STRUCTURAL, OPTICAL AND ELECTRICAL PROPERTIES OF BULK $CuIn_{0.7}Ga_{0.3}Se_2$ SEMICONDUCTOR COMPOUND

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ABSTRACT

In this work, we report on the study of structural, electrical and optical properties of the $CuIn_{0.7}Ga_{0.3}Se_2$ compound. Analysis by X-ray diffraction showed that the prepared ingots are polycrystalline and of chalcopyrite structure. The preferential orientation in the plane (112) which is very suitable for the photovoltaic conversion was obtained. On the other hand, the lattice parameters *a* and *c* were calculated from the X-ray spectra, the c/a ratio was found to be equal to 2. Measurements of the electrical properties permitted us to get 7,645 Ω cm for the resistivity and $4{,}761.10^{16}$ cm^{-3} for the carrier concentration. Characterization by energy dispersive spectrometer (EDS) of the prepared ingots, allowed us to infer that their chemical composition is quasi-stoichiometric. Absorption measurements were performed using a UV-VIS-NIR spectrophotometer and a value of 1.13 eV for the band gap width was obtained.

Keywords: $CuIn_{0.7}Ga_{0.3}Se_2$; elaboration; characterization; photovoltaic conversion.

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1. INTRODUCTION

The production of electricity from solar cells requires the use of a photoconductive layer, said absorbent layer which converts the light radiation in electron-hole pairs, the created carriers are collected by performing a junction on the surface of the absorbent. For the photovoltaic conversion, silicon remains the most used material. However, in order to reduce the cost of solar modules, other materials, particularly those in polycrystalline thin films such as Cu-III-VI_2 compounds are currently the subject of many researches. With their high absorption coefficient exceeding 10^5 cm^{-1}, the chalcopyrite structure compounds are used as an absorber

in the manufacture of solar cells. Indeed, the solar cells based on chalcopyrite structure materials have a number of advantages in the race to produce solar modules on a large scale. In this regard, we are interested in the development and study of $CuIn_{0.7}Ga_{0.3}Se_2$ compound for the manufacture of solar cells.

2. EXPERIMENTAL CONDITIONS

$CuIn_{0.7}Ga_{0.3}Se_2$ compound ingots were prepared by a technique based on the vertical Bridgman method [1, 2]. We followed the following steps: placing the mixture of the four elements (Cu, In, Ga, Se) in a quartz tube sealed under a high vacuum of 10^{-6} torr. A temperature-resistant wire permits to introduce the tube into the furnace, and to place the mixture in the middle of the latter. The elements forming the mixture are in the form of grains with a consistent purity: 5N for copper and 6N and for indium, gallium and selenium. After sealing, the tube is placed in an oven where it is subject to a thermal cycle, which lasts 5 days. At the end of the cycle, we take out of the quartz tube from the furnace and retrieve the formed product.

The thermal cycle required for the preparation of the $CuIn_{0.7}Ga_{0.3}Se_2$ compound comprises seven steps (Figure 1).

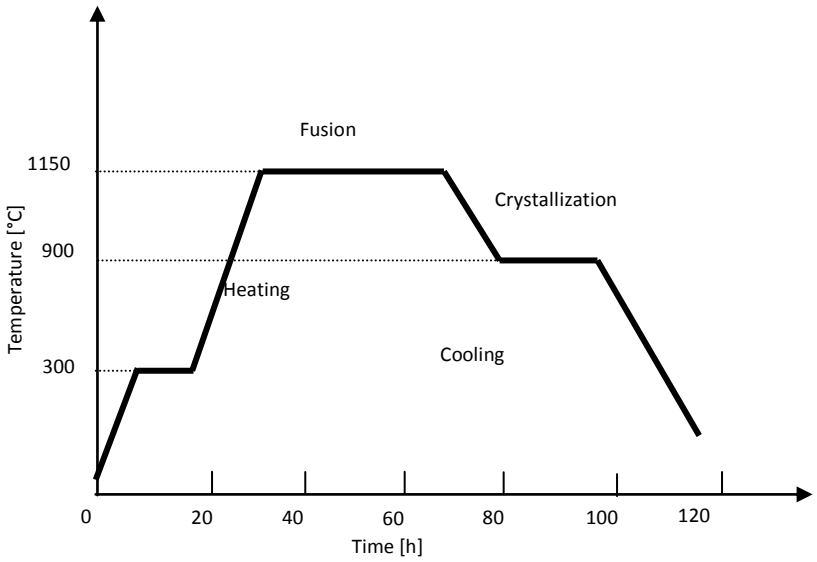

Fig.1. Thermal Cycle for preparing the $CuIn_{0.7}Ga_{0.3}Se_2$ compound

• Step 1: Heating up gradually from room temperature to 300 ° C.

• Step 2: Flat level at 300 ° C for 5 hours.

