$CuInSe_2$ THIN LAYERS FABRICATION AND THEIR KINETIC PROPERTIES

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Abstract: Thin $CuInSe_2$ layers were obtained by "flash" evaporation method, possessed a p-type conductivity and a hole concentration of more than ~ 10^{19} cm^{-3}. The energy of the intrinsic defects associated with the interstitial selenium atoms is 0.13 eV, and the low values of the charge carriers mobility indicate the presence of a compensation effect.

Keywords: solar cells, thin layers $CuInSe_2$, kinetic properties

1. INTRODUCTION

Recently the widely used solar energy converters are built on the basis of crystalline silicon, their efficiency can reach ~ 25% [1], but their cost is too high. The $A^1B^3C^6$ semiconductors compounds are deservedly considered to be one of the most promising materials (the laboratory samples efficiency is up to 20%) for the creation of solar batteries on their basis [2], which is primarily due to the availability and cheapness of the materials used. At the same time, the efficiency of solar cells is determined by the possibility of planar technologies using for obtaining materials with predefined parameters. At present, there is no detailed information on the study of kinetic effects in thin layers of $CuInSe_2$, which is mainly determined by the method of their production and the perfection of the structure.

2. RESULTS AND DISCUSSION

2.1. Method of thin layers obtaining

The use of thin $CuInSe_2$ layers in solar energy is determined by the possibility of obtaining of layers with a minimum number of intrinsic defects, given value of charge carriers concentration , and high photosensitivity. The choice of the method for $CuInSe_2$ thin layers obtaining is related to the peculiarities of this compound dissociation upon heating. Thus, the pressure of saturated selenium vapor exceeds by several orders of magnitude the pressure of saturated indium and copper vapor, which leads to the appearance of these materials vacancies. There are various methods for $CuInSe_2$ layers fabrication: Evaporation from several sources; Transport chemical reactions method; Flash method; Method of a quasi-closed volume.

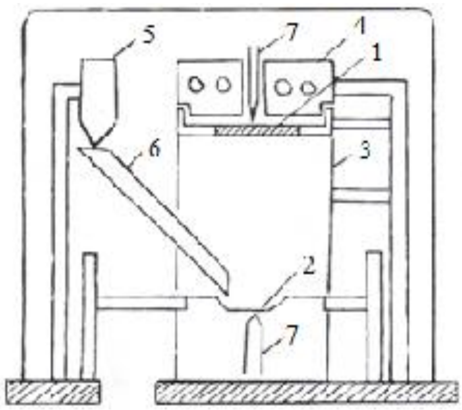

Fig.1. The „flash" evaporation method

The results of study of $CuInSe_2$ layers obtained by the flash method are given in this paper. In the data you are working on the results and the resulting layer of the flash method. The holder 1 and evaporator 2 are mounted in a quartz tube 3 (Fig. 1) in order to assure the stability of the thermodynamic parameters. The support is heated with a graphite block 4. The shredded $CuInSe_2$ granules having the dimension of 50-100 μm are placed

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in the bunker 5. At the bunker vibration, a portion of the granules fall through a quartz mortar, then clot on the evaporator and evaporate practical instantly. This allows you to obtain layers having the same composition as the source. The source temperature was of (~1100÷1150 ^{o}C) and the temperature of the substrate (~250÷400 ^{o}C) and was controlled by a thermocouple. The layer growth rate was 0.1-0.4 μm / min, the thickness of the layers was 0.2 ÷ 3μm .The epitaxial layers have the irregular form and therefore the Van der Pauw method was used for the measurements of electrical properties.

2.2. Kinetic properties of CuInSe2.
The charge carriers concentration and electrical conductivity temperature dependences (in the temperature range 80 ... 350 K) of the studied $CuInSe_2$ layers (Fig. 2) are presented in this paper. All the layers had a p-type conductivity and a rather high concentration of holes, which indicates the presence of metal vacancies. At low temperatures (less than 160K), the hole concentration is practically constant, due to the degeneration of the electron (at 300 K, the Fermi level is situated in the valence band and the hole concentration reaches ~ $3 \cdot 10^{19}$ cm^{-3}). In the temperature range higher than 200 K, the temperature dependence of the concentration has an activation character, which is due to the presence of an impurity level near the valence band.

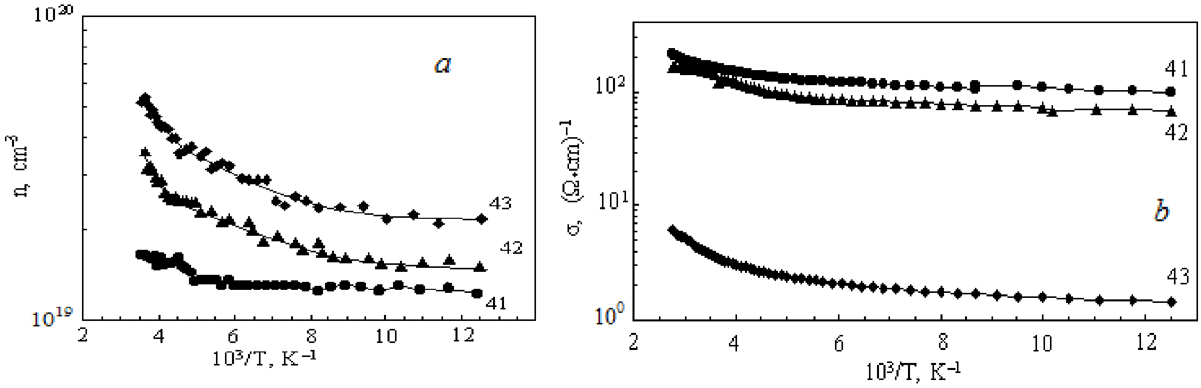

Fig. 2. Charge carriers concentration (*a*) and electrical conductivity temperature dependence (*b*).

The activation energy, which is 0.13 eV, was estimated from the slope of the temperature dependence of the concentration in this temperature region. Presumably, this energy is associated with the presence of defects in the crystalline structure of $CuInSe_2$, which lead to the formation of additional energy levels related to the selenium interstitial atoms. Almost the same result was obtained from an analysis of the temperature dependence of the electrical conductivity. The analysis of the obtained experimental results and the equation of electroneutrality

$$\frac{p(N_D + p)}{N_A - N_D - p} = \frac{2}{g}\left[\frac{2\pi m_p k_0 T}{h^2}\right]^{3/2} e^{-\frac{E_A}{k_0 T}} \qquad (1)$$

indicates the compensation of the intrinsic defects (the compensation factor is 0.9 ... 0.95.)

3. CONCLUSIONS

It was shown that the „flash” evaporation method makes it possible to obtain thin films of $CuInSe_2$ with a charge carriers concentration of 10^{19} cm^{-3}, and electrical conductivity in the range 1 ... 100 Ohm•cm. However, the mobility of the holes remains rather low (~ 30 cm^2 / V•s), which is due to the compensation effect.

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