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A Simple Method for Synthesis of Cadmium Oxide Nanoparticles Using Polyethylene Glycol

M. Tabatabaee[a*], A. A. Mozafari[a], M. Ghassemzadeh[b], M. Reza Nateghi[a], I. Abedini[c]

[a]*Department of Chemistry, Yazd Branch, Islamic Azad University, Yazd, Iran*
[b]*Chemistry & Chemical Engineering Research Center of Iran, Tehran, Iran*
[c]*Department of Applied Chemistry, Malek-e-Ashtar University, Esfahan, Shahin Shahr, Iran*

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Nano-sized cadmium oxide was synthesized by a simple method using $Cd(NO_3)_2.4H_2O$ as a reagent in the presence of polyethylene glycol (PEG 2000). X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and energy dispersive spectrometry (EDS) were used to characterize the structure and morphology of the synthesized powder. The results showed that PEG played a significant role in the decomposition of cadmium nitrate to cadmium oxide nanoparticles. The CdO crystals were grown in face-centered cubes over the range (15-25 nm).

Keywords: Nanoparticles; Cadmium oxide, Polyethylene glycol

INTRODUCTION

In the past few years, much attention has been focused on the research field of nano-crystalline oxide materials both because of their fundamental importance and the wide range of potential technological applications [1–6]. CdO is a degenerate, n-type semiconductor used in optoelectronic applications such as photovoltaic cells [7], solar cells [8], phototransistors [9], IR reflectors [10], transparent electrodes [11], gas sensors [2, 12, 13] and a variety of other materials. These applications are based on its specific optical and electrical properties [14]. Polyethylene glycols (PEG) in aqueous solution are highly mobile molecules with a large exclusion volume, mostly free of charges, which can avoid the strong interaction between the constituents [15]. A number of studies have reported that PEG can modify or control the surface of the nanometer crystals; moreover it can act as a dispersing agent of the nanometer crystals in the process of synthesis [16, 17]. There are some reports on the synthesis of CdO nanoparticles for nanowires and nanofilms by chemical co-precipitation or sonochemical methods [2, 18–20], but to the best of our knowledge, there are no reports in the literature dealing with the use of polyethylene glycol for the synthesis of CdO. In this work, we report a new and simple method for the synthesis of nano-sized cadmium oxide by decomposition of cadmium nitrate in polyethylene glycol.

EXPERIMENTAL PROCEDURE

2 g of cadmium nitrate tetrahydrate, $Cd(NO_3)_2 \cdot 4H_2O$, with 99% purity were added to 30 g of polyethylene glycol (average molecular weight 2000, abbreviated as PEG2000). A transparent solution was obtained at 80ºC, which was refluxed for two hours at 250°C. 30 ml of deionized water were added to the resulting brown suspension. The precipitate was filtered off and washed three to four times using double distilled water and ethanol to remove polyethylene glycol and other impurities. The prepared CdO powder was dried at 200ºC for 5 min. The sample was characterized by powder X-ray diffraction (Bruker, Advance D8) with Cu Kα (λ=1.5406 Å) incident radiation. The size distribution and morphology of the sample was analyzed by scanning electron microscopy (SEM, Philips XL30) and transmission electron microscopy (TEM, Philips CM10). Energy dispersive spectrometry (EDS) attached to SEM was employed to perform the elemental analyses of the nanostructured materials.

RESULTS AND DISCUSSION

The XRD pattern of nano-sized CdO is shown in Fig.1. It shows the diffraction peaks at 2θ values of 33.0º, 38.3º, 55.3º, 65.9º and 65.9º, which are attributed to the formation of CdO.

* To whom all correspondence should be sent:
E-mail: tabatabaee45m@yahoo.com

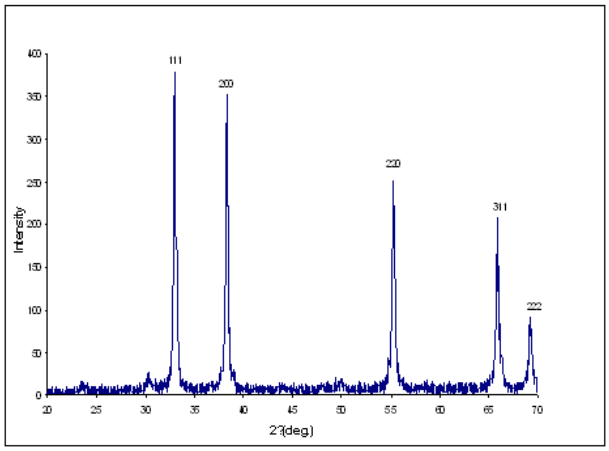

Fig. 1 XRD patterns of the synthesized CdO nanocrystallite.

No characteristic peaks from other impurities were detected. The crystal structure consists of face centered cubes and the entire d-line patterns match the reported values. The crystallite size was estimated from the broadening of CdO (111) diffraction peak (2θ = 32.2◦) using Debye-Scherrer's formula:

$$t = \frac{k\lambda}{B\cos\theta}$$

where t is the average size of the crystallite, assuming that the grains are spherical, k is 0.9, λ is the wavelength of X-ray radiation, B is the peak full width at half maximum (FWHM) and θ is the angle of diffraction. The crystallite size of nano-sized CdO is found to be ~25 nm. The TEM micrograph of the nano-sized powder along with the electron diffraction pattern is shown in Fig. 2.