• Step 3: Heating up to 1150 ° C.

• Step 4: Fusion at 1150 ° C for 25 hours.

• Step 5: Crystallization between 1150 ° C and 900 ° C.

• Step 6: Continued crystallization at 900 ° C for 10 hours.

• Step 7: Slow cooling to room temperature.

The prepared sample has a good morphology with complete solidification. Figure 2 shows a sample of $CuIn_{0.7}Ga_{0.3}Se_2$ obtained by using the thermal cycle shown above.

Fig.2. $CuIn_{0.7}Ga_{0.3}Se_2$ Sample showing complete solidification and good morphology

3. RESULTS AND DISCUSSION

3.1. Structural properties

3.1.1. Morphology and chemical composition of the ingots

The prepared $CuIn_{0.7}Ga_{0.3}Se_2$ ingots were characterized by EDS. The chemical composition of the constituents is obtained after analysis of five different parts of the ingot (Figure 3).

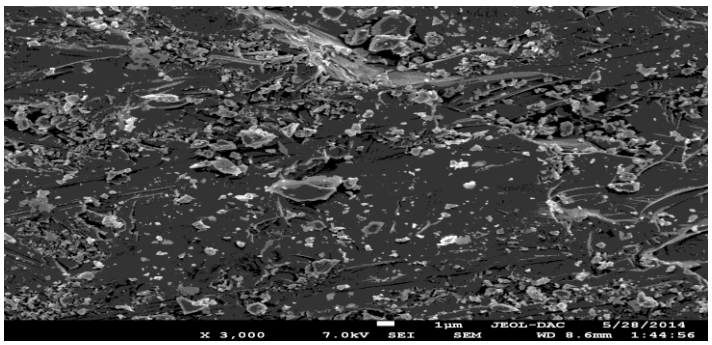

Fig.3. SEM images of $CuIn_{0.7}Ga_{0.3}Se_2$ ingot

The results reported in Table 1, show that the obtained $CuIn_{0.7}Ga_{0.3}Se_2$ ingot is rich in copper.

Table 1. Chemical composition of ingot $CuIn_{0.7}Ga_{0.3}Se_2$

Sample	Cu (%)	In (%)	Ga (%)	Se (%)	Cu/(In+Ga)
$CuIn_{0.7}Ga_{0.3}Se_2$	25,83	19,98	4,72	49,47	1.04

3.1.2. X-ray characterization

Figure 4 shows the spectrum obtained by X-ray diffraction of $CuIn_{0.7}Ga_{0.3}Se_2$ ingot. We notice that the planes of orientation (112) and (204) have a high intensity with a preferred orientation along the direction (112). Similar results were reported by Suryanarayana et al. [3], which also indicated that the orientation planes (112) are desirable for photovoltaic conversion.

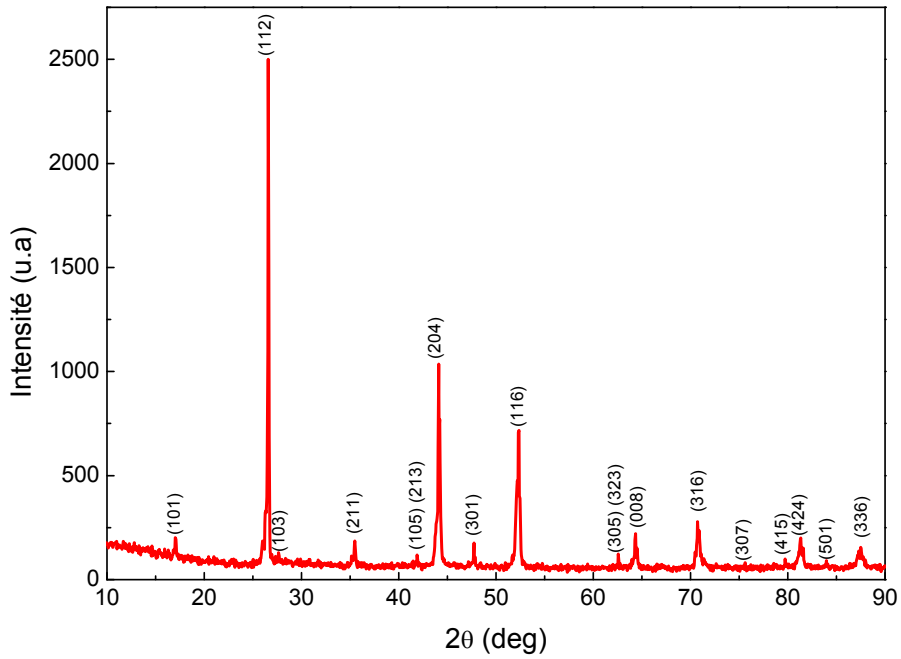

Fig.4. XRD patterns of the $CuIn_{0.7}Ga_{0.3}Se_2$ bulk

In addition to the planes of orientation (112), (103), (204), (116), (323) and (316) of the ternary compound $CuIn_{0.7}Ga_{0.3}Se_2$, most characteristic peaks of the chalcopyrite structure (101), (211), (301) and (305) are shown by the spectrum of the sample obtained $CuIn_{0.7}Ga_{0.3}Se_2$. These various orientation planes also show that the prepared ingot is polycrystalline.

