PLASMONIC ENHANCEMENT OF LUMINESCENCE EFFICIENCY IN LIGHT EMITTING STRUCTURES

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I. INTRODUCTION

The last year's show the following promising trends in light-emitting diode (LED) production: the development of new colloidal LED technologies replacing in some cases epitaxial LED (based on GaN or InGaN quantum well hete rostructures) and thereby using of quantum dots (CdSe, InP, perovskites) as building blocks in all types of LEDs. There are some advantages of semiconductor nanoparticles for LEDs such as: the emission color can be tuned by simply changing particle size, the narrow emission band, color purity and eye-friendly lighting, covering full visible spectrum by single excitation source, high photo- and thermal stability. Also colloidal technologies are less expensive than epitaxial and allow producing flexible devices. The actual aim remains the optimizing of LED design to get better devices performance. One of the ways to improve the performance of light emitting structures is nanoplasmonics.

The main idea is that metal nanostructures strongly enhance light – matter interaction owing to high local concentration of electromagnetic field [1]. In certain "hot spots" substances emit light with higher intensity than in air or in solution. Metal nanostructures act as nanoantenna and effect both on excitation of luminophore through local field enhancement as well as on emission through density of states modifying.

So, in certain conditions plasmonic can help to improve photo- and electroluminescene features of light emitting materials.

II. RESULTS

In 2002 our group obtained the first experimental realization of the plasmon amplification of the photoluminescence of quantum dots with the help of metallic nanoparticles [2]. Several processes are realized near a metal nanoparticle surface: some promote photoluminescence enhancement (an increase in the intensity of the electromagnetic field at the plasmon resonance frequency, an increase in the radiative decay rates due to Purcell effect), while others contribute to quenching (an increase of the nonradiative decay rates due to of energy and electron transfer from luminophore to the metal). For possible electroluminescence enhancement metal nanoparticles can affect only on emission. The resulting luminescence enhancement or quenching will depend on the contribution of each process. Plasmon-enhanced fluorescence is a complex process depending on multiple parameters including sizes and morphologies of the metal nanostructures, distance between metal and luminophore, position of luminophore absorption and emission toward plasmon resonance (for photoluminescence). In all cases (enhancement or quenching of luminescence) decreasing of excited state lifetime (τ) can lead to diminish the role of the Auger process and to photostability enhancement [3] and modulation rate enhancement for LEDs.

The next plasmonic advantage is possible anisotropy of optical response. Possible polarization of luminescence using anisotropic plasmonic nanoparticles is important for improve the backlight sources in LCD devices [4] as well as the enhancement of the directionality of light emission allows to reduce light dissipations and to maximize light output [5]. These results can be explained by anisotropy of luminophore excitation and emission near nonsperical plasmonic nanoparticles [6].

III. CONCLUSIONS

There are successful evidences of plasmonic nanoparticle utility for QLEDs efficiency for both photo- and electroluminescence. The potentially promising plasmonic ehnancement of LED performance consists in: photo- and electroluminescence intensity enhancement; decay rate enhancement, modulation rate enhancement; luminophore photostability enhancement; improving light directionalities and light polarization of LEDs.

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REFERENCES

[1] S.V. Gaponenko, H.V. Demir, Applied Nanophotonics, Cambridge University Press, Cambridge, 2018.

[2] O. Kulakovich, N. Strekal, A. Yaroshevich, S. Maskevich, S. Gaponenko, I. Nabiev, U. Woggon, M. Artemyev, Enhanced Luminescence of CdSe Quantum Dots on Gold Colloids", Nano Lett. Vol. 2 pp. 1449-1452, 2002.

[3] O.Kulakovich, L.Gurinovich, Hui Li, A.Ramanenka, L.Trotsiuk, A.Muravitskaya, Jing Wei, Hongbo Li, N. Matveevskaya, D. V. Guzatov, S.Gaponenko "Photostability enhancement of InP/ZnSe/ZnSeS/ZnS quantum dots by plasmonic nanostructures", Nanotechnology, v. 32 035204, 2021.

[4] L. I. Gurinovich, L. L. Trotsiuk, O. S. Kulakovich, N. I. Sushko, H. V. Demir, and S. V. Gaponenko, "Polarization Properties of Photoluminescence of Anisotropic Polymer Films Containing Aligned Au Nanorods and Semiconductor Nanoparticles of Various Shape" ,Semiconductors, Vol. 52, pp. 2052–2054, 2018.

[5] Giessen, H., & Lippitz, M., Directing Light Emission from Quantum Dots. Science, 329,pp. 910–911,2010.

[6] Trotsiuk, L., Muravitskaya, A., Kulakovich, O., Guzatov, D., Ramanenka, A., Kelestemur, Y., Demir, H.V. and Gaponenko, S.," Plasmon-Enhanced Fluorescence in Gold Nanorod-Quantum Dot Coupled Systems". Nanotechnology, v. 31, pp. 105201 (1-10), 2020.