Zinc oxide quantum dots as a candidate for memory devices

Paula Obreja, Dana Cristea, Cristian Kusko, Raluca Gavrila, Iuliana Mihalache, Mihai Daniala, Adrian Dinescu

National Research and Development Institute for Microtechnologies,
126A (32B) Erou Iancu Nicolae Street, R-077190, Voluntari, Ilfov,
P.O. BOX 38-160, 023573 Bucharest, ROMANIA
paula.obreja@imt.ro

Abstract

In the last ten years, zinc oxide quantum dots (ZnO QDs) have attracted considerable attention due to their wide applications such as ultraviolet light-emitting diodes, blue luminescent devices, UV lasers and bio-sensing devices. ZnO QDs were synthesized by several methods, such as RF magnetron sputtering, ion implantation, vapor phase transport process, metal-organic chemical-vapor deposition, spray pyrolysis and by wet chemical methods. These dots are the particle size smaller than 8 nm (typically 3-6 nm). The wet chemical methods are simple and less expensive, but the obtained ZnO QDs need to be stabilized to keep them dispersed in solution or capped with polymers, amines, organic thiols or oleic acids to limit the growth. This causes some drawbacks when ZnO QDs processed into thin films for applications in electronic devices.

In this paper ZnO QDs have been synthesized by direct precipitation of zinc acetate dihydrate solution in methanol with potassium hydroxide in methanol, added drop by drop under constant and continuously magnetic stirring, at room temperature [1, 2]. At the beginning 1% aluminum chloride was added in the solution to enhance n-type conduction; propyltrimethoxysilane was added to the solution at the end to maintain dispersion, to prevent the aggregation of ZnO QDs and their further growth. ZnO QDs were separated from solution by centrifuging and removing of the supernatant, washed three times with methanol, re-dispersed in ethanol at different concentrations and used for the investigation of ZnO QDs characteristics. Also, the solutions were used for spin coating of the thin film on different substrates (quartz, SiO_2/Si and SiO_2/Si substrates with pre-patterned Cr/Au electrodes for electrical characterization).

ZnO QDs size was evaluated using atomic force and scanning electron microscopy. The morphology, structure and optical properties were investigated by X-ray diffraction, photoluminescence and UV-Vis spectra. The as synthesized ZnO QDs thin film showed a hexagonal wurtzite structure, having a size of 4-6 nm, in good agreement with the estimations from AFM and SEM images (Fig.1). The photoluminescence of the as-prepared ZnO QDs measured at the room-temperature exhibit an ultraviolet emission at 380 nm and a broad emission in the range of 420–700 nm (Fig.2). In the absorption spectra determined on the thin layer spin-coated on quartz substrate the absorption in UV and its decrease at ~330 nm could be observed (Fig.3).

Negative differential resistance was observed in a two terminal device in which the current can decrease with increasing voltage [3]. Current-voltage characteristics of ZnO QDs thin film spin coated on pre-patterned Cr/Au electrodes showed bipolar hysteretic response and two distinctive regions of negative differential resistance, recommending this material for memory devices development (Fig.4).

Acknowledgements: This work was supported by the Romanian Program STAR contract no. 14/2012 and IMT-Bucharest Program Convert - project PN09290211.

References

[1] M.K. Patra, M. Manoth, V.K. Singh, G. Siddaramana Gowd, V.S. Choudhry, S.R. Vadera, N. Kumar, Journal of Luminescence **129** [2009] 320–324;
[2] A. H. Moharram, S. A. Mansour, M. A. Hussein, and M. Rashad, Journal of Nanomaterials, Volume **2014**, Article ID 716210, http://dx.doi.org/10.1155/2014/716210;
[3] Ya Yang, Junjie Qi, Wen Guo, Zi Qin, and Yue Zhang, Applied Physics Letters **96** [2010] 093107.

