COMPOSITION OF $CuInSe_2$ CRYSTALS SURFACE INFLUENCED BY Xe^+ ION IRRADIATION

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Investigation of influence of Xe^+ irradiation on composition of crystal $CuInSe_2$ surface layers by Rutherford backscattering and channeling was conducted. In the paper we represent concentration changes of Se, In and Cu atoms in the surface layers of crystal $CuInSe_2$.

1. Introduction

Ternary semiconductor compounds based on $CuInSe_2$ (CIS) are of great interest for the production of solar cells and other optoelectronic devices [1-3]. The efficiency achieved to date for the CIS based solar cells has been reported to be in excess of 20% [4]. One of the most important properties of these cells is a resistance to radiation [1]. The classical approach to the consideration of the radiation hardness property involves mostly study of the fluence dependence of the accumulation of radiation damages [5] and less the influence of irradiation on composition of materials. Therefore the purpose of this research is to investigate the influence of Xe^+ irradiation on surface composition of $CuInSe_2$.

2. Experimental

The sample used for the study was p-type conducting CIS single crystal. It was cut from the middle part of the ingot grown by the vertical Bridgman technique, mechanically polished and etched [5]. The orientation of the crystal surface was found to be within 5° from the (112) plane. The prepared surface was irradiated at room temperature with 40 keV Xe^+ to fluences (Φ): 10^{13}, 3×10^{13}, 10^{14}, 3×10^{14}, 10^{15} and 3×10^{15} cm^{-2}. Different fluences were implanted into different stripes of 3 mm width. One stripe was left undamaged for reference. The ion current density was ~1.9 $\mu A/cm^2$.

Rutherford backscattering/channeling (RBS/C) measurements were carried out with the incident 2 MeV He^+ ion beam normal to the surface and with a scattering angle 168°. The detector energy resolution was 25 keV. The RBS aligned spectra were taken along the <221> axial channel straight after the implantation. The calculated depth resolution was 31 nm. The depth, where the analysis has been carried out, became ~65 nm. Concentration of Cu, In and Se atoms was found by iteration method [6].

3. Result and discussion

RBS aligned and random spectra for fluences in the range of 1×10^{14}-3×10^{15} cm^{-2} along with one from virgin area are shown in Fig. 1.

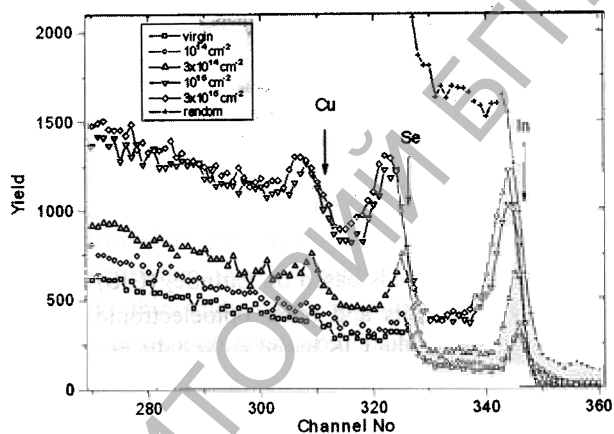

Figure 1. Effect of 40 keV Xe^{+} irradiation on RBS aligned spectra from $CuInSe_2$ crystal.

For fluences larger than 1×10^{14} cm^{-2} three distinguishable peaks related to defects in the indium, selenium and copper sublattices appeared in the aligned spectra. The area under spikes goes up by rise of the fluence. This is connected with the rise of amount of defects in elements sublattices.

To study the composition of radiated samples we used backscattering yields of helium ions from Cu, Se and In atoms in the aligned spectra on the depth of samples directly after the damage peaks. Using the known procedure [6] step by iteration step we have analyzed the composition of multicomponent target radiated with Xe^{+} ions.

It was determined, Fig. 2, that the rise of the fluence results in an increase of In and Se concentration from ~15 at.% and ~39 at.% if $\Phi = 1\times10^{14}$ cm^{-2} to ~19 at.% and ~45 at.% if $\Phi = 1\times10^{15}$ cm^{-2}. Then we can observe insignificant concentration decrease of selenium (~18 at.%). The rise of the xenon fluence results in a concentration decrease of copper from ~46 at.% if $\Phi = 1\times10^{14}$ cm^{-2} to

~36 at.% if $\Phi = 1\times10^{15}$ cm^{-2}. So, the rise of the fluence results in increasing concentration of such elements as indium, selenium, but it results in concentration decrease of copper (Table 1).

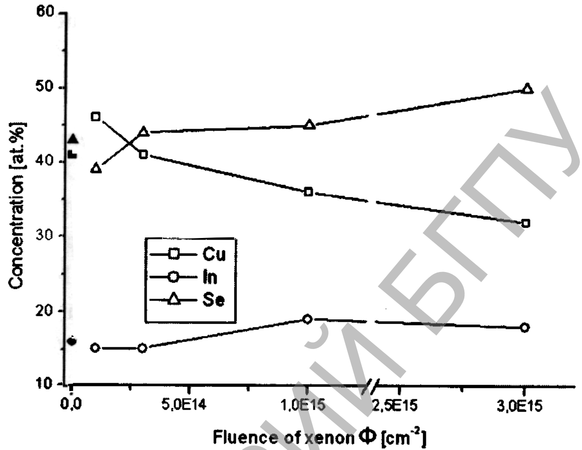

Figure 2. Dependence of the concentration of Cu, In, Se on radiation fluence.
Full signs represent concentration of elements in virgin crystal (aligned spectrum).

There is a concentration difference of elements in virgin crystal and crystal which has received the minimal flux of the implanted Xe^{+}: Cu concentration is rising from ~41 at.% to ~46 at.%, In concentration is decreasing from ~16 at.% to ~15 at.%, Se concentration is decreasing from ~43 at.% to ~39 at.%. The rise of the irradiation fluence results in a significant increase of Se concentration from ~39 to ~50 at.%.

Table 1. Dependence of the elemental composition of near-surface layer of the crystal $CuInSe_2$ on the fluence of Xe^{+}.

Φ, cm^{-2}	Concentration, at.%		
	Cu	In	Se
virgin		16 ± 2	
1×10^{14}		15 ± 1	
3×10^{14}		15 ± 1	
1×10^{15}		19 ± 1	
3×10^{15}		18 ± 1	

Concentration of Cu is decreasing considerably from ~46 to ~32 at.% if the irradiation fluence is rising. We eventually observe copper depletion in the irradiation region. The mass of Cu atoms is less then mass of In and Se atoms. Therefore because of significant sputtering taking place in the case of xenon irradiation we can consider that preference sputtering of Cu atoms takes place.

4. Conclusion

Presented study allows conclusion that concentration of components in the near surface layer of CIS is affected by radiation fluence of Xe^+ ions. When the fluence is 1×10^{14} copper concentration is rising, indium concentration and selenium concentrations are decreasing. As the result of the rise of irradiation fluence (3×10^{14}–3×10^{15}) we observe copper de-enrichment. It can be ascribed to significant sputtering taking place in the case of xenon irradiation of CIS crystals.

Acknowledgments

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