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DAMAGE PRODUCTION IN As IMPLANTED $GaAs_{1-x}P_x$

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Post-implantation damage in $GaAs_{1-x}P_x$ compounds ($x = 0$, 0.15, 0.39, 0.65, and 1) implanted with 150 keV As ions in the dose range 1×10^{13}–8×10^{13} cm^{-2} at 120 K was investigated. The depth distribution of damage and the degree of amorphization were measured by Rutherford backscattering 1.7 MeV He^+ channeling technique. The critical damage dose and the critical energy density necessary for amorphization were determined. It is shown that GaAsP is easier to amorphize (lower critical damage dose) than the binary crystals (GaAs, GaP) at low temperatures.

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1. Introduction

Ion implantation is a well established technique for modifying surface properties of semiconductor materials. There are several reports on the implanted binary crystals [1–6] but only very few papers have been devoted to the damage produced by ion implantation in ternary compounds [7–11]. In the case of device fabrication it is necessary to remove the post-implantation damage by some recrystallization process to achieve optimum operating characteristics of a device. It was shown that annealing properties and the crystalline quality of the implanted layer depend very strongly on the kind and concentration of post-implantation defects [13]. GaAsP being a wide gap semiconductor is a promising compound for optoelectronic devices (e.g. LEDs, heterojunction lasers) [12] and for that reason it was decided to study the damage production in this material.

In this paper we present (for the first time) the preliminary results on the critical damage dose (CDD) and the critical energy density (CED) for amorphization in As implanted ternary compound $GaAs_{1-x}P_x$ at low temperature. For comparison GaAs and GaP samples were also included (i.e. for $x = 0, 1$). The implanted samples were characterized by Rutherford backscattering spectrometry (RBS).

2. Experimental

Commercially available (ITME, Institute of Electronic Materials Technology, Warszawa, Poland) $GaAs_{1-x}P_x$, 5 μm epilayers grown by liquid phase epitaxy method on $\langle 100 \rangle$ GaAs : Te substrates were used. In the experiment the samples with $x = 0.15$, 0.39 and 0.65 were studied. For comparison, the GaAs, 2×10^{17} Te, *n*-type $\langle 100 \rangle$ and GaP $\langle 111 \rangle$ orientation wafers (both crystals from ITME) were used. All samples were implanted with 150 keV As ions in the dose range 1×10^{13}–8×10^{13} cm^{-2} at 120 K. The samples were misoriented in order to minimize channeling. The ion beam intensity was lower than 0.2 μm cm^{-2} to avoid heating of the target. The post-implantation damage distributions were measured by RBS channeling technique with 1.7 MeV He^+ ions using the classical relation [14].

3. Results and discussion

The RBS spectra from 150 keV As implanted layers of $GaAs_{1-x}P_x$ for various doses were measured. As an example, Fig. 1 shows random and aligned RBS spectra of $GaAs_{0.61}P_{0.39}$ samples implanted with 150 keV As ions for doses in the range 1–5 $\times 10^{13}$ cm^{-2} at 120 K. From the spectra the depth damage distributions were calculated using formula [14] and the "Spectr" computer program [16].

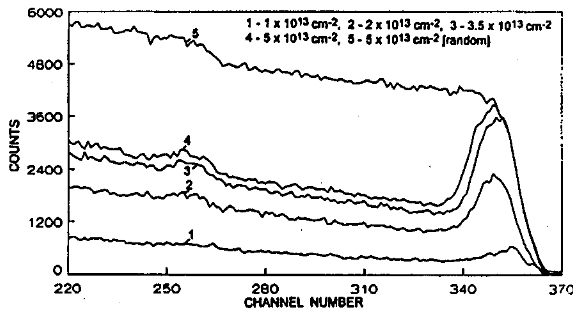

Fig. 1. Random and aligned spectra from 150 keV As implanted $GaAs_{0.61}P_{0.39}$ samples at 120 K.

In Fig. 2 there is shown a set of curves representing the damage profiles for the dose 2×10^{13} cm^{-2} As implantation in GaAs, $GaAs_{1-x}P_x$ ($x = 0.15, 0.39, 0.65$) and GaP at low temperatures. Similar results were obtained for other implantation fluences used. The results show clearly that the highest damage created occurs for ternary samples.

Table summarizes the critical damage doses and the critical energy densities as a function of a sample composition. CDD is an extrapolated value of RBS measured damage to 95% of amorphization at R_P. CED were calculated using the computer code TRIM'91.

Figure 3 presents the CDD and CED values from Table. We note that CDD decreases with the increase in x being the P content in the ternary compound and always stays below the CDD value for a binary crystal GaP having $x = 1$.

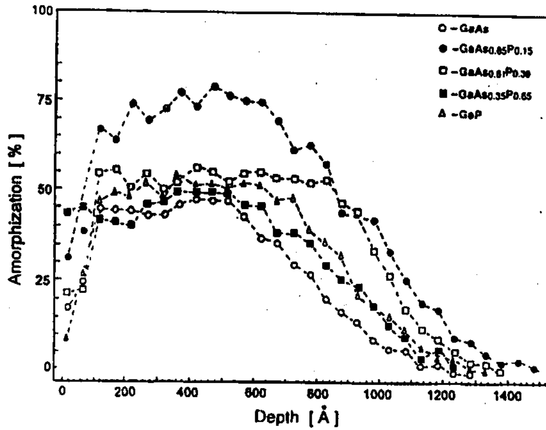

Fig. 2. Damage depth distribution for 2×10^{13} cm^{-2}, 150 keV As ion implantation of $GaAs_{1-x}P_x$ at 120 K.

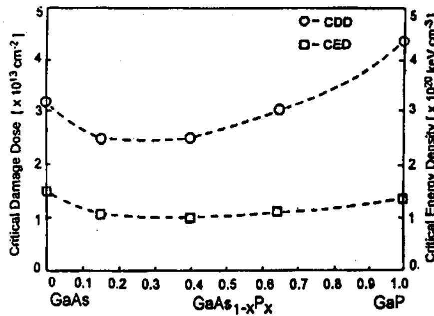

Fig. 3. Critical damage dose and critical energy density for amorphization as a function of composition x after 150 keV As implantation at 120 K.

TABLE

The critical damage dose and the critical energy density for 150 keV As implanted $GaAs_{1-x}P_x$ at 120 K.

	CDD [$\times 10^{13}$ cm^{-2}]	CED [$\times 10^{20}$ keV cm^{-3}]
GaAs	3.2	1.5
$GaAs_{0.85}P_{0.15}$	2.4	1.1
$GaAs_{0.61}P_{0.39}$	2.5	1.05
$GaAs_{0.35}P_{0.65}$	3.0	1.12
GaP	4.2	1.28

In a more recent paper by Jones and Santana [15] on the effect of composition on the threshold damage density for amorphization, the data for GaP and GaAs, although for a higher dose and lower implanted energy, confirm our results.

4. Conclusion

The effect of composition on the damage production in ternary compounds $GaAs_{1-x}P_x$ was investigated. It was shown that the ternary compounds are more liable to amorphization with respect to the P content. The observed dependence of CDD and CED may be ascribed to the post-implantation annealing. Bench et al. [4] demonstrated that at 300 K "no recovery of damage is observed in GaP, in contrast to the greater than 50% recovery seen in GaAs".

In the case of ternary crystals there are other possible factors influencing CED (bond energy, mechanism of amorphization) — for more thorough discussion see [15]. Further work would be necessary to explain the importance of these factors.

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