Photoinduced Ultrafast Charge Separation in CdSe/CdS-Au Hybrid Nanoparticles for ETL

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Abstract

We present a novel synthesis method for CdSe/CdS-Au hybrid nanoparticles, which exhibits excellent site controllability. By adjusting the laser power density, the deposition of single-site gold nanoparticles within different morphologies can be achieved, including quantum rods with different aspect ratios, tadpoles, tetrapods and dots. This achievement will lay the foundation for the application of hybrid nanoparticles in transport layers of ELED.

Author Keywords

QDs, CdSe/CdS, photodeposition, Hybrid nanoparticles

1. Introduction

Quantum dot light-emitting diodes (QLEDs) have the characteristics of high luminous efficiency, adjustable luminous color, and narrow luminous peak[1-3]. They are an important direction for the next generation of display technology[4]. In response to the development needs of new display cutting-edge technologies, especially quantum dot LED devices,[5] it is very important to break the bottleneck of insufficient transmission layer materials for electroluminescent devices and develop new electronic transmission layer materials with originality and independent intellectual property rights.

Currently, the electron transport layer materials for QD-ELED are mainly concentrated in oxides such as ZnO and ZnMgO, and organics such as Alq_3 and TPBi. Limited by their energy band selectivity, it is difficult to optimally match the energy level of the QD luminescent layer, which limits the current efficiency and life of the QD electroluminescent device. The semiconductor-metal multi-domain hybrid nanocrystal (HNC) stands out as a distinctive member of the nanoparticle (NP) family, attracting significant attention in recent years for its remarkable synergistic optical, electronic, and magnetic properties. Notably, Banin and colleagues conducted pioneering research[6], demonstrating the attachment of gold nanoparticles to the tips of CdSe nanorods and tetrapods. Sasanka Deka and coworkers demonstrated the ability to adjust the energy bands of CdSe/CdS-Au hybrid nanoparticles[7], which provides a direction for the construction of new electron transport layers (ETL). However, until now, the detailed mechanism study of the photodeposition process is still rather limited, especially in terms of growth mechanism.

Our previous work has shown that the deposition site can be controlled by the optical power density[8]. However, the universality of this method needs further verification. In order to solve this problem, in this work, we prepared nanocrystals with different morphologies based on the existing work[9-11]. Under the optimal conditions, we achieved the construction of single site deposition based on different shapes. Our work provides novel experimental ideas for the discovery of new ETL layer materials. By carrying out scientific issues such as carrier transport and energy level matching in devices, it is expected to break through the application bottleneck in QD-ELEDs, which is a key issue in future QLED research.

2. Results and discussion

In this work, we adjusted the power density of the laser and found that as the power density increased, it was easier to achieve single-site deposition (**Fig. 1a**), which is consistent with our previous work[8, 12, 13]. Therefore, we built a laser-induced reaction device to achieve single-site deposition of Au on the surface of nanocrystals with different morphologies (**Fig. 1b**), the blue laser intensity is larger than 200 mW.

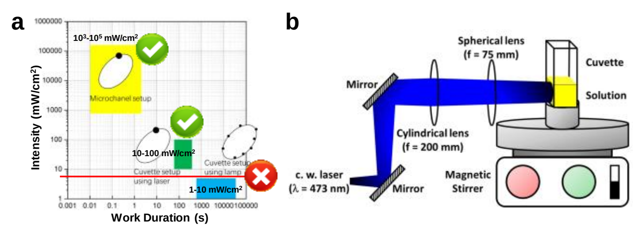

Figure 1. (a) The effect of intensity on the deposition sites; (b) Schematic diagram of laser deposition equipment, 200 mW blue lasers are used for the deposition of single-tipped HNPs.

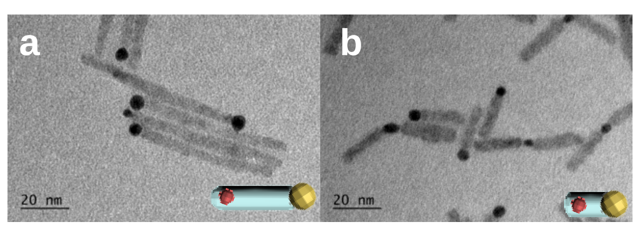

Figure 2. TEM images of CdSe/CdS-Au hybrid nanoparticles based on quantum rods with different aspect ratios. (a) AR= 11; (b) AR= 4.

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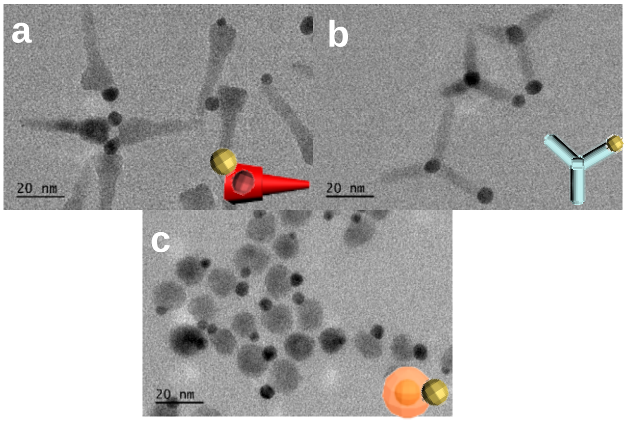

Figure 3. TEM images of CdSe/CdS-Au hybrid nanoparticles based on different morphologies. (a) tadpoles, (b) tetrapods, and (c) dots

Based on this device, we first conducted experiments on dot-in-rods CdSe/CdS nanoparticles with different aspect ratios[14], and found that both AR=11 and AR=4 can achieve single site deposition, as shown in **Fig.2**. We further CdSe/CdS nanocrystals with different morphologies such as tadpoles, tetrapods and QDs. As shown in **Fig. 3**, using the same laser power intensity, single-site deposition can also be found. This means that our process is universal and can obtain ideal results for nanocrystals with different morphologies. These results can provide a basis for future research on the replacement of pure transport layer materials for electroluminescent devices.

3. Conclusion

In summary, we have described detailed synthetic methods for CdSe/CdS-Au hybrid nanoparticles. Based on the controllable preparation of the deposition site, we have achieved the construction of hybrid nanoparticles with different morphologies. Since the construction of heterojunctions can achieve fine-tuning of the energy levels of quantum dots, while improving the charge separation, the energy band matching between the heterojunction layer and the light-emitting layer can be optimized. In principle, this method allows composite fabrications using CdSe/CdS-Au hybrid nanoparticles covering a wide range of sizes and energy levels. And the as prepared heterojunctions have great potential to be used in ELED as ETL layer.

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