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SYNTHESIS AND PHYSICAL PROPERTIES OF CADMIUM SULPHUR (CdS) NANOPARTICLES

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Abstract: In this article, we present a simple and less hazardous route for the synthesis of CdS nanoparticles. We use the coprecipitation method for the synthesis of CdS nanoparticles, and obtain nanoparticles by calcination at 400°C. The synthesized CdS nanoparticles were characterized by optical microscopy and X-ray diffraction. The uniqueness of hexagonal (Wurtzite) CdS was revealed by X-ray diffraction peaks. The article also presents a study of the optical and electrical properties of polymer suspensions containing carbon nanotubes and composites based on them. These suspensions were also used to obtain composite thin films. Carbon nanotubes are of great interest in science and technology due to the combination of outstanding mechanical and electrical properties, extremely large interfacial contact area, high aspect ratio and low mass density. The use of nanotube concentrations as fillers in various composites, even less than 1 wt.%, has a significant impact on the optoelectronic properties of the final devices, making their use in nanoelectronics applications promising.

***Keywords**: nanoparticles, hexagonal, diffraction, coprecipitation, polymer suspensions*

INTRODUCTION

"Nanotechnology is the design, characterization, fabrication, and application of various structures, devices, and systems by controlling their shape and dimensions at the nanometer scale" [1]. Nanotechnology is an emerging field due to its wide applicability and practicality. Nanotechnology is the scientific convergence of physics, biology, chemistry, nanotechnology, and nanotechnology. Nanoparticles present at the nanoscale have a high surface-to-volume ratio, exhibit good optical, electrical, and chemical properties due to the high surface-to-volume ratio, and good mechanical stability. Nanoparticles are very important and useful because they are a new property obtained at the nanoscale compared to bulk materials. We can build special nanostructures and devices for controlled functions at the atomic and molecular levels. They attract several researchers due to their potential applications in biomedical, optical, and electronic fields. Cadmium is an inorganic compound of sulfur with the formula CdSe. It is classified as an n-type II-VI semiconductor. Nanoparticles made from CdS with dimensions below 10 nm exhibit a property known as quantum confinement. Quantum confinement results in the confinement of electrons in the material to a very small volume. The quantum confinement is size-dependent, meaning that the properties of CdSe nanoparticles can be tuned according to their size.[2] The three crystal structures of CdS are wurtzite (hexagonal), sphalerite (cubic), and rock salt (cubic). The transition begins at about 130 °C and is complete at 700 °C within a day. The rock-salt structure is only observed under high pressure.[3] CdS nanoparticles are used in many applications such as solar cells, thin films, photoresistors, light-emitting diodes, biofluorescent labeling, etc. Cadmium selenide nanoparticles are synthesized by several researchers using various methods such as sol-gel method, hydrothermal method. Now, in this work, CdS nanoparticles were prepared by co-deposition method and the nanoparticles were characterized by Optical Microscopy and XRD (X-ray diffraction). Various other methods have been used to prepare CdS nanoparticles, but these traditional methods usually produce large particles, irregular dimensions and low specific surface area. Nanoscale structures based on two-dimensional materials are widely used as a component of the elemental basis of nanoelectronics, optoelectronics and photonics [1-5]. The properties of these materials meet the criteria dictated by certain applied problems [4-5]. Some of the most promising two-dimensional materials for the fabrication of optoelectronic and nanophotonic devices are colloidal semiconductor nanocrystals [6,7], two-dimensional materials based on graphene and carbon nanotubes, chalcogenides and dichalcogenides of transition metals, as well as compounds of various metals. From the point of view of developing universal materials for flexible transparent electronics and nanophotonics, it is an important task to obtain effective analogues of widely used materials such as indium tin oxide with excellent optical properties and electrical conductivity. Due to the limitations dictated by the crystal structure, this material cannot be used in flexible applications. At the same time, the use of new two-dimensional materials such as graphene and carbon nanotubes opens up wide opportunities for obtaining flexible structures with good electro-optical properties on their basis. The optical properties and electrical conductivity of thin composite films based on carbon nanotubes depend on the mass of nanotubes in the composite, the thickness and morphology of the obtained thin films.