Figures

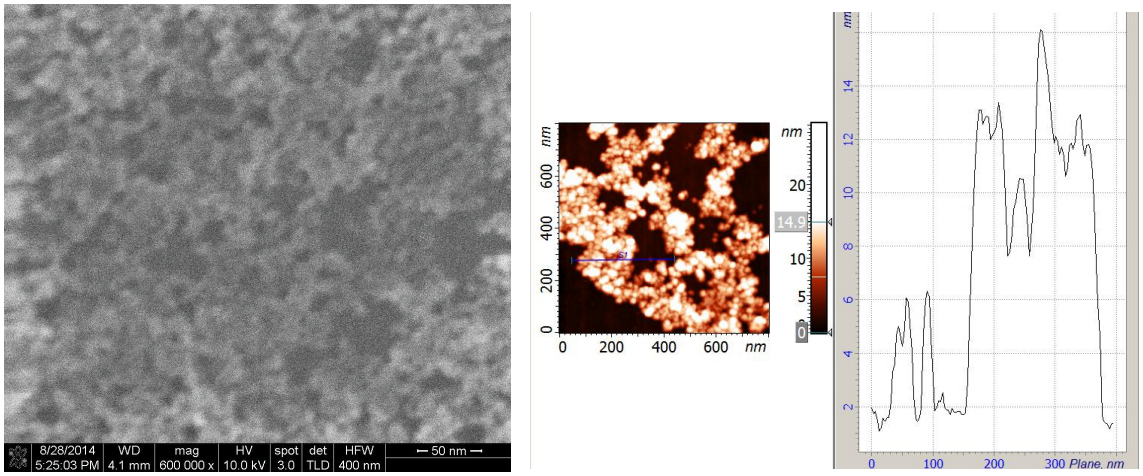

Fig.1 SEM and AFM image of ZnO QDs thin film prepared from a diluted solution

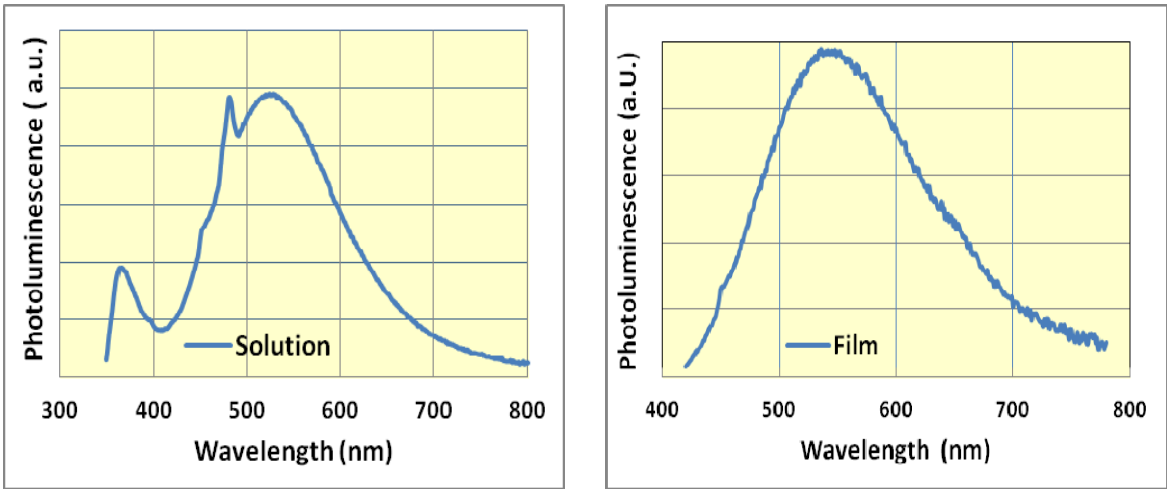

Fig.2 ZnO QDs photoluminescence for diluted solution and for a thin film

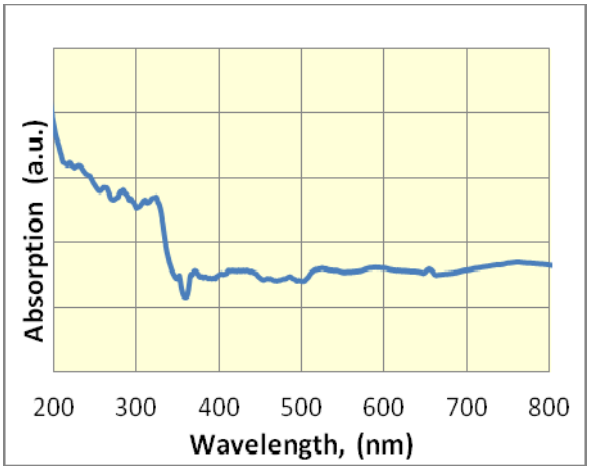

Fig.3 ZnO QDs absorption in a thin film

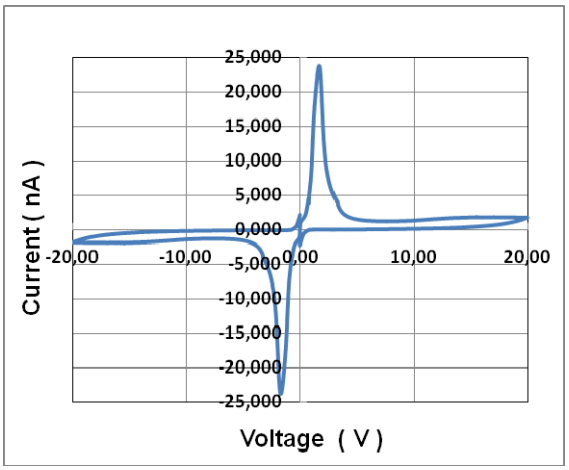

Fig.4 Current-voltage characteristics of ZnO QDs spin coated on pre-patterned Cr/Au electrodes