PHYSICS AND CHEMISTRY OF SOLIDSTATE
V. 18, № 3 (2017) P. 338-341
DOI: 10.15330/pcss.18.3.338-341

ФІЗИКА І ХІМІЯ ТВЕРДОГО ТІЛА
Т. 18, № 3 (2017) С. 338-341

UDK 544.774 : 546.47’24

ISSN 1729-4428

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Properties of Highly Dispersed Systems on The Base of Cadmium Telluride Obtained by Electrochemical Dispergation

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Physical and chemical properties of highly dispersed systems on the base of metallic (cadmium, tellurium) and semiconductor materials (cadmium telluride) obtained by the plasma-electrochemical method are studied. It is shown that obtained systems consist of particles of different sizes, and in some cases there are two polymorphic modifications of the systems.

Key words: cadmium telluride, microcrystals, nanocrystals, dispergation, dispersed systems, X-ray analysis.

Article acted received 28.08.2017; accepted for publication 05.09.2017.

Introduction

Two main directions in material designing for electronic technology can be single out – synthesis of new structures and modification of already available in order to obtain materials with more advanced characteristics or materials which have qualitatively new properties [1]. The peculiarity of the technology of highly dispersed and nanoscale materials is a multidirectionality of the methods of their obtaining. This point is associated with a complex of problems related to obtaining and studies of highly dispersed systems and nanoparticles – size effects in nanochemistry, manyphase complexes within a single nanoparticle, nanoreactors and nanocontainers etc [2]. The most common classification of the methods is based on a change of particle size during the growing. These are "descending" (methods based on dispergation of bulk materials) and "ascending" (methods based on obtaining highly dispersed and nanoscale systems in which the substances are dispergated at the molecular (atomic) level).

At present there are a wide range of the methods for obtaining low-dimensional semiconductor systems [3]. A group of dispergation methods is based on the grinding of the source material, but mechanical dispergation is not widely used for nanoparticle obtaining. The most effective are mechanochemical processes which take place at grinding in ball, planetary, vibration and other mills [4]. An average particle size of a material obtained by mechanical grinding varies from 5 to 200 nm. By varying the conditions of the process, one can get particles of required size. However, distribution in size of the particles obtained by mechanical dispergation is often quite wide [5]. This determines an importance of finding the ways of effective dispergation of the source materials. A promising direction is a destruction of metal and semiconductor crystals by electrochemical dissolution or their dispergation under the action of an electric arc [6, 7].

I. Experimental method

The object of the study is the formation of micro and nanocrystals of elementary and complex substances under the action of an electric arc. The materials for electrodes were CdTe crystals grown by the Bridgman method and high purity cadmium and tellurium crystals. Deionized water was used as a medium for the obtaining dispersed systems by electrochemical destruction of the crystals, and thioglycol acid (HS-CH_2-COOH) was used as a stabilizer of dispersed systems. The set up for obtaining highly dispersed systems consists of a current source and two electrodes immersed in a stabilizer solution at a distance of 1÷1.5 mm from each other. The electrodes were supplied by DC voltage up to 320V.

Optical characteristics of obtained systems were studied with the use of SF-46 spectrophotometer at a wavelength λ=220-400 nm. To determine a dispersed

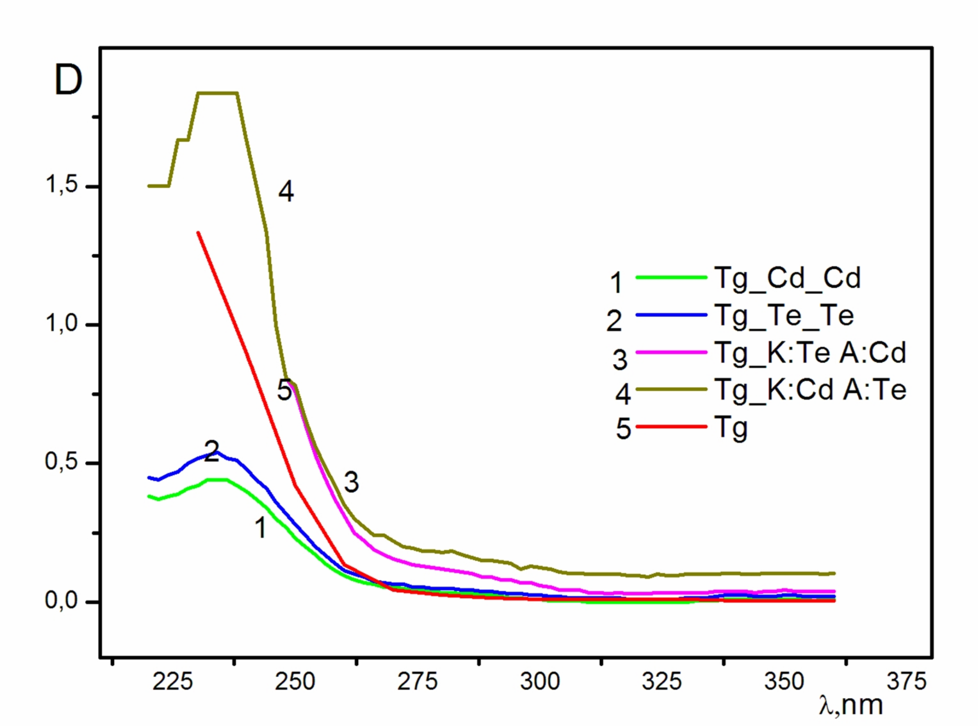

Fig. 1. Absorption spectra of obtained systems.

