# Spray pyrolysis deposition and optical properties of $Cu_2ZnSnS_4$ thin films

**I.G. Orletsky, E.V. Maistruk, V.V. Brus, D.P. Koziarskyi, P.D. Maryanchuk**

*Cherinvtsi National University, 2 Kotsubinsky str., 58012 Chernivtsi, Ukraine*
*e-mail: i.orletskyi@chnu.edu.ua*

$Cu_2ZnSnS_4$ (CZTS) thin films with near to optimal values of the band gap ~ 1.5 eV and the absorption coefficient ( $>10^4$ $cm^{-1}$) in the visible range for the fabrication of high efficient solar cells are of great interest for research and application. CZTS solar cells are a low-cost alternative of the expensive $CuInS_2$ (CIS) solar cells. The chemical elements of the CZTS thin films are not toxic and widely available. The fabrication process of the CZTS-based solar cells is usually carried out by the sulfurization of the Cu-Zn-Sn thin films [1]. However, the application of low-cost and simple, from the technological point of view, spray pyrolysis method can considerably decrease the final cost of the solar cells.

For the deposition of the $Cu_2ZnSnS_4$ thin film the 0.1 M aqueous solution of copper chloride $CuCl_2 \cdot 2H_2O$, zinc chloride, $ZnCl_2$, tin tetrachloride $SnCl_4 \cdot 5H_2O$ and thiourea $(NH_2)_2CS$ were used. The solutions were mixed before the spray pyrolysis process in the appropriate volume ratios and consistency. As usually, CZTS thin films with the p-type of conductivity and specific resistance of $\rho = 1 \div 10$ Ohm·cm are used in solar cells. Therefore, the elevated sulfur composition in comparison to the stoichiometric composition of the CZTS thin films should be reached ($CuCl_2 \cdot 2H_2O$ : $ZnCl_2$ : $SnCl_4 \cdot 5H_2O$ : $(NH_2)_2CS$ = 2.1 : 1 : 1 : 10). The spraying of the solutions was carried out with the velocity of 3 ml/min onto heated glass substrates. The best structural perfection and adhesion was obtained at the substrate temperature T ≈ 290 $^oC$. Depending on the deposition time, the CZTS films were 0.2-1 um thick.

The fig. 1 shows the spectral distribution of the transmittance T and absorption $(\alpha h\nu)^2 = f(h\nu)$ coefficients of the $Cu_2ZnSnS_4$ thin films. The value of the band gap $E_g$ = 1.54 eV of the thin films was determined.

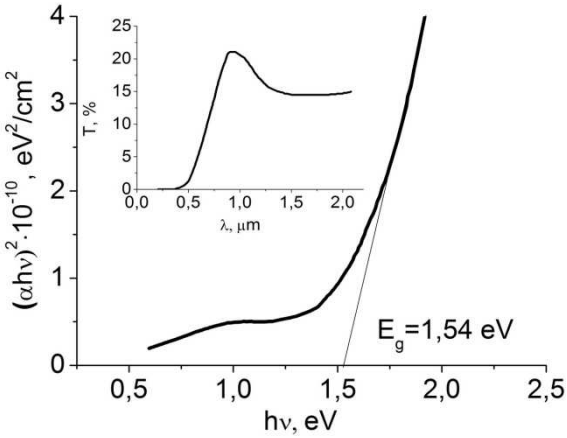


Fig. 1. Spectral distribution of the transmittance (the inset) and absorption coefficient of the thin films.

[1] J.P. Leitão, N.M. Santos, P.A. Fernandes, P.M.P. Salomé, A.F. da Cunha, J.C. González, F.M. Matinaga, *Thin Solid Films* **519,** 7390 (2011).
[2] Z.Zhou, Y.Wang, D.Xu, Y.Zhang, *Solar Energy Materials and Solar Cells* **94**, (2012) 2010.