

Characterization and Properties of CdO Nanocrystals Incorporated in Polyacrylamide

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CdO quantum dots (QDs) incorporated in polyacrylamide were synthesized adding aqueous suspension of cadmium oxide in acrylamide:bisacrylamide copolymer. Optical properties of CdO nanocrystals were studied by optical absorption. The size ranges (2-3 nm) were calculated by the effective mass approximation.

Keywords: CdO quantum dots (QDs); Polyacrylamide; Optical properties

I. INTRODUCTION

Nanoparticles have attracted great interest in recent years because of their unique chemical and physical properties, which are different from those of either the bulk materials or single atoms [1].

In recent years, researchers have focused on cadmium oxide (CdO) due to its applications, specifically in the field of optoelectronic devices such as solar cells [2-3], photo transistors [4] and diodes [5], transparent electrodes [6], gas sensors [7], etc. These applications of CdO are based on its specific optical and electrical properties. For example, CdO films show a high transparency in the visible region of the solar spectrum, as well as a high ohmic conductivity. The intensity of optical and electrical effects of CdO depends on the deviations from the ideal CdO stoichiometry, as well as on the size and shape of the particles [8]. Bulk CdO is an n-type broad band gap (2.3 eV) semiconductor, with an indirect band gap of 1.36 eV [9].

Some researchers try to modify the synthesis procedure for CdO with the aim to improve chemical and physical properties of this material. Some examples of this are: Gulino et al. [10] that investigated the formation of CdO thin films by thermal decomposition of cadmium hexafluoroacetylacetonate dehydrate $[\text{Cd}(\text{C}_5\text{F}_6\text{HO}_2)_2 \cdot \text{H}_2\text{O}]$. The $\text{Cd}(\text{C}_5\text{F}_6\text{HO}_2)_2 \cdot \text{CH}_3\text{OCH}_2\text{OCH}_3$ complex was used as a ligand MOCVD (metal-organic chemical vapor deposition) precursor in the preparation of thin CdO films [11]. The thermal decomposition of cadmium itaconate monohydrate ($\text{C}_5\text{H}_4\text{O}_4\text{Cd} \cdot \text{H}_2\text{O}$) in N_2 , H_2 or air was also investigated [12]. Uplane et al. [13] reported the preparation of CdO thin films onto the hot glass substrate at 400 °C by spray pyrolysis of the aqueous cadmium acetate solution. Varkey and Fort [14] prepared transparent CdO thin films on glass substrate using the aqueous solution of soluble cadmium amine complexes as a precursor of CdO. $\text{Cd}(\text{OH})_2$ deposited on the glass substrate was transformed into CdO after heating. Matsuura et al. [15] prepared CdO thin films using the Langmuir-Blodgett deposition technique. Alétru et al. [16] prepared $\text{Cd}(\text{OH})_2$ gel by mixing cadmium acetate and sodium hydroxide solutions. Peng et al. [17] reported on the formation of CdO nanowires by oxidation of mixed Cd/Te film on aluminium substrate in

the O_2/Ar stream at 400 °C [18].

In this present work CdO quantum dots (QDs) incorporated in polyacrylamide have been synthesized in which electrons are confined in all three spatial directions. Due to the increased quantum confinement, these QDs exhibit new physics properties that are strongly dependent upon nanocrystal size. The sizes of the particles were calculated by the effective mass model approximation [19-20].

II. EXPERIMENTAL DETAILS

All employed chemicals were used as received. The chemicals were purchased from different companies: acrylamide 99.9% (Bio-Rad), bisacrylamide 98% (Sigma), cadmium oxide (Nuclear), ammonium persulfate 98% (Invitrogen), and TEMED (N,N,N',N'-tetramethylethylenediamine) 99% (Sigma).