phase, X-ray diffraction (XRD) analysis on powder X-ray diffractometer ARL X'tra (Thermo Fisher Scientific) with θ-θ-Bragg-Brentano geometry was carried out. Cu Kα radiation was used. The voltage on the tube was of 45 kV and the current was of 30 mA. Measurements were carried out with a scan step of 0.030° and a set time of 1 second. Phase analysis was performed using ICDD, PDF-2 Release 2012 database. Obtained colloidal solutions were dispergated, and the samples were prepared from the precipitate in the form of tablets in order to carry out XRD studies.

II. Results and discussion

It is found that an electric arc comes up at a potential difference of 20 - 50 V at a distance of 1.0-1.5 mm. Traces of electrodeposite destruction at the anode are visually observed after 30 seconds of current flow. Opalescence of the solutions takes place when cadmium electrodes are used. The solution get yellow-brown color in the case of tellurium (Cathode) - cadmium (Anode); cadmium (Cathode) - tellurium (Anode); tellurium (Cathode) - tellurium (Anode) systems. A layer of coarse particles of black color is formed on the bottom of the cell after 30 seconds in all cases. Absorption spectra of the obtained dispersed systems (Fig. 1) show the formation of microheterogenic systems in the dispersed medium. All spectra have an absorption band in the wavelength range of 230 - 260 nm. After storing the solutions at room temperatures, the maximum of their absorption spectra slowly shifts towards greater wavelengths, and intensity of the color of the solutions decreases, that indicates on an association of the particles into more larger aggregates. Obtained systems have high stability (up to 12-14 days), but do not exhibit photoluminescent properties like in source cadmium telluride.

XRD analysis shows that obtained systems consist of particles of different sizes, and in some cases, there are two polymorphic modifications of the systems. The diffraction image of the sample obtained with the use of metal cadmium electrodes (Fig. 2a) has no diffraction peaks. Existence of two diffuse halo clearly indicates on the presence of coherent scattering regions with dimensions of no more than 1 nm (amorphous state). Chemical reactions do not occur when elemental tellurium is used as electrodes. Dispergation of tellurium takes place in this case (Fig. 2b). In the case when both electrodes are made of cadmium telluride, there are two polymorphic modifications of cadmium telluride in the dispersed phase – tetragonal and cubic (Fig. 2c). The question of the nature of such a reaction is still open. It is known, that the presence of high temperatures in discharge channels and, consequently, the formation of high-temperature phases is a characteristic feature of the plasma-electrochemical method for nanocrystalline powders obtaining. This is also facilitated by high cooling rates at solidification of dispergated drops. From another point of view, in [8] have been shown that there is an alternative way of obtaining high-temperature states – by reducing the size of the particles (crystallites) to nanometer scale. For ZrO_2, a "critical size" of crystallites (about 20 nm) was predicted, below which, due to the effect of significant surface energy, a high-temperature tetragonal phase may exists under normal conditions.