Methods of Materials and Studies

The starting materials used in the coprecipitation method were cadmium oxide (CdO), sulfur dioxide (SO2), ammonia (NH3), and thioglycerol as a cap. In this work, CdS nanoparticles were prepared by coprecipitation method. In this process, CdS nanoparticles were prepared by dissolving CdO and SO2 in a 2:1 ratio. The solution was prepared by dissolving 0.66 g of CdO and 1.1096 g of SO2 in 10 ml of distilled water. This solution was taken in a 100 ml beaker and kept above a magnet and allowed to stir again at 350-400 rpm for 2 h at room temperature. Then, two drops of thioglycerol were added to the solution, thioglycerol acts as a cap to keep the formed nanoparticles in nanoscale. Now, ammonia was slowly added to it dropwise using continuous stirring. Add ammonia until the pH reaches 11 and keep it at this pH only. The whole process is carried out under continuous stirring conditions. After the addition of ammonia, a mixed precipitate was formed which was allowed to stir for 2 hours. The CdS is placed at the bottom of the beaker. Then the beaker is carefully separated. The entire precipitate is washed thoroughly with double distilled water so that the precipitate is free from impurities or foreign elements. Finally, the precipitate is mixed in a centrifuge machine for 5 minutes. Place the sample in a hot air oven at 50°C for 3 hours for complete drying. Now the CdS sample is dried and the sample is ground with a mortar. CdS nanoparticles were obtained by a controlled calcination process using a muffle furnace at 400°C for 15 hours. If we increase the calcination time, we will obtain very fine nanoparticles.

Figure 1. CdS nanoparticles

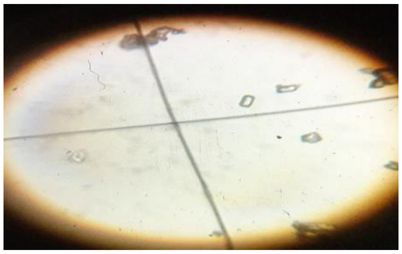

Figure 2. Image without CdS nanoparticles Optical Microscope

CdS nanoparticles were characterized by optical microscopy and X-rays

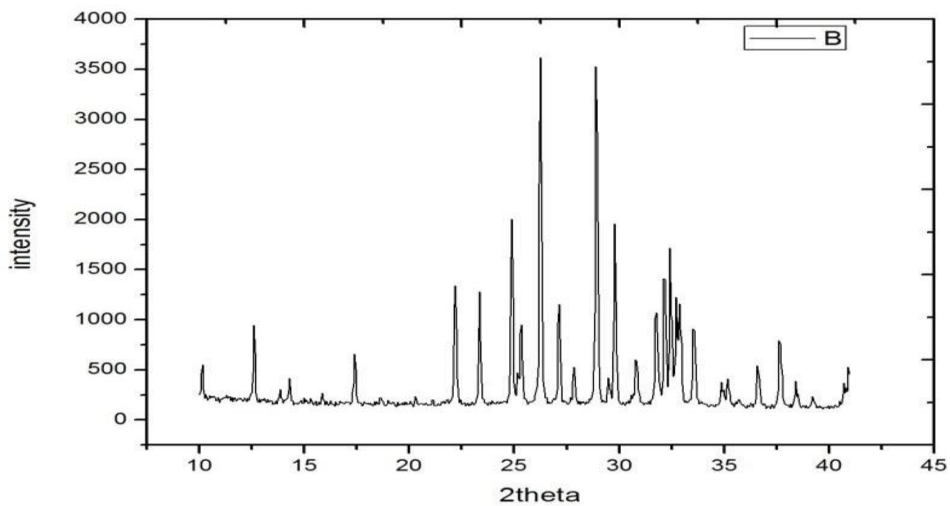

Figure 3. Powder X-ray diffraction (XRD) patterns of CdS nanoparticles.

The synthesized CdS sample is shown in Figure 1. The positions of several diffraction peaks shown in the XRD data analysis (Table 1) are in good agreement with the standard powder diffraction data (a = 4.299 Å and c = 7.010 Å). The diffraction of several peaks of CdS nanoparticles is obtained by (002), (101), (102), (103), (202), (211), (114) hexagonal (Wurtzite) planes of CdS, which shows a very good similarity with the hexagonal (P6mc) structure of the Joint Committee on Powder Diffraction Standards (JCPDSpdf #77.2307) (a = 4.299 Å and c = 7.010 Å are also observed in other samples). pattern. Pure and single-phase CdS has not been successfully obtained under current conditions.

