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OPTICAL PROPERTIES OF CdSe THIN FILMS PRODUCED BY THE CBD METHOD FROM FOUR-COMPONENT AND THREE-COMPONENT SOLUTIONS

M.H. Huseynaliyev   L.N. Ibrahimova

Nakhichevan Department of Azerbaijan National Academy of Sciences, Institute of Natural Resources, Nakhichevan Azerbaijan, mamedhuss@mail.ru, leyla.ibrahimova.1992@bk.ru

Abstract- At room temperature cadmium selenide (CdSe) thin films are deposited onto glass substrate employing chemical bath deposition (CBD) method. A comparative analysis of the optical properties of CdSe thin films deposited from a solution containing four components (cadmium chloride, ammonium hydroxide, triethanolamine (complexing agent), and sodium selenesulphate) and from a solution containing three components (cadmium chloride, ammonium hydroxide and sodium selenesulphate) was carried out. A shift in the band gap of a CdSe thin film obtained from a three-component solution towards higher energies was observed.

Keywords: CdSe, Triethanolamine, Chemical Bath Deposition, Sodium Selenosulphate, Thin film, Optical Absorption Spectrum, Tauc Equation, Band Gap.

1. INTRODUCTION

Cadmium selenide (CdSe) is considered a promising compound for use in solar energy converters due to its high optical absorption coefficient and optimal band gap. The semiconductor compound CdSe can crystallize in two different structures: zinc blende (cubic- optical band gap ~1.71 eV) and wurtzite (hexagonal- optical band gap ~1.80 eV). This compound can be used as window material, buffer layer and absorber in solar cells. The nanostructured thin CdSe films, depending on the size of the nanostructure, acquire new interesting properties that differ significantly from their bulk compounds. In addition, it is possible to control the electronic and optical properties of a nanostructured CdSe thin film by simply changing the size of nanocrystals, which allows it to be used as solar cells, high-performance thin-film transistors, photodetectors, and light-emitting diodes [1-4]. CdSe is used as an active medium in semiconductor lasers [5], liquid crystal displays, gamma-ray detectors and gas analyzers [6].

In addition, Cadmium selenide is a promising compound for the creation of photoresistors and light-emitting diodes [7], [8], highly efficient thin-film transistors [9], optical amplifiers, photocatalysts and materials for photocatalytic systems [10]. The widespread use of this material dictates the need to develop new methods of synthesis or improve old ones. More accessible are hydrothermal methods [11], spray pyrolysis [12, 13], ion layering (SILAR) [14], electrochemical [15, 16] and hydro chemical deposition [17-18].

The CBD method for the deposition of thin films from an aqueous solution is a promising technique because of its simplicity, affordability, convenience for large-scale deposition and having easily-controllable parameters such as concentration, pH, deposition temperature and deposition time, etc. The preparation conditions such as solution concentration, pH value, deposition time and bath temperature are optimized in order to get good quality of CdSe thin films. In the present investigation a comparative analysis of the optical properties of CdSe thin films obtained by chemical bath deposition method from a solution containing four components (cadmium chloride, ammonium hydroxide, triethanolamine, and sodium selenesulphate) and from a solution containing three components (cadmium chloride, ammonium hydroxide and sodium selenesulphate) was carried out.

2. EXPERIMENTAL METHODS

The chemical bath deposition (CBD) method was used to obtain CdSe thin films. Equal volumetric amounts (each 13 ml) of 0.5M cadmium chloride ($CdCl_{2x2.5}H_2O$), 13.4M (25%) ammonia (NH_3OH), 7.4 M triethanolamine ($C_6H_{15}NO_3$) and 0.2 M sodium selenosulfate (Na_2SSeO_3) were mixed in a 60 ml beaker. Sodium selenosulfate (Na_2SeSO_3) was prepared in the laboratory by dissolving an appropriate amount of selenium powder in 100 ml of sodium sulfite (Na_2SO_3) aqueous solution at 90 °C for 7 hours. After the undissolved selenium particles were filtered off, a clear solution of sodium selenosulfate was obtained [19].

