Radiation Defects Profiles in Boron Implantated MBE MCT Graded-Gap Epilayer

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Abstract – In the paper experimental results on boron implantation of the $Cd_xHg_{1-x}Te$ epilayers with various composition near surface of the material are discussed. The electron concentration in the surface layer after irradiation vs irradiation dose and ion energy are investigated for range of doses 10^{11} – $3·10^{15}$ cm^{-2} and energies of 20 – 150 keV. Also the results of the electrical active defects distribution measurement, carried out by differential Hall method, after boron implantation are represented. Consideration of the received data shows, that composition gradient influence mainly on the various dynamics of accumulation of electric active radiation defects. The electric active defects distribution analysis shows, that the other factors are negligible.

1. Introduction

The $Cd_xHg_{1-x}Te$ (MCT) epitaxial films, grown by a molecular-beam epitaxy (MBE) method are widely used for photodetectors creation [1, 2]. The boron implantation is one of the main method for the photodiode structures manufacturing [3, 4]. It is noted, that the varied zone epilayer are used for improving a performance of these structures. For example, the wide graded-band layer are decreased of the surface recombination [5, 6]. Therefore the study of radiation defect formation processes in varied zone MCT epilayers are actual.

Our earlier experiments on Ar^+ and N_2^+ implantation in the MCT epifilms have allowed to suppose, that the graded-band layer near surface are influenced on the processes of radiation defect formation [7]. At the same time the problem of determination of major factors of this effect remains no solved. The purpose of this paper was examination of boron implantation on electrophysical parameters of epitaxial MCT films with various composition distribution near surface.

2. Experimental details

For the experiments the epitaxial films with various composition distribution near surface have been grown at ISP RSB Novosibirsk specially. As-grown film had n-type with concentration ~$2·10^{14}$ cm^{-3} and mobility ~$5·10^4$ $cm^2·V^{-1}·c^{-1}$. For p-type manufacturing the films was annealed in a neutral ambient of hydrogen or helium [1]. Parameters of epitaxial structures after anneal presented in Table 1. For experiments four series samples are prepared. Fig. 1 presented the distribution of a composition near films surface. With growth of the number of a series sample the composition gradient is increase from 0 up to a peak value.

The boron implantation was carried out at a room temperature. The band of doses and energies were 10^{11} – $3·10^{15}$ cm^{-2} and 20 – 150 keV, respectively. The ion current density was j=0.001 – 0.2 $mkA·cm^{-2}$. The measurement of the electrophysical parameters before and after irradiation was at liquid nitrogen temperature by a Van der Pauw method.

Table 1. Initial parameters of epitaxial structures (d, p, μ_p – film thickness, hole concentration and mobility, respectively).

Sample series No	d, mkm	p, cm^{-3}	μ_p, $cm^2·V^{-1}·c^{-1}$
1	10.75	$8.0·10^{15}$	550
2	10.1	$7.4·10^{15}$	530
3	10.9	$7.8·10^{15}$	510
4	10.7	$3.3·10^{15}$	500

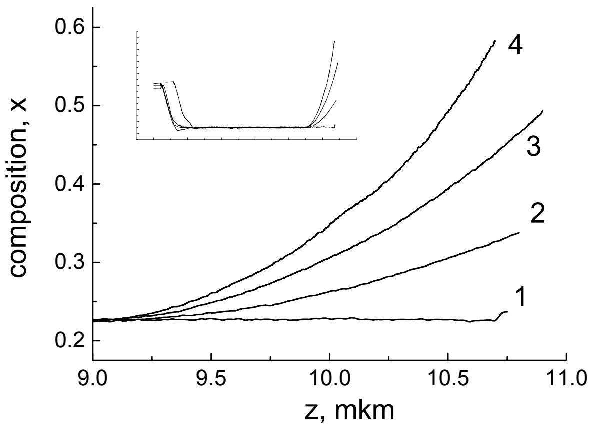

Fig. 1 Composition on depth near surface in MCT epitaxial film. The curve number is as in Table 1. The MCT composition for all epitaxial film are in the frame