Crystalline Phase	*2θ(observed)*	*2θ(reference)*
CdS	25.3361(002)	25.391(002)
CdS	27.1345(101)	27.097(101)
CdS	35.1772(102)	35.136(102)
CdS	45.8176(103)	45.810(103)
CdS	55.8585(202)	55.879(202)
CdS	67.8477(211)	67.880(211)
CdS	69.0965(114)	69.099(114)

Table1. θ(observed)and2θ(reference)value of CdS nanoparticles

Crystalline Phase	*(Å)(observed)*	*Lattice parameters (Å)*[8]
	a=4.2914 c=7.0014	a=4.299 c=7.010
CdS	-	-
CdS	-	-
CdS	-	-
CdS	-	-
CdS	-	-
CdS	-	-

Table2. Reference and observed lattice parameters of CdS nanoparticles.

Composites combining carbon nanotubes and glass microfibers have been proposed and studied. The conductivity of the composites is influenced by the structure of the base - the fibrous matrix. The leakage limit of such structures can be significantly lower than that of traditional polymer composites based on carbon nanotubes. The percolation theory predicts the following dependence of the electrical conductivity of the composite on the filler content: $\sigma = \sigma 0 \cdot (\phi - \phi \mathrm{c}) t$. It has been shown that changing the composition of the polymer matrix results in higher changes in the conductivity of the composite than on the filler. This can be explained by the very strong dependence of the tunneling between carbon nanotubes. Two types of composites were prepared (Fig. 4 (a, b)). The first type of composite depends on the glass fiber (glass fiber composite) containing 0.06 – 1.1 wt. % of carbon nanotubes (Fig. 5 (a)). The second type of composite is a mixed cellulose ether (cellulose composite) with carbon nanotubes, with pore sizes of 0.45 µm, in the range of 0.1–10 wt. % (Figure 4 (b)). Impedance spectroscopy was used to assess the contribution of conductive mechanisms within and between carbon nanotubes in the nanocomposites.

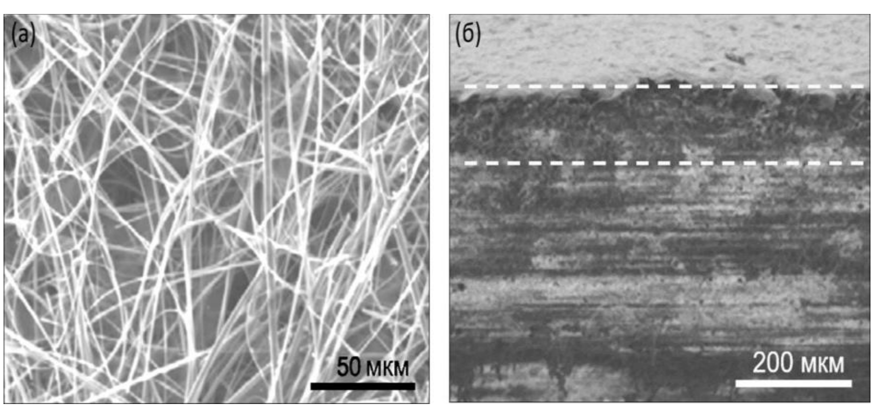

Figure 4. – SEM image of composite I with 0.11 wt. % carbon nanotubes (a); SEM image of composite – II with 5 wt. % carbon nanotubes