Before the amorphous glass substrates (38×26×1 mm) were put into the solution, they were soaked in diluted acid, rinsed in deionized water and then dried in air. The substrates were put in glass vessels vertically. Chemical baths have waited for 48 hours at room temperature (27 °C) and this regime turned out to be the most optimal for obtaining a high-quality thin film. When the solutions are mixed, a white precipitate first forms at the bottom of the beaker. Over time, this precipitate and solution acquire a dark yellow color, and then a red color corresponding to CdSe. After deposition substrates were removed from the beaker, washed with distilled water and dried.

In the three-component (in the absence of triethanolamine) case, the chemical process was carried out completely according to the technology corresponding to the four-component case described above, that is, mixture of cadmium chloride, ammonium hydroxide and sodium selenosulfate was prepared while maintaining all of the above conditions. As a result, in both cases a red and homogeneous CdSe thin film was obtained on the glass substrate, with good adhesion. CBD film has thickness of around 200 nm. Partial discharge activity in a solid dielectric material depends upon applying voltage, dielectric constant of the material and the size of the void. These are considered as the important factors affecting Partial Discharge in solid dielectrics.

3. RESULTS AND DISCUSSION

In Figure 1 is shown the X-ray spectrum of a thin CdSe layer obtained for the four-component case. This spectrum shows that the resulting thin layer is polycrystalline in nature. The two theta peaks at 25.3, 42 and 49.8 are the result of reflections from the (111), (220) and (311) planes, respectively. The (111) plane is considered the main direction of CdSe, which crystallizes in a zinc blende (cubic) crystal structure (JCPDS No. 190191). The optical absorption measurement was carried out in the wavelength range of 200÷1100 nm, by using a U-5100 Spectrophotometer. Figure 2 shows optical absorption spectrum CdSe thin films obtained from four-component and three-component solutions by chemical bath deposition method.

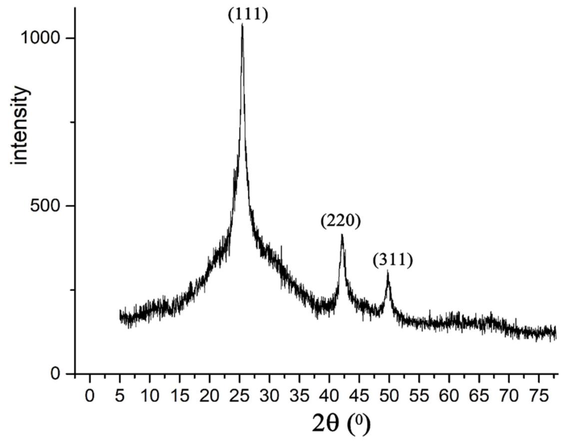

Figure 1. X-ray spectrum of CdSe thin film obtained by chemical bath deposition from a solution containing four components

In Figure 3, dependences $\alpha(h\nu)$ for CdSe thin films obtained from four-component and three-component solutions by chemical bath deposition were plotted.