The gel material was did with aqueous suspension of cadmium oxide in acrylamide:bisacrylamide copolymer. The cadmium oxide suspension was prepared using distilled water with concentration of 1.0×10^{-4} , 2.0×10^{-4} , 5.0×10^{-4} , 10.0×10^{-4} , 20.0×10^{-4} and 40.0×10^{-4} mol/L. The suspension was immersed in ultrasound bath during 30 min for homogenization. For the copolymerization reaction 10 mL of a mixture containing 0.098 g of acrylamide and 3.6g of bisacrylamide was prepared. The CdO solution was added slowly to the jelly monomer mixture. Ammonium persulfate (10%) and TEMED were added to the jelly matrix, allowing the copolymerization reaction to take place at room temperature. The polymerization was carried at presence of light at room temperature.

Were did two groups of samples: the first was stored at room temperature and aqueous atmosphere for 5 days (120h) and the second was stored under vacuum to dry for 5 days. The Optical Absorption (OA), of the first group (gel material) was done just after the polymerization and after 2, 4, 24, 48, and 120h to observe the stability of the synthesized material. The second group had this optical properties analyzed only after totally dried.

Using the values of AO the nanoparticules sizes were determined from the absorption onset by the effective mass model approximation.

$$E \cong E_{bulk} + \frac{\hbar^2 \pi^2}{2er^2} \left(\frac{1}{m_e m_0} + \frac{1}{m_h m_0} \right)$$

where E is the band gap of the nanoparticles, E_{bulk} is the band gap of the bulk material, r is the particle radius, m_e and m_h are effective masses of the electrons and holes, respectively, and m_0 is the free electron mass.

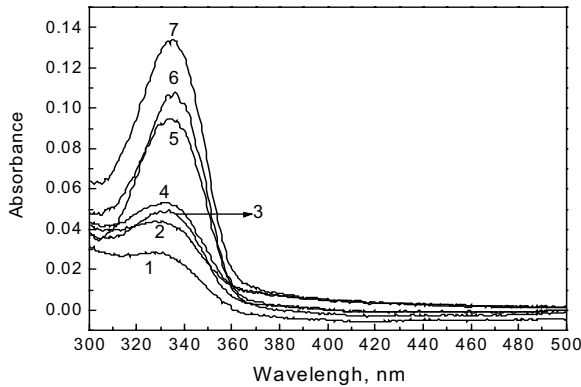


FIG. 1: Absorption spectra of gel polyacrylamide doped with CdO (2.0×10^{-4} mol/L) nanoparticles after (1) 0 h; (2) 2 h; (3) 6 h; (4) 4h; (5) 24 h; (6) 48 h and (7) 120 h.

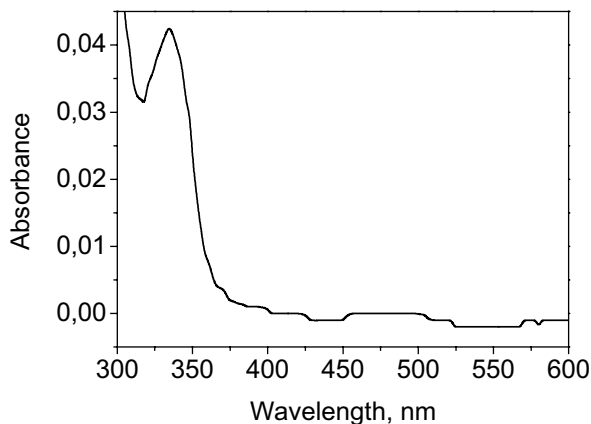


FIG. 2: Absorption spectra of solid polyacrylamide doped with CdO nanoparticles in the concentration of 1.0×10^{-4} mol/L.

III. RESULTS AND DISCUSSION

The obtained materials are transparent and the solid material looks like glass, presenting a good transparency and rigidity.

The best result in the first group (gel material) was observed in the sample with CdO concentration of 2.0×10^{-4} mol/L and the result of the OA spectroscopy of this material in different times of store can be observed in Fig. 1. The narrow peaks indicate that the size distribution is very homogenous.