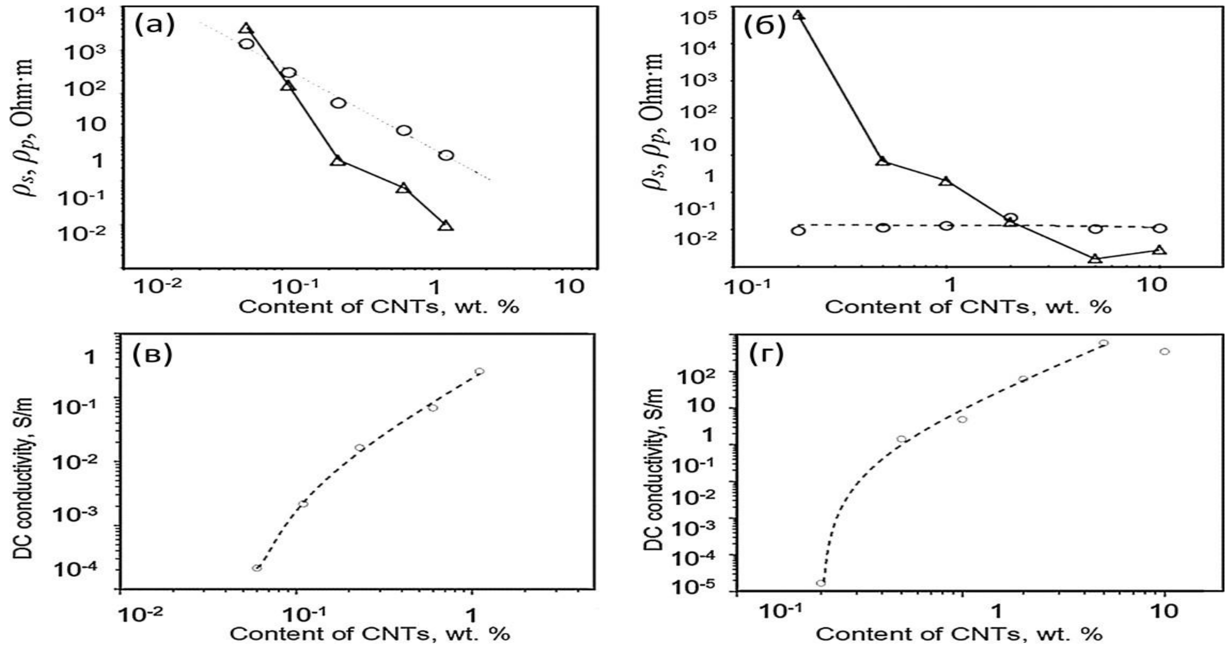

Figure 5. – Dependences of the specific resistance within carbon nanotubes (s – circles) and between carbon nanotubes (p – triangles) on the carbon nanotube content in glass fiber (a) and cellulose composites (b); Dependences of the direct current conductivity on the carbon nanotube content in glass fiber (c) and cellulose composites (d) are presented as a log-log plot and the results of the corresponding mathematical approximation (linear line).

The impedance spectra of all samples were simulated using an equivalent circuit consisting of a parallel-connected resistor R1 and a series-connected resistor R2 and a fixed phase element [18]. Experimental data and the corresponding approximation results are presented in Figure 5 (c, d). The leakage limit ρs values found for these fittings are 0.04 wt% (composite I) and 0.2 wt% (composite II), respectively. When calculating these values, tunneling through potential barriers between carbon nanotubes was not taken into account. The optical and electrical properties of a third type of composite based on suspensions of carbon nanotubes with a polymer-stabilized polyarylate (polyarylate composite) are shown. The possibilities of using polymer glass fiber and cellulose composites for the creation of a prototype of a gas-sensitive sensor are discussed here.

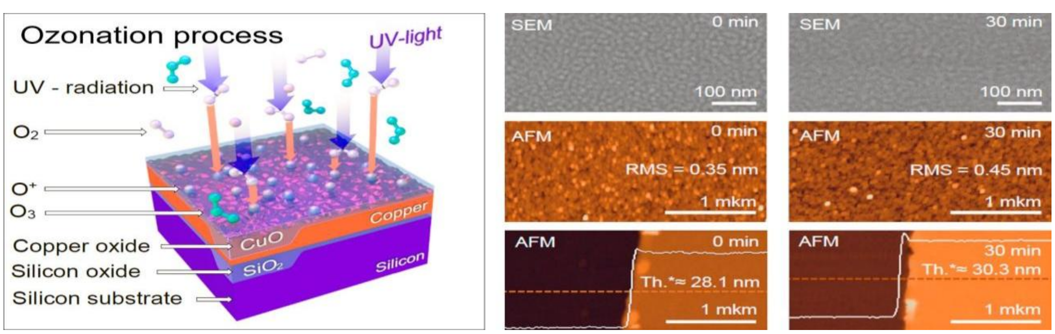

Figure 6. – Diagram of the ozonation process (left); On the right - microphotographs taken using a scanning electron microscope and an atomic force microscope.

In addition, the study presents experimental studies of other two-dimensional materials and metal oxide complexes. One of the sections is devoted to the problem of preserving optoelectronic properties by creating a protective composite oxide layer of CuO using the UV ozonation method (Fig. 6). Along with plasmonic materials such as gold and silver, copper also has excellent optical properties. Compared to gold, copper is more accessible and has lower optical losses in the visible and near-IR ranges. Under normal conditions, under the influence of the external environment, copper oxidizes, mainly forming Cu2O oxide on its surface and, to a lesser extent, CuO oxide. To use copper for plasmonic applications, its surface can be protected in several ways, using a protective coating consisting of SiO2, Al2O3 or graphene [19]. The article presents a new, technically simple UV ozonation method that allows to quickly obtain a thin CuO oxide layer on the surface of the copper layer, which effectively protects the copper from further degradation. Copper films with a thickness of 25 nm were formed by electron beam evaporation, and then the samples were exposed to UV ozonation for different time intervals (10, 20, 30, 40 and 120 min). The obtained results of ellipsometric measurements (Fig. 7 (a)), AFM (Fig. 6 – right) and XPS analysis (Fig. 7 (b)) showed a significant difference in copper oxidation under ambient conditions and with UV ozonation. For films oxidized in the ambient atmosphere, Cu2O predominates with or without a small amount of CuO; for copper films treated with UV-ozone, oxidation occurs mainly due to the formation of CuO. The thickness of the formed oxide was estimated (3-4 nm). Since the CuO layer effectively protects copper from oxidation, UV ozonation is a simpler and cheaper solution to preserve the functional properties of copper.