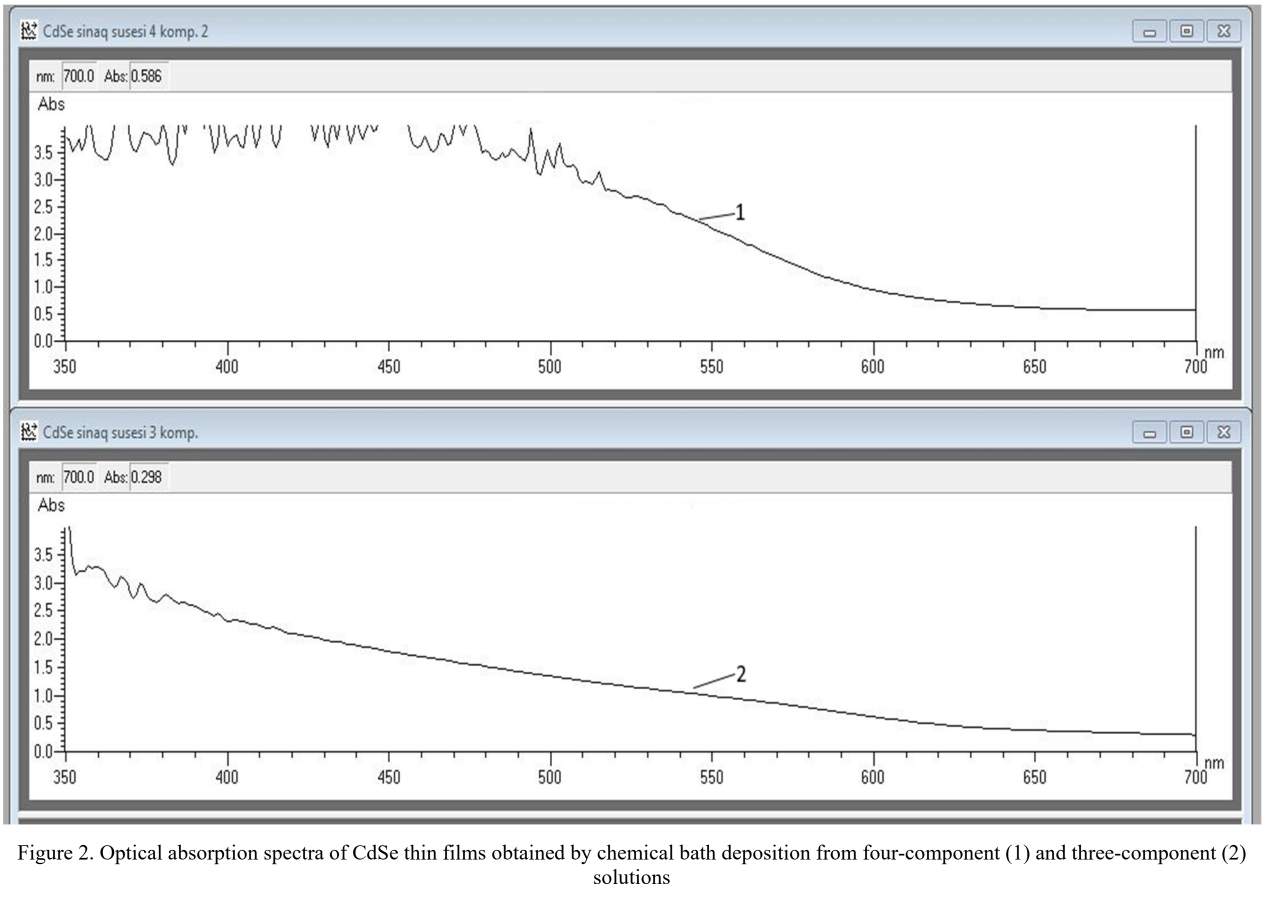

Figure 2. Optical absorption spectra of CdSe thin films obtained by chemical bath deposition from four-component (1) and three-component (2) solutions

As we know, the Tauc equation is used to calculate the width of the band gap of semiconductor [17]:

$$(\alpha h\nu)^{\frac{1}{n}} = A(h\nu - E_g) \quad (1)$$

where, A is a constant and E_g is band gap of semiconductor, and ($h\nu$) is the energy of the photon. The values of n can take in this expression depend on the type of transition and can take on the following values [20]:

- for an allowed direct transition $n = \frac{1}{2}$
- for an allowed indirect transition $n = 2$
- for a forbidden direct transition $n = \frac{3}{2}$
- for a forbidden indirect transition $n = 3$

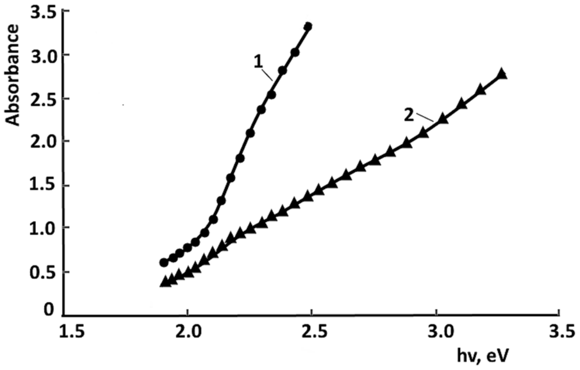

Figure 3. $\alpha(h\nu)$ dependences of thin CdSe films obtained by chemical bath deposition from four-component, 1- three-component, 2- solutions

As it was reviewed in [21] the CdSe thin films have an optical transition corresponding to the first case near fundamental absorption edge, so for spectral dependence of absorption coefficient can be applicable a formula;

$$(\alpha h\nu)^2 = A(h\nu - E_g) \quad (2)$$

Constructing $(\alpha h\nu)^2$ as a function of ($h\nu$) according to an optical absorption spectrum of CdSe thin films, obtained by CBD given in Figure 4.

