used to illuminated the single pixels of the LC unit. However more advanced approaches to use QDs in a TV like electroluminescence, on chip color conversion or as a replacement for the color filters lack of QDs with suitable properties. Especially the stability at high flux is a mayor issue.

Therefore, the next generation of optoelectronic display devices have to use more advanced quantum dots, which can face these challenges. Beside the possibility of using particles with an elongated shell (1D), another superior particle design consists of a core with a typical spherical, but very thick shell (giant shell quantum dot, GSQD). These 3D structures still show the quantum size effect due to the small size of the core, but the giant shell leads to enhanced stability and huge absorption coefficients in the blue while the reabsorption rate remains neglectable. [1, 2]

For the integration of GSQDs for color conversion in QDTV they need to be incorporated into a suitable polymer film with a very high QD load to allow high absorption rates within a thin composite film (see fig. 2). The polymer matrix also offers protection against moisture and oxygen extending the lifetime of the QDs.

Fig. 1 Simplified schema of established QDTV

Fig. 2 CdSe/CdS nanoparticles in monomer (top) and polymer (bottom)

The main challenge while embedding QDs in a polymer matrix is the suppression of unwanted agglomeration. This clustering lead to an unwanted shift of the emission wavelength, broadening of the emission signal and to a reduction of quantum yield due to energy transfer processes.

2 Experiment
To allow the fabrication of suitable QDs for these demanding applications, Fraunhofer IAP-CAN has developed an automated synthesis for GSQDs.[3] The diameter of the core particles can be varied between 1.6 and 5 nm so that the band gap is strongly influenced by the size quantization effect. On these cores, a shell is grown expanding the particle diameter up to 20 nm. The
continuous addition of the precursors allow a defect free
growth of the shell with a pronounced crystallinity (fig. 3).

To utilize these particles for color conversion
applications, Fraunhofer IAP-CAN has developed a
strategy to adjust the ligand shell to fit the different polarity
of solvent, monomer and polymer matrix. Using this
 technique the GSQDs were incorporated into a different
matrices with a QD load above 1% suitable for high flux
applications.

3 Results and Discussion
The quantum yield of the synthesized GSQDs is close
to 1, absorption in the blue is high, while the reabsorption
rate is low (fig. 4). Stability measurements of these GSQDs
prove that this shape is superior to QD, 1D and 2D particles,
especially concerning photoluminescence stability at high
flux. However, the shell growth also results in a
tremendous red shift of the emitted light compared to the
core prior to shell growth. This effect makes the synthesis
of red emitting GSQD favorable, while the synthesis of
green emitting GSQD is a major problem. Fraunhofer IAP-
CAN has solved this problem by adapting the intermediate
layer between core and shell. So far, we were able to
produce GSQDs with an emission between 530 and
640 nm in gram scale. The synthesis of GSQDs with red
and green emission will be discussed and measurements
of the resulting particles will be shown.

We will show results for polyacrylate, silicon and
polyurethane based composites. The resulting hybrid
materials can be used to form thin films with high
absorbance in the blue and emission in red or green. We
will show measurements of blue light LEDs covered with
this matrix so underline their unique properties as color
conversion material.

Fig 5 Examples of polymer/GSQD composites:
polyacrylate (left) and polyurethane based (right)

4 Conclusions
The controlled synthesis of a giant shell QD system in
gram scale with excellent emission properties (QY and
stability) in red and green allows moving on from using a
QD sheet in the TV backlight to color conversion at a high
flux. This is not limited to blue light LEDs, it is also a very
interesting opportunity to combine this technology with
OLEDs and especially μLEDs.

In addition the homogeneous embedding of these
GSQDs in a suitable matrix is of great importance to
create an efficient color converter, especially at high QD
loads and without loss of quantum yield.

References
[1] O. Chen, J. Zhao, V. Chauhan, J. Cui, C. Wong, D.
Harris, H. Wei, H. Han, D. Fukumura, R. Jain, M.
Bawendi, “Compact high-quality CdSe-CdS core-
shell nanocrystals with narrow emission linewidths
and suppressed blinking,” Nature materials. 12,
J. Lupton, A. Rogach, O. Benson, J. Feldmann, H.
Weller, “Highly Emissive Colloidal CdSe/CdS
Heterostructures of Mixed Dimensionality,” Nano
Quantum Dots for color conversion and as active
material in QLEDs,” Proceedings of the International
Display Workshops. 29, 934 (2022).