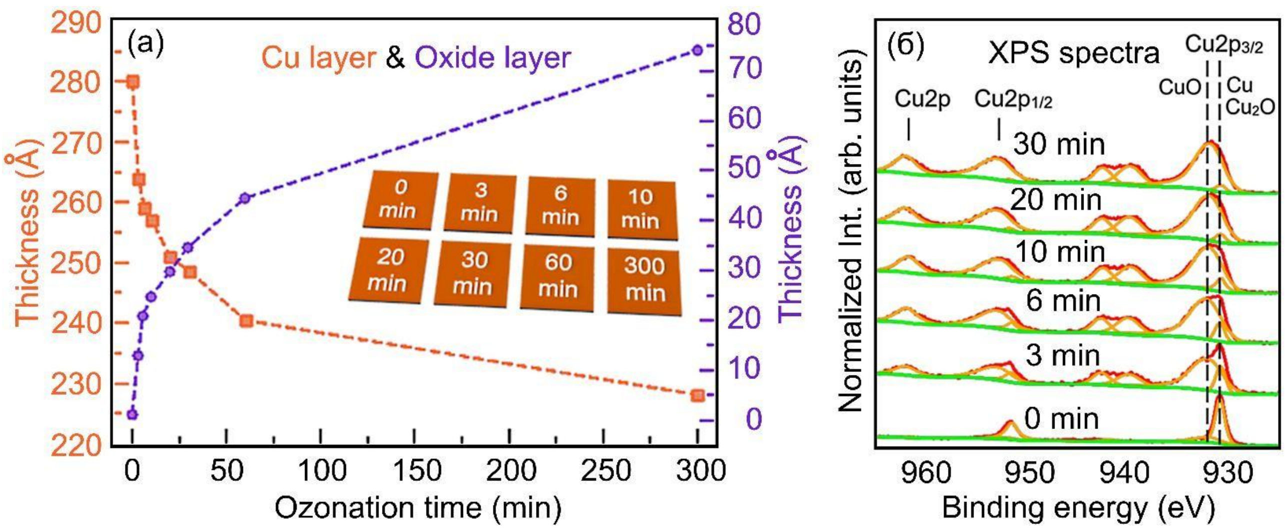

Figure 7– Dynamics of oxide growth on the surface of a copper layer obtained as a result of processing data from ellipsometric measurements using the Drude mathematical model – (a); XPS analysis of samples before and after UV ozonation – (b).

CONCLUSION

In this article, we present a simple and less hazardous route for the synthesis of CdS nanoparticles. We use the coprecipitation method for the synthesis of CdS nanoparticles, obtaining nanoparticles by performing a calcination process at 400°C. The synthesized CdS nanoparticles were characterized by optical microscopy and X-ray diffraction. The uniqueness of hexagonal (Wurtzite) CdS was revealed by X-ray diffraction peaks. A conductive composite was prepared based on a polymer conductive suspension of semiconducting carbon nanotubes (20 wt%) stabilized with a tetrachloroethane-polyarylate solution. For the first time, transparent (~ 80% in the wavelength range of 400-900 nm) thin (less than 1 μm) thin films with a sheet resistance of 120 Ohm/nm were obtained based on a polyarylate composite. The introduction of a new tetrachloroethane-polyacrylate stabilizer and the use of 2D/3D printing methods (without the use of fibrous matrices) made it possible to obtain mechanically strong, flexible, transparent conductors that are more commercially viable analogues of crystalline indium tin oxide. An important result is the demonstration of the formation of a protective thin-film oxide layer of CuO on the surface of copper layers using the UV ozonation method for nanophotonic applications. Organic composites of the functional layers of paintings were studied using Raman spectroscopy. A method for preparing composite microsections based on paint samples from colored canvases was developed and improved. The potential of a new scientific method for determining the elemental and structural composition of composites is confirmed by the qualitative results of micro spectral analysis of functional composite layers of paintings.

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