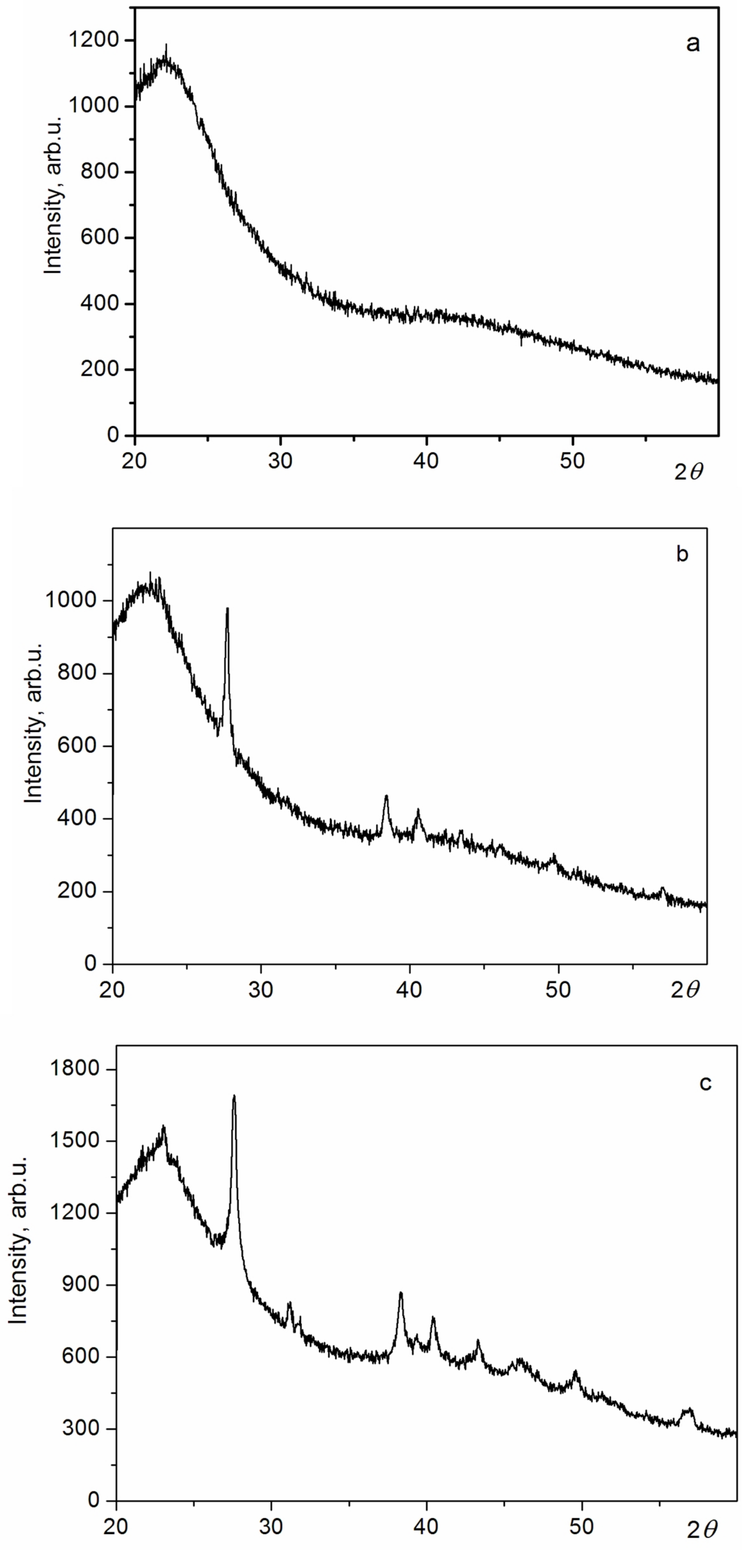

Fig.2. X-ray diffraction images of dispersed samples of K:Cd A:Te(a), K:Te A:Cd(b), K,A:CdTe(c) systems.

Conclusions

It was found that the plasma-electrochemical method gives a possibility to obtain highly dispersed systems using metallic (cadmium, tellurium) as well as semiconductor materials (cadmium telluride). A material of the anode is mostly turns in highly dispersed state. It is shown that the materials obtained by this method can exist both in amorphous and in crystalline state. Our studies have proved the emergence of nanosized particles.

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[1] E.I. Kapinus, J. Fiz. Chemistry. 85 (4), 748 (2011).
[2] Priyam, A. Chatterjee, S.K. Das, A. Saha, Res. Chem. Intermed. 31 (7-8), 691 (2005).
[3] T. Vossmeyer, L. Katsikas, M. Giersig, I.G. Popovic, K. Diesner, A. Chemseddine, A. Eychmueller, H. Weller, J. Phys. Chem. 98 (31), 7665 (1994).
[4] X. Ma, G. Lu, B. Yang, App. Surf. Sci. 187, 235 (2002).
[5] A.E. Raevskaya, A.L. Stroyuk, S.Ya. Kuchmiy, Theoret. and Experiment. Chemistry. 39 (3), 153 (2003).
[6] V.V. Shvalagin, A.E. Raevskaya, A.L. Stroyuk et al., Theoret. and Experiment. Chemistry. 43 (3), 170 (2007).
[7] R.G. Gadjimammadov, M.B. Muradov, G.M. Eyvazova, JL- Chemistry. 224 (1996).
[8] A.E. Rayevskaya. A.L. Stroyuk., G.Ya. Grodziuk et al., Scientific and Theoretical Journal. 46 (5), 265 (2010).
[9] Yao, G. Zhao, G. Han, Journal of Materials Science Letters. 22, 1491 (2003).
[10] E.V. Krupko, G.Ya. Grodziuk, Yu.B. Halavka et al., Teoret. and Experiment. chemistry. 47 (2), 99 (2011).
[11] N.G. Piven, L.P. Scherbak., P.I. Feychuk, Scientific Journal of ChNU. Chemistry. 307, 97 (2006).
[12] G.Z. Wang, W. Chen, C.P. Liang [et. al.], Inorganic Chemical Communication. 4, 208 (2001).
[13] S.V. Larionov, T.G. Leonova, L.A. Glinskaya et al., Journal of Inorganic Chemistry. Coordination compounds. 57 (3), 431 (2012).

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Властивості високодисперсних систем на основі телуриду кадмію, отриманих шляхом електрохімічного диспергування

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Досліджено фізико-хімічні властивості високодисперсних систем на основі металічних (кадмій, телур) та на основі напівпровідникових матеріалів (кадмій телурид), отриманих плазмоелектрохімічним методом. Показано, що отримані системи складаються з частинок різного розміру, а в окремих випадках існують в двох поліморфних модифікаціях.

Ключові слова: телурид кадмію, мікрокристали, нанокристали, диспергування, дисперсні системи, рентгенофазовий аналіз.