A batocromic effect (red-shift) was observed with the time, indicating an increase of the particle's size, and an absorbance increase with time shows that the primary particles growth. The samples with other concentrations presented similar results but in less absorbance intensity for less concentrations and biggest red-shift for higher concentrations.

In the second group (solid) the best result was observed in the concentration of 1.0×10^{-4} mol/L Fig. 2. In bigger concentrations the band of CdO nanocrystals was not observed, indicating the formation of bulky CdO.

The size range of CdO nanoparticles is about 2-3 nm in the two groups.

IV. CONCLUSION

The CdO nanoparticles was prepared adding aqueous suspension of cadmium oxide in acrylamide:bisacrylamide copolymer and the size range of CdO nanoparticles obtained was about 2-3 nm.

The observed increase in absorbance and red-shift with the time, in the gel material, indicate that the supplied energy at room temperature was sufficient to improve the nanocrystals growth and that the gel structure permit the movement of the ions and nanocrystals.

The solid material is more stable that the gel and is a material transparent like glass, making it a promissory material for future applications.

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- [1] T. Trindade, P. O'Brien, and N. L. Pickett, *Chem. Mater.* **13**, 3843 (2001).
- [2] C. Sravani, K.T.R. Reddy, O. Md. Hussain, and P.J. Reddy, *J. Solar Energy. Soc. India* **1**, 6 (1996).
- [3] L. M. Su, N. Grote, and F. Schmitt, *Electron. Lett.* **20**, 716 (1984).
- [4] R. Kondo, H. Okimura, and Y. Sakai, *Jpn. J. Appl. Phys.* **10**, 1547 (1971).
- [5] F. A. Benko, F. P. Koffyberg, *Solid State Commun.* **57**, 901

(1986).

- [6] A. Shiori Jpn. Patent No. **7**, 909 (1997).
- [7] D. R. Lide (Ed.), *CRC Handbook of Chemistry and Physics*, 77th edn., CRC Press, Boca Raton, 1996/1997, 3/278, p. 12/97.
- [8] M. Ristić, S. Popović, and S. Musić, *Mater. Lett.* **58**, 2494 (2004).
- [9] K. Gurumurugan, D. Mangalaraj, and Sa. K. Narayandass *J. Cryst. Growth* **147**, 355 (1995).
- [10] A. Gulino, F. Castelli, P. Dapporto, P. Rossi, and I. Fragala,

- Chem. Mater. **14**, 704 (2002).
- [11] A. Gulino, P. Dapporto, P. Rossi, and I. Fragala, Chem. Mater. **14**, 1441 (2002).
- [12] M. A. Mohamed, S. A. Halawy, J. Anal. Appl. Pyrolysis **65**, 287 (2002).
- [13] M. D. Uplane, P. N. Kshirsagar, B. J. Lokhande, and C. H. Bhosale, Mater. Chem. **64**, 75 (2000).
- [14] A. J. Varkey, A. F. Fort, Thin Solid Films **239**, 211 (1994).
- [15] N. Matsuura, D. J. Johnson, and D. T. Amm, Thin Solid Films **295**, 260 (1997).
- [16] C. Alétru, G. N. Greaves, and G. Sankar, J. Phys. Chem. B **103**, 4147 (1999).
- [17] X. S. Peng, X. F. Wang, Y. W. Wang, C. Z. Wang, G. W. Meng, and L. D. Zhang, J. Phys. D: Appl. Phys. **35**, L101 (2002).
- [18] M. Ghosh, C. N. R. Rao, Chem. Physic. Lett. **393**, 493 (2004).
- [19] N. O. Dantas, A. F. G. Monte, W. A. Cardoso, A. G. Brito-Madurro, J. M. Madurro, and P. C. Morais, Microelectron. J. **36**, 234 (2005).
- [20] W. Dong, C. Zhu. Optic. Mater. **22**, 227 (2003).