Synthesis of Colloidal InP Nanocrystal Quantum Dots

L. Sirbu[1], T. Gutul[1], A. Todosiciuc [1], M. Danila[2],R. Muller[2],
A. Sarua[3], R. Webster[3], I.M. Tiginyanu[1,4] and V. Ursaki[4,5]

[1]*Institute of Electronic Engineering and Nanotechnologies "D. Ghitu ", 3/3, Academiei str., MD-2028 Chisinau, Moldova*
[2]*National Institute for R&D in Microtechnologies- IMT Bucharest, Erou Iancu Nicolae 126 A str., Bucharest, Romania*
[3]*H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS81TL, United Kingdom*
[4]*Institute of Applied Physics, Academy of Science of Moldova, 5, Academiei str., MD-2028 Chisinau, Moldova*
[5]*Technical University of Moldova, 168, Stefan cel Mare str., MD-2004 Chisinau, Moldova*

***Abstract* — InP nanodots with the diameter of 4−10 nm were synthesized using sol-gel method. The nanodot dimensions were obtained using TEM, and we found the d(111) spacing to be 0.328nm which agrees within 3% of the literature value. Prepared nanoparticles where characterized then by Raman spectroscopy and X-ray diffraction. Performed measurements confirm good crystalline quality of obtained InP particles, which can be used as a basis for THz emitters, LED, and OLED displays.**

***Index Terms* — quantum dots, colloids, InP, Raman, TEM, XRD.**

I. INTRODUCTION

Nanocrystals and quantum dots of colloidal InP are nanometer-scale structures that represent one of the most intensively developing areas of modern semiconductor physics. Semiconductor nanomaterials have attracted much interest due to their new optical properties and immense potential applications in optoelectronics, arising from the quantum confinement effects. The optical, magnetic, electronic, mechanical and biochemical properties of materials are beginning to be modified using nanoscale structures. The new physical phenomena in nanoscale structures have been revealed and are applied in lasers and optical amplifiers, light emitting diodes, photodiodes, memory devices, biological luminescence markers, OLED displays, THz emitters, MOEMS, MEMS, NEMS, etc.

In last years, the fundamental physical properties of colloidal nanocrystals have been studied intensively [1].

II. SAMPLE PREPARATION

The synthesis of InP semiconductor nanodots was performed in a round-bottom three-neck flask equipped with a magnetic stirrer and heater with temperature control unit. The Na_3P was obtained as a result of reaction of sodium and white phosphorous (similar as for GaP nanodots, reference [2]).

The reaction mixture turned dark during synthesis due to the formation of Na_3P suspension. The subsequent synthesis of indium phosphide nanodots was carried out by rapid injection of a suspension of sodium phosphide, maintained at room-temperature into a high stirred solution of indium chloride heated 150^{o}C under N_2 atmosphere.

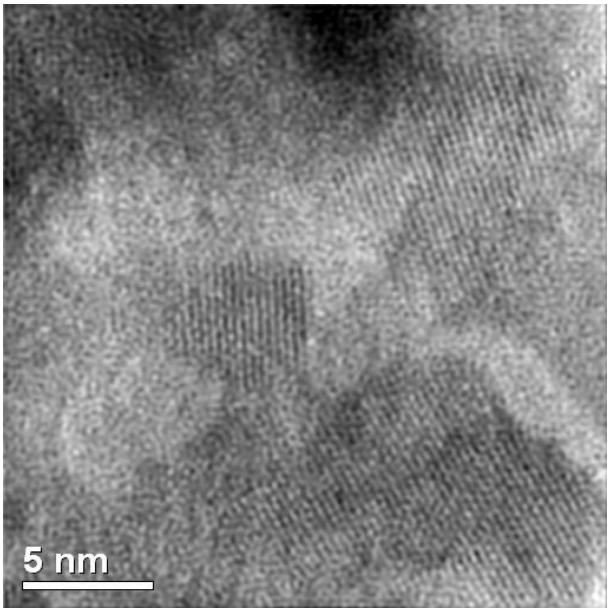

Fig.1. TEM image of InP nanodots.

$$InCl_3+Na_3P \rightarrow InP+3NaCl \qquad (1)$$

The reaction mixture was then maintained at the fixed temperature for 2 h and then promptly cooled to room temperature using an ice-water bath. A solution containing 50% of ethanol and 50% of distilled water was used to dissolve the sodium chloride precipitated at the same time with the InP nanoparticles.

III. CHARACTERIZATION

The Raman spectra were recorded by a Renishaw spectrometer (Bristol University, UK) using a 785 nm diode laser as excitation source. The Raman spectrum of InP nanodots is presented in Fig.3. The two relatively sharp peaks around 303 cm^{-1} and 345 cm^{-1} were assigned to the first-order scattering from TO and LO phonons of InP crystal, respectively, while weak peaks around 650-690 cm^{-1} were assigned to the second-order Raman scattering (see the inset Raman spectrum) [3]. The observed strong and narrow LO phonon peak of InP is similar to that of the bulk and manifest a good crystalline quality of obtained nanoparticles.

