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Development of flexible hybrid LEDs based on copper nanoclusters and investigation of their properties

A.O. Kuznetcova[1], V.Yu. Yurova[1], E.V. Skorb[1]*

[1] ITMO University,

Lomonosova, 9, St. Petersburg, 191002, Russia

* Research supervisor - Dr. Prof. Ekaterina V. Skorb

In this work, an alternative method of production of LEDs based on copper nanoclusters is discussed. For this purpose, we obtained several samples of copper nanoclusters encapsulated in various films as well as evaluated their properties. Obtained samples proved to be stable maintaining high emission intensity, what enables further development of technology for the production of flexible LEDs based on copper quantum dots.

Now LEDs are mostly produced of straight-band semiconductors using complex technology, which leads to high cost of their production. This problem can be overcome by use of quantum dots instead. These are easily produced by a colloid method and have similar properties to semiconducting LEDs. In both cases spectrum of emission is monochromatic, however in case of nanoclusters it depends on method and temperature of synthesis, not on material used. Therefore, one widespread affordable material can be used for production of LEDs with any wavelength. This leads to lowering of both complexity and cost of production.

Quantum dots are nanoclusters of conductors or semiconductors, whose charge carriers (electrons) are limited in space in all three directions. At such small sizes, they manifest quantum, discrete, properties of electrons. One of these quantum effects is emission of photons at the electron transition to a lower energy level. Due to this, quantum dots emit visible light when irradiated with ultraviolet light. Moreover, spectrum of quantum dots emission depends on their size, not only structure. Therefore, emission spectrum can be varied by application of different technologies of synthesis to one source material.

Quantum dots commonly have wide excitation band, which makes it possible to excite nanoclusters of different sizes and materials with a single irradiation source. This enables production of multi-color systems. In addition, quantum dots are extremely photostable, have high fluorescence quantum yield and are resistant to photoflowering, which makes them a perfect material for LEDs.

Most of quantum dots are stable in air. However, copper nanoclusters are easily hydrolyzed by water, especially in solution, to form of copper hydroxide, which leads to significant and quick decrease of emission intensity. The solution we found to prevent this process is quick encapsulation of obtained copper quantum dots in agar films and drying of these in drying chamber. After this process, samples become waterproof and its emission intensity does not change considerably over time. Several methods of production of films with copper quantum dots were tested, however only two of them showed required results.

In this work, colloid method of synthesis of copper nanoclusters was used due to its easiness. During this process copper two plus ions are reduced to copper atoms in solution, followed by clustering of copper atoms. X-ray spectroscopy was used to determine the composition of received particles. As expected, it confirmed the presence of copper and reducing agent used.

There is a common correlation between sizes of obtained nanoclusters with temperature of synthesis for some materials. However, this correlation did not prove for copper nanoclusters due to small range of available temperatures for colloid synthesis, used in this research. In both synthesis at 20 and 0 Celsius degrees quantum dots with same emission intensity were obtained. Therefore, the main way to vary the size of obtained nanoclusters is to vary reducing agent in synthesis.

Unique optical characteristics are the reason why quantum dots are now becoming more and more popular and find application in a wide range of industries such as gadgets production (as main compound of LEDs), medicine and biology (as biomarkers). Our technology of production of agar films with copper nanoclusters can ease the process of creation of quantum dots LEDs, as it is less complex process than one used now of application of nanoclusters strips to the substrate.