EMISSION ENHANCEMENT OF SEMICONDUCTOR NANOCRYSTALS BY GOLD NANORODS: A RECIPE

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I. INTRODUCTION

Semiconductor nanocrystals have attracted great interest of researchers and industries over the last few decades due to their fascinating electronic and optical properties caused by the strong carrier confinement. Narrow-band emission, high quantum efficiency and photostability make them promising objects for optoelectronic (lasers, colloidal LEDs, solar cells etc.) and biomedical (e.g. imaging) applications [1]. Despite the huge progress in the synthesis of semiconductor nanocrystals with nearly unit quantum efficiency in organic phase, aqueous nanocrystals still suffer from several problems. For instance, ligand exchange reactions, which used for the transfer of nanocrysrals from organic to aqueous solutions, lead to a dramatic fall in quantum efficiency [2]. Plasmonic nanoparticles, which are the optical analogues of antennas and able to amplify optical signals from emitter in their vicinity, are often proposed to improve optical properties of semiconductor nanocrystals. Among many plasmonic structures, gold nanorods (GNRs) are especially promising due to their anisotropic shape and adjustable plasmonic properties [3].

In this work, we experimentally and theoretically investigated conditions of the emission enhancement of semiconductor nanocrystals (on the example of CdSe-based quantum dots, QDs) by GNRs [4].

II. RESULTS

GNRs with the longitudinal localized surface plasmon resonance (LSPR) at 615 nm were synthesized via seed-mediated growth method [5]. To manipulate the plasmonic antenna efficiency and investigate the influence of distance between GNR and QDs, GNRs were coated with 0, 2, 4 and 6 polyelectrolytes (PE) layers (Fig. 1(a-b)) that corresponded to app. 3 (due to the surfactant bilayer on the GNR surface), 5, 7, and 9 nm separation.

We chose two types of QDs with emission maxima at 595 and 620 nm, which fell on the shortwave and longwave slopes of the longitudinal LSPR, correspondingly (Fig.1c). The fluorescence enhancement

occurred only in the complexes with QD emission at 620 nm, which can be attributed to the higher nanoantenna efficiency at this wavelength. Also, we established the inverse dependence of the enhancement factor on the QD concentration in the complexes, due to the augmentation of QDs adsorbed on GNR sides. We found theoretically that the GNR sides feature lower enhancement of the electric field and emitter quantum efficiency than GNR tips, which results in the fluorescence quenching for the high QD concentration. Moreover, we found that an increase in the GNR-QD separation led to the fall of fluorescence enhancement (Fig.1d).

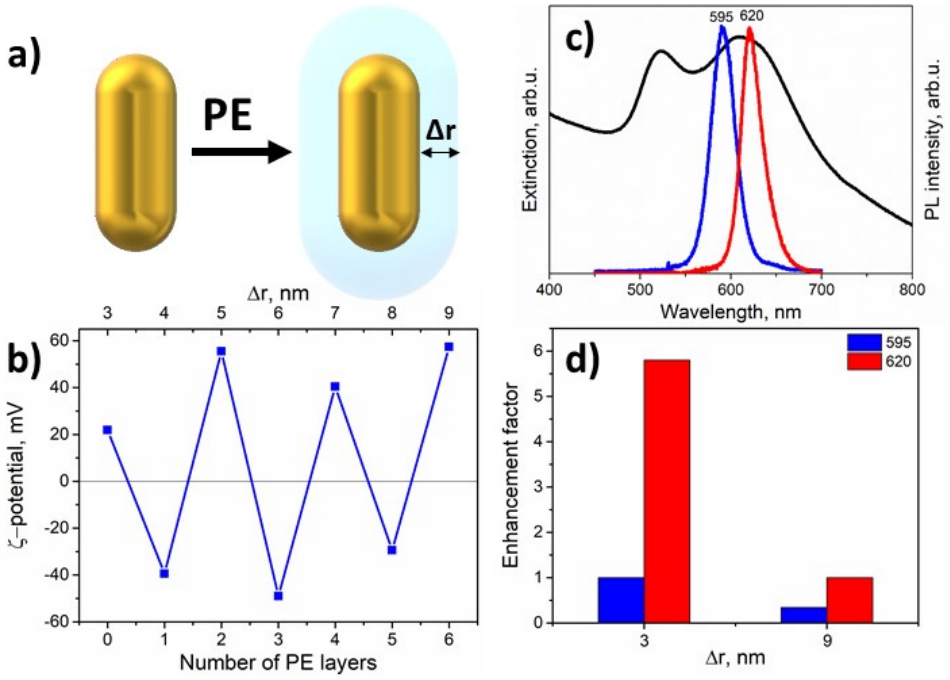

Figure 1. a) scheme of a GNR coated by PE shell; b) zeta-potential measurements of GNRs coated by PE; c) Extinction (black) spectrum of GNRs and fluorescence spectra of CdSe/ZnS (blue) and CdSe/CdZnS (red) QDs; d) Dependence of fluorescence enhancement factor on the thickness (Δr) of PE shell on GNRs

III. CONCLUSIONS

We demonstrated the influence of QDs localization, concentration, excitation and emission wavelengths as well as their separation with GNRs on the fluorescence enhancement [4]. We achieved almost 11-fold fluorescence enhancement in GNR-QDs complexes, in which the emission band overlapped with the longwave slope of the longitudinal plasmon resonance of GNRs, and the strong emission suppression for QDs with emission at the shortwave slope.

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