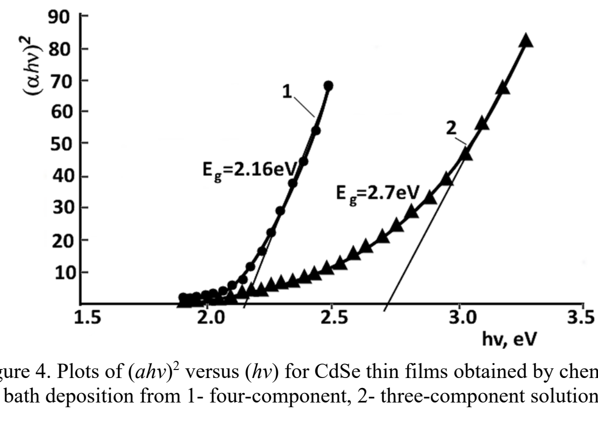

Figure 4. Plots of $(ah\nu)^2$ versus ($h\nu$) for CdSe thin films obtained by chemical bath deposition from 1- four-component, 2- three-component solutions

The estimated value E_g for CdSe thin films obtained by chemical bath deposition from four-component and three-component solutions correspond E_g=2.16 eV and E_g=2.7 eV respectively, i.e., a shift in the band gap of a CdSe thin film obtained from a three-component solution towards higher energies was observed.

4. CONCLUSIONS

Optical absorption spectra of CdSe thin films obtained by the CBD method at room temperature are measured for two regimes: in the presence of triethanolamine in solution and without it. Using the Tauc equation, the widths of band gaps of CdSe thin films were determined. The estimated values E_g for CdSe thin films obtained from four-component (in the presence of triethanolamine) and three-component (without triethanolamine) solutions correspond E_g= 2.16 eV and E_g=2.7 eV, respectively.

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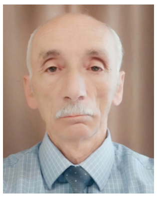
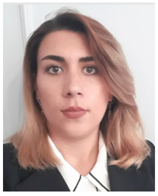
BIOGRAPHIES



Name: **Mammad**
Middle Name: **Huseynali**
Surname: **Huseynaliyev**
Birthday: 09.07.1952
Birth Place: Nakhichevan, Azerbaijan
Master: Faculty of Physics, Azerbaijan State University, Baku, Azerbaijan, 1974
Ph.D.: Candidate of Physical-Mathematical Sciences, Semiconductor Physics, Institute of Physics, Baku, Azerbaijan, 2009
The Last Scientific Position: Assoc. Prof, Chief of Physical Investigations, Institute of Natural Resources, Nakhichevan, Azerbaijan, Since 2011
Research Interests: Solar Energy Materials, Symmetry Problems
Scientific Publications: 101 Papers, 3 Books, 7 Patents, 9 Theses



Name: **Leyla**
Middle Name: **Nadir**
Surname: **Ibrahimova**
Birthday: 01.09.1992
Birth Place: Nakhichevan, Azerbaijan
Bachelor: Physics, Physical and Mathematical Faculty, Nakhichevan State University, Nakhichevan, Azerbaijan, 2013
Master: Semiconductor Physics, Masters Department, Nakhichevan State University, Nakhichevan, Azerbaijan, 2016
Ph.D.: Student, Semiconductor Physics, Institute of Natural Resources, Azerbaijan National Academy of Sciences, Nakhichevan, Azerbaijan, Since 2017
Research Interests: Semiconductor Physics, Optics
Scientific Publications: 35 Papers, 3 Theses