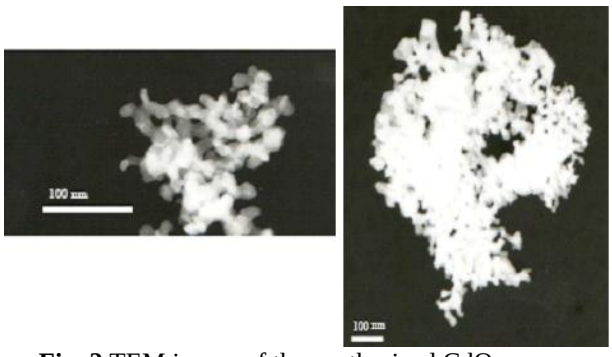

Fig. 2 TEM image of the synthesized CdO.

The TEM micrograph clearly shows that the particle size of nano-sized CdO is ~15–25 nm. This result is in good agreement with the crystallite size calculated using the XRD data. The morphology of the CdO nanocrystallites is shown in Fig. 3.

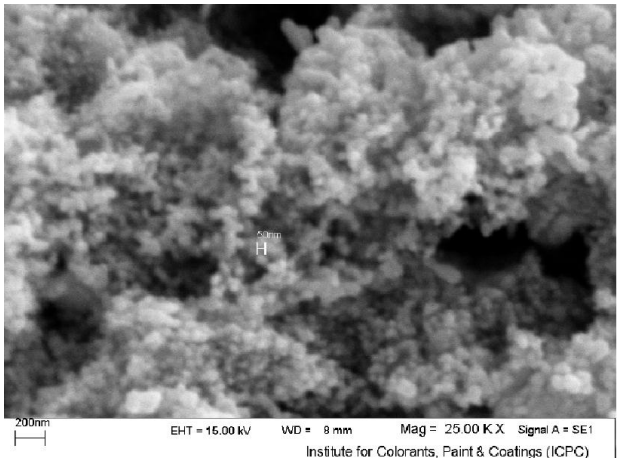

Fig. 3 Scanning electron micrographs of the synthesized CdO.

In the analysis of the cadmium oxide nanoparticles by energy dispersive spectroscopy (EDS), the presence of strong CdLa signals confirms the presence of CdO in the sample (Figure 4).

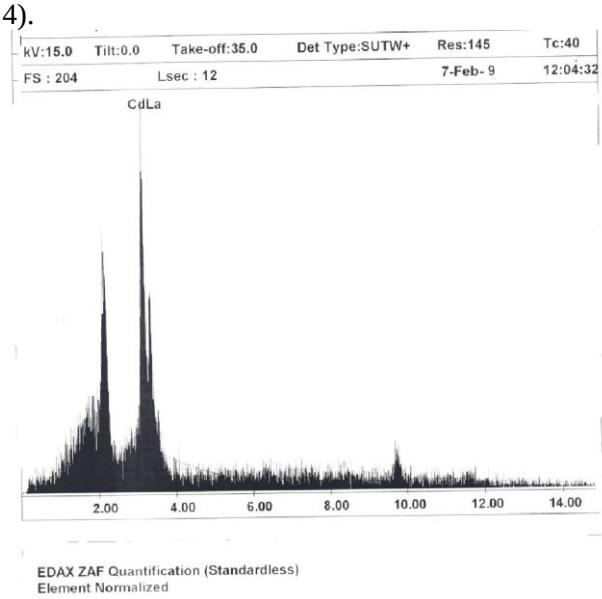

Fig 4. EDS image of the synthesized CdO.

The results showed that PEG played a significant role in the decomposition of cadmium nitrate to cadmium oxide nanoparticles. The CdO crystals were grown in face-centered cubes over the range (15-25 nm).

By the co-precipitation method used, $Cd(OH)_2$ was formed in a basic medium. The subsequent calcination of $Cd(OH)_2$ lead to the formation of CdO. In polyethylene glycol, decomposition of cadmium nitrate was assumed. This indicates that NO_2 was the main product during the decomposition. This observation is fully consistent with the following mechanism proposed for other anhydrous nitrates of divalent metals [21]:

$$M(NO_3)_{2(s)} \longrightarrow MO_{(g)} + 2NO_{2(g)} + 0.5O_2$$

followed by

$$MO_{(g)} \longrightarrow MO_{(s)}$$

CONCLUSION

By the co-precipitation method used, $Cd(OH)_2$ was formed in a basic medium. The subsequent calcination of $Cd(OH)_2$ lead to the formation of CdO. In polyethylene glycol, $Cd(NO_3)_2 \cdot 4H_2O$ decomposed and nano-sized cadmium oxide was directly formed, without formation of $Cd(OH)_2$. The CdO crystals were grown as face-centered cubes over the range (15-25 nm).

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ПРОСТ МЕТОД ЗА СИНТЕЗА НА НАНОЧАСТИЦИ ОТ КАДМИЕВ ОКСИД ПРИ ИЗПОЛЗВАНЕТО НА ПОЛИЕТИЛЕНГЛИКОЛ

М. Табатабаее[a], А.А. Мозафари[a], М. Гасемзаде[b], М. Реза Натеги[a], И. Абедини[c]

[a]*Департамент по химия, Клон Язд, Ислямски университет „Азад“, Язд, Иран*
[b]*Ирански изследователски център по химия и химично инженерство, Техеран, Иран*
[c] *Департамент по приложна химия, Университет „Малек-е-Ащар“, Есфахан, Шахин Шахр, Иран*

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(Резюме)

Синтезирани са наноразмерни частици от кадмиев оксид по прост метод, използвайки $Cd(NO_3)_2.4H_2O$ в присъствие на полиетиленгликол (PEG 2000). Използвани са рентгенова дифракция, сканираща електронна микроскопия, трансмисионна електронна микроскопия и енерго-дисперсионна спектроскопия за охарактеризиране на структурата и морфологията на синетзираните прахове. Резултатите показват, че PEG играят значителна роля за разлагането на кадмиев нитрат до наночастици от кадмиев оксид. Кристалите от CdO израстват в лицево-центрирана кубична решетка с размери в интервала15-25 nm.