The XRD measurement was performed with an X-ray diffractometer SmartLab Rigaku (IMT-Bucharest) employing Cu Ka radiation from a rotating anode source and a Ge monochromator. As we can see from the Fig.2, the peaks look broader than normally found for bulk material which is typical for small diameter of QDs [4]. The TEM image is presented in Fig. 1, and we found the d(111) spacing to be 0.328nm which agrees within 3% of the literature value for zincblende InP. The diameter of InP nanodots is around 4−10 nm.

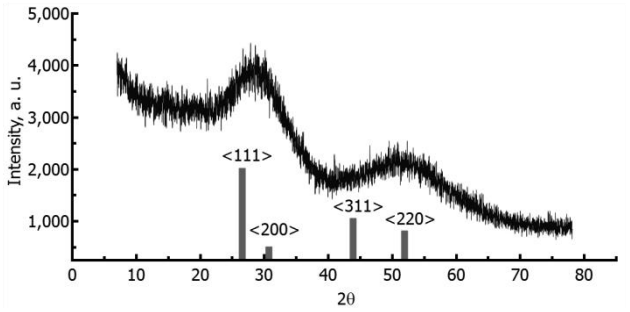

Fig.2. XRD pattern for InP nanodots.

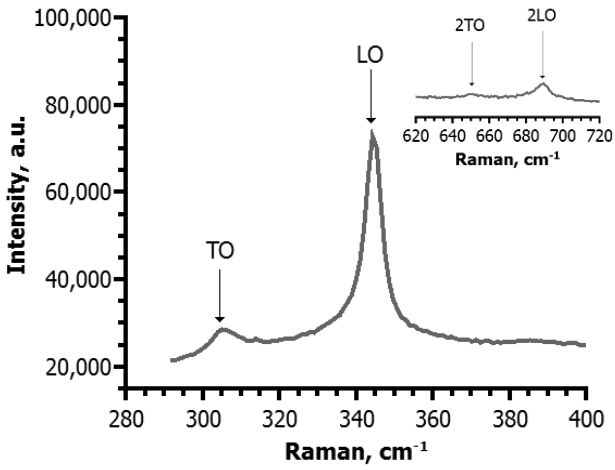

Fig.3. Raman spectra of InP nanodots at room temperature

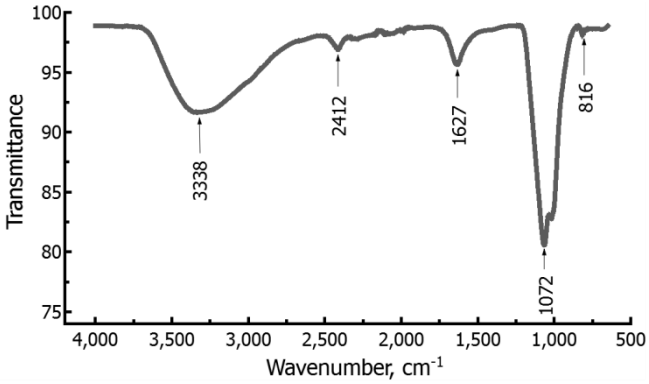

Fig.4. FTIR spectra

Away from reststrahlen region (>500 cm^{-1}) the FTIR spectrum (Fig. 4) of indium phosphide QD shows a carbonyl peak (C=O) at 1627 cm^{-1}, a stretching vibration peak of hydroxyl group (the functional group in alcohols, C-H, (ethanol, methanol, etc.)) at 3000-3500cm^{-1}, in addition, there is also a peak from hydroxyl group (xylene) at 1072 cm^{-1}. These peaks indicate that surfaces of InP QD are decorated with organic molecules, as a result of fabrication.

IV. CONCLUSIONS

Performed measurements confirm good crystalline quality of obtained InP particles, which can be used as a basis for THz emitters, LED, OLED displays, MEMS, MOEMS, NEMS, etc. In particular, THz emitters based on InP nanodots are excellent candidates for biosensor devices and lab-on-chip platforms, and further work on these applications is underway.

ACKNOWLEDGEMENT

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REFERENCES

[1] René Overney / UW Nanothermodynamics and Nanoparticle Synthesis NME 498A / A 2010

[2] Zhao-Chun Zhang, Bao-PingWang, Diamond and Oxidized Disordered Graphite on the Surface of Gallium Phosphide Nanoparticles, Part. Part. Syst. Charact. 26 (2009) 53–57

[3] G. Irmer, M. Wenzel, and J. Monecke, The temperature-dependence of the LO(Gamma) and TO(Gamma) phonons in GaAs and InP, Phys. Status Solidi B 195, 85 (1996)

[4] Derrick W. Lucey, David J. MacRae, Madalina Furis, Yudhisthira Sahoo, Alexander N. Cartwright, and Paras N. Prasad, Monodispersed InP Quantum Dots Prepared by Colloidal Chemistry in a Noncoordinating Solvent, Chem. Mater. (2005) 17, 3754-3762