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Synthesis of $Cu_2ZnSnSe_4$ nanoparticles by colloidal method

O.A. Dobrozhan, A.S. Opanasyuk, S.I. Kshnyakina

Department of Electronics and Computer Technics, Sumy State University, Rymskogo-Korsakova st., 2, Sumy-40007, Ukraine.
E-mail: dobrozhan.a@gmail.com

Recently the thin films of semiconductor compound $Cu_2ZnSnSe_4$ (CZTSe) have attracted the attention of scientific community as alternative layers of $CuInSe_2$ (CIS), $CuIn_{1-x}GaxSe_2$ (CIGS) and CdTe for designing cheap thin film solar cells (SCs). This material has the optimum for conversation solar energy into electricity band gap ($E_g = 1$ eV), high absorption coefficient ($\alpha > 10^5$ cm^{-1}), *p*-type conductivity and it's characterized long lifetime as well as high mobility of charge carriers [1]. The colloidal synthesis is promising among nonvacuum chemical methods for obtaining CZTSe nanoparticles which allows synthesizing nanoparticles of a wide range of materials with the possibility of forming films using spin-coating, spray pyrolysis techniques. Also, it is important that the properties of the synthesized nanoparticles strongly depend on the shape and size. The above mentioned purpose main aim of this work which is to study the morphological characteristics and chemical composition of nanoparticles CZTSe with different sizes and shapes of the synthesized by colloidal method.

The size and shape of the nanoparticles were changed by adding of various type phosphonic acids (propyl-, hexyl-, dodecyl- and tetradecyl-) to the initial solutions which used for the general synthesis.

The morphology of the nanoparticles was studied by transmittance electron microscopy (TEM). Scanning electron microscopy (SEM) was performed using a ZEISS Auriga SEM with an energy dispersive X-ray spectroscopy (EDAX) detector to study composition.

It was established that the synthesized CZTSe nanoparticles were monodisperse and had small size (15-30 nm), their shape was like a circle, triangle, or was multifaceted, depending on the type phosphonic acid. EDAX analysis showed that the particles were not stoichiometric with low level of zinc ions. The best results with respect stoichiometry were obtained using tetradecylphosphonic acid: $Cu_{1.87}Zn_{0.43}Sn_{0.99}Se_4$. This results can be used for obtaining absorbing layers of SCs.

1. *Opanasyuk A.S., Kurbatov D.I., Cheong H. et al*. Properties of the window layers for the CZTSe and CZTS based solar cells // J. Nano- Electron. Phys.- 2012. - **4.** - P. 01024-1-01024-3.

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