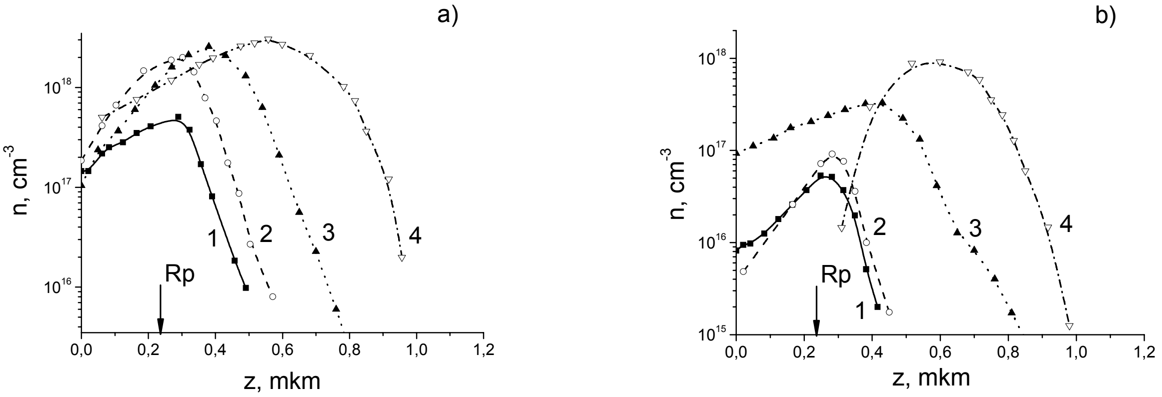

Fig. 2. Carrier concentration vs depth MCT samples for series 1 a) and 4 b) after boron irradiation. Ion energy E=100 keV. Radiation dose: 1 – 10^{12}, 2 – 10^{13}, 3 – 10^{14}, 4 – 10^{15} cm^{-2}.

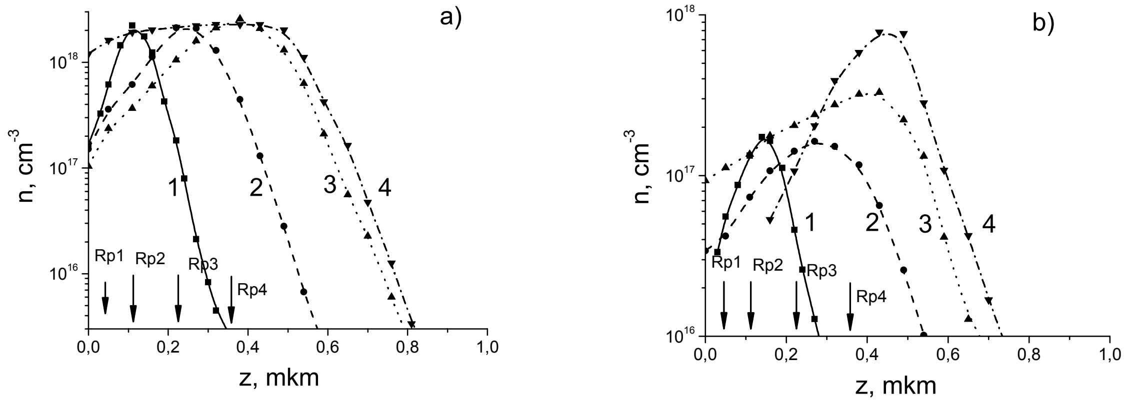

Fig. 3. Carrier concentration vs depth MCT samples for series 1 a) and 4 b) after boron irradiation. Radiation dose: Φ= 10^{14} cm^{-2}. Ion Energy: 1 – 20, 2 – 50, 3 – 100, 4 – 150 keV.