The obtained X-ray spectrum allowed us to calculate the lattice constants of $CuIn_{0.7}Ga_{0.3}Se_2$ ingot, using the following equation:

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2}$$

The values found are given in Table 2.

Table 2. Lattice parameters "a", "c" and c/a of the sample prepared $CuIn_{0.7}Ga_{0.3}Se_2$

Sample	a (Å)	c (Å)	c/a
$CuIn_{0.7}Ga_{0.3}Se_2$	5.82	11.64	2.00

The presence of chalcopyrite structure characteristic peaks and the ratio of lattice constants c/a = 2 show that the obtained $CuIn_{0.7}Ga_{0.3}Se_2$ ingot has a chalcopyrite structure.

3.2. Electrical Properties

The electrical properties of $CuIn_{0.7}Ga_{0.3}Se_2$ ingots were determined by Hall effect and resistivity measurements at room temperature. The obtained values are reported in Table 3.

Table 3. Electrical characteristics of the prepared ingot $CuIn_{0.7}Ga_{0.3}Se_2$

Sample	ρ (Ωcm)	μ (cm^2/vs)	σ (1/Ωcm)	Carriers concentration (cm^{-3})
$CuIn_{0.7}Ga_{0.3}Se_2$	7,645	17,15	0.1308	$4{,}761.10^{+16}$

3.3. Optical properties

The optical properties were measured using a Cary 500 UV-VIS-NIR spectrophotometer in the region of 250 nm to 1200 nm. Figure 5 shows the variation of $(\alpha h\nu)^2$ as a function of (hv) of the prepared $CuIn_{0.7}Ga_{0.3}Se_2$ ingot. The gap value deduced by extrapolation of this curve

with the axis of the energy is Eg = 1.13 eV. Similar results have been reported by other authors [4-6].

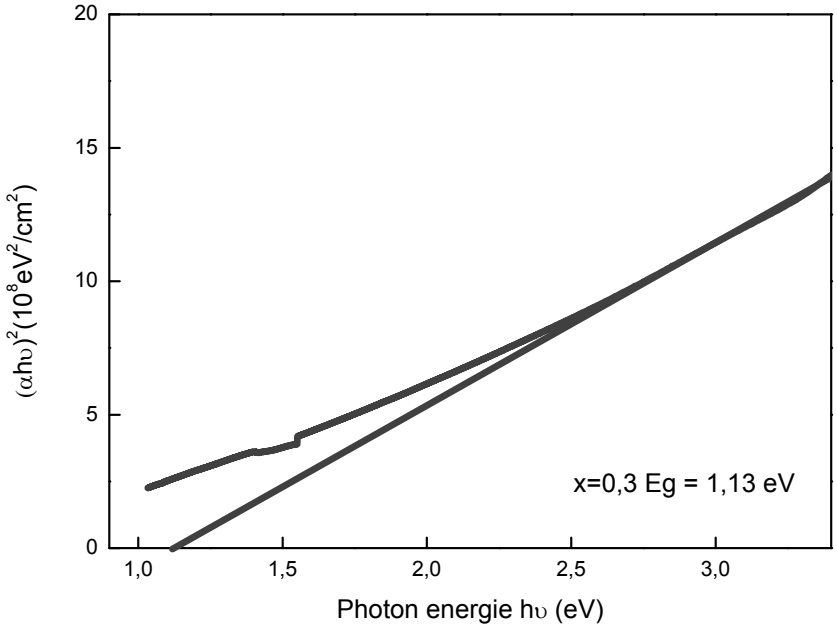

Fig.5. Plot of $(\alpha h\nu)^2$ versus photon energy hν of $CuIn_{0.7}Ga_{0.3}Se_2$ ingot

4. CONCLUSION

$CuIn_{0.7}Ga_{0.3}Se_2$ ingots were prepared by a technique based on the vertical Bridgman method. The obtained results showed that these ingots are polycrystalline and of chalcopyrite structure. The preferential orientation in the (112) plane was obtained., The lattice parameters a and c were calculated from the X-ray spectra, the c / a ratio was found to be equal to 2. The obtained resistivity and carrier concentration were 7,645 Ωcm, and $4{,}761.10^{16}$ cm^{-3} respectively. The gap of the obtained $CuIn_{0.7}Ga_{0.3}Se_2$ ingot was found to be equal to 1.13 eV.

5. REFERENCES

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