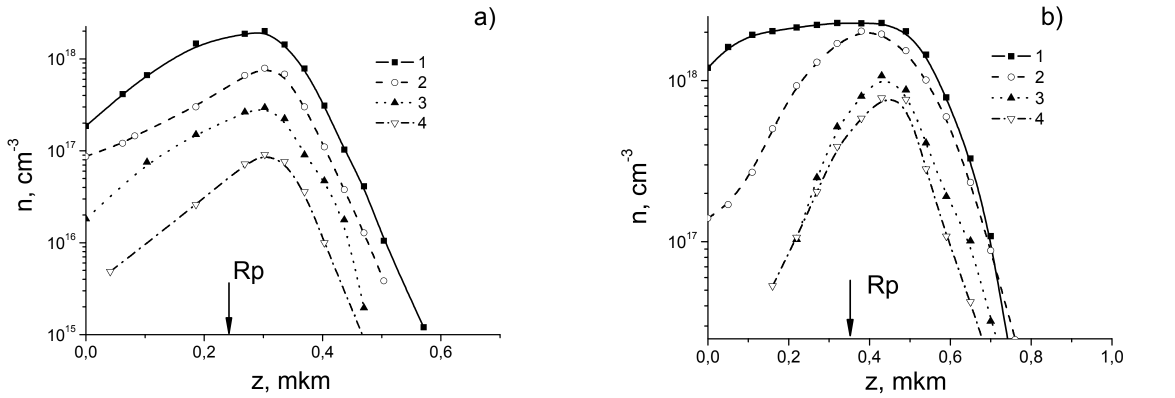

Fig. 4. Carrier concentration vs depth MCT samples after boron irradiation. a) Ion energy E=100 keV, Radiation dose Φ=10^{13} sm^{-2}; b) E=150 keV, Φ=10^{14} cm^{-2}. The curve number is as in Table 1.

3. Results and discussion

The results of the electrophysical measurements of the irradiated samples has shown, that the after ion implantation the conversion type conductivity is occur because of high doped n+ layer formation near the samples surface. This layer is formed owing to generation of the radiation defects (RD) with donor properties [8–10].

Fig. 2, 3 are presented spatial profiles of carrier concentration n(z) for films from series 1 and 4 after boron irradiation with doses 10^{12} – 10^{15} cm^{-2} and ion energies 20 – 150 keV. The results for series 1 are like as implantation data for volume material [8–12]. In this case the epitaxial material also was the homogeneous in composition distribution. For irradiation dose of 10^{12} cm^{-2} maximum electron concentration is find at R_p of boron. If dose is ride up to $\Phi_{sat}=10^{14}$ cm^{-2} the maximum of a electron concentration increase to value $n_{sat} = (2 \div 3)\cdot 10^{18}$ cm^{-3}. The further increasing of irradiation dose result in translation of an electrical profile in a depth of a sample, thus the maximum n(z) value practically the same, i.e. there is a carrier concentration saturation (Fig. 2a). The Increase of an implanted ions energy gives the same effect and n_{sat} does not depending on energy of an ion (Fig. 3a).

For a films of a series 4 having maximum composition gradient the carrier profile dynamic with changing of radiation dose and implanted ion energy has essential difference. The maximum value n (z) continuously varies with increasing of radiation dose and energy of an implant, and saturation effect is not observed. There is the electrical active damage profile moves in a depth of a sample for radiation doses > 10^{14} cm^{-2} though the maximum electron concentration n_{sat} yet has not reached (Fig. 2b, 3b).

Comparison of electron concentration profiles for films of various series irradiated by B^+ over the range doses from 10^{12} up to 10^{15} cm^{-2} and energies from 20 up to 150 keV has shown that maximum n (z) values for all explored samples are different (Fig. 4). And the value of concentration is the less the more composition of an epitaxial film in the region of profile n(z) localization. It is necessary to note here, that n(z) maximums have the same depth. Besides the right front of profiles for epitaxial films of various series has the same sharpness. The obtained data allow as concluding, that additional factors, related with composition gradient near film surface have no sufficient influence on processes of primary radiation defects migration.

Measurements of electron mobility μ_n spatial distribution in irradiated samples has shown, that the greatest difference in μ_n values for all epitaxial films is observed near material surface for radiation doses 10^{12} and 10^{13} cm^{-2}. For higher doses there are differences in the carrier mobility in the implanted region only, and deeper the differences are negligible.

4. Conclusion

Experimental researches of electrophysical parameters of the MBE material after ion implantation have shown that mechanisms of electrical active radiation damages formation are similar both in epitaxial films, and in volume MCT. Observable differences in implantation processing for a varied zone epitaxial MCT films are caused by mainly various dynamics of electrical active radiation damages accumulation and physical properties dependence from material composition. The experimental results show, that additional factors, related with composition gradient near film surface have no sufficient influence on processes of primary radiation defects migration. The new experimental evidence presents here that the main radiation damages in MCT are ones in metal sublattice HgTe.

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