The Radiation Defects Accumulation Dynamics at Ion Implantation of the MCT Graded-Gap Epilayer

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Abstract – In the work experimental researches of electrical active radiation defects accumulation dynamics on boron implantation of the MCT epilayers with various composition distribution near surface area of the material are discussed. The graded-gap epilayer samples were bombardment of the boron at room temperature. The analysis of then experimental data has shown, that the natural logarithm of the electrical active defects introduction speed has linear dependence on material composition at R_p region. The received results have shown, that electrical active defects accumulation dynamics is determined by composition distribution of the epilayer film in the implantated ions mean projective path region.

1. Introduction

At present time the most perspective material for infrared photodectors manufactured are epitaxial films $Cd_xHg_{1-x}Te$ (MCT) with varied zone layers near surface region and in the volume of the material [1, 2]. The ion implantation is widely used for the creation heterogeneous semiconductors structure, such as p-n junction [1–3]. The irradiated MCT material main feature is that all properties (electrophysical, optical, etc.) are completely determined by radiation defects (RD) [4–6]. For acknowledging usability of the ion doping process reference to vary zone MCT epitaxial films it is necessary to investigate the RD formation and evolution processes at region where variation composition of the MCT material is observed.

Our earlier experiments on Ar^+ and N_2^+ implantation in the MCT epifilms have shown, that differences are observed as a measurement of irradiated graded-gap epitaxial films and stationary composition volume material MCT electrophysical parameters [7]. The received experimental results it is possible to explain specificity RD accumulation dynamics and features of their spatial distribution.

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 ~$2\cdot10^{14}$ cm^{-3} and mobility ~$5\cdot10^4$ cm$^2\cdot$V$^{-1}\cdot$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} – $3\cdot10^{15}$ 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$^2\cdot$V$^{-1}\cdot$c^{-1}
1	10.75	$8.0\cdot10^{15}$	550
2	10.1	$7.4\cdot10^{15}$	530
3	10.9	$7.8\cdot10^{15}$	510
4	10.7	$3.3\cdot10^{15}$	500

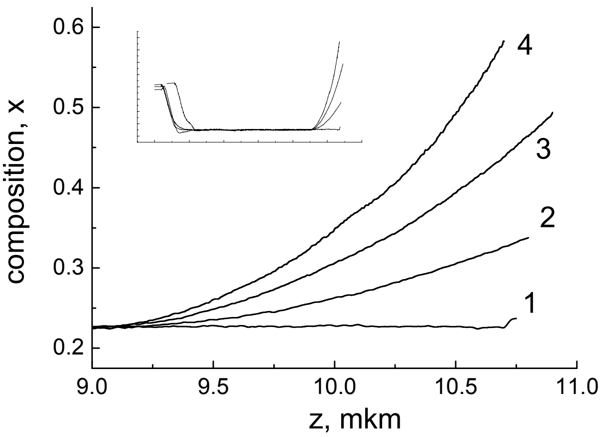

Fig. 1 Composition on depth near surface in MCT epitaxial film. The curve number is as in Table 1. The MCT composition for all epitaxial film are in the frame

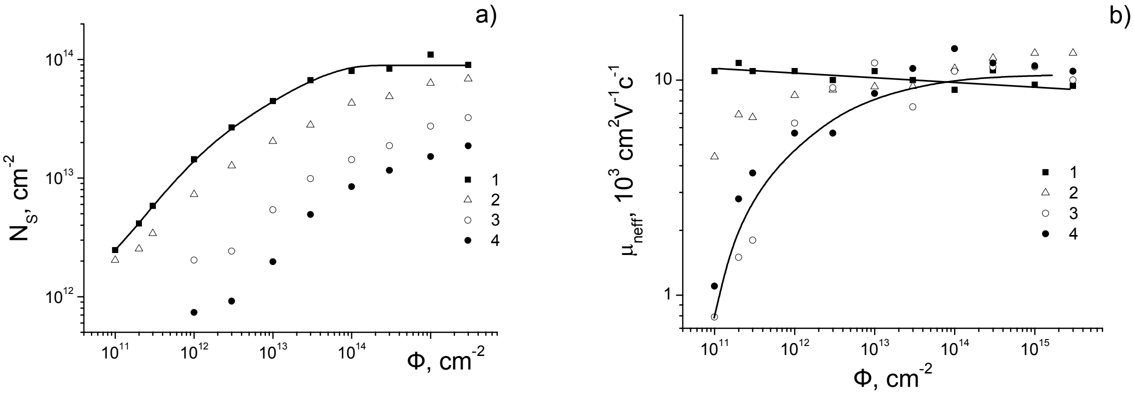

Fig. 2. Surface carrier concentration N_S and effective carrier mobility μ_{neff} after boron irradiation. Ion energy E=100 keV. The curve number is as in Table 1

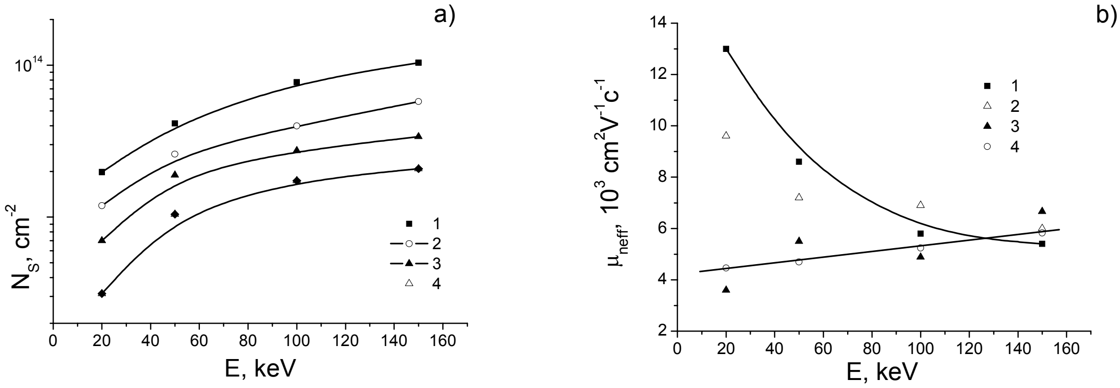

Fig. 3. Surface carrier concentration N_S and effective carrier mobility μ_{neff} after boron irradiation. Radiation dose $\Phi=10^{14}$ cm^{-2}. The curve number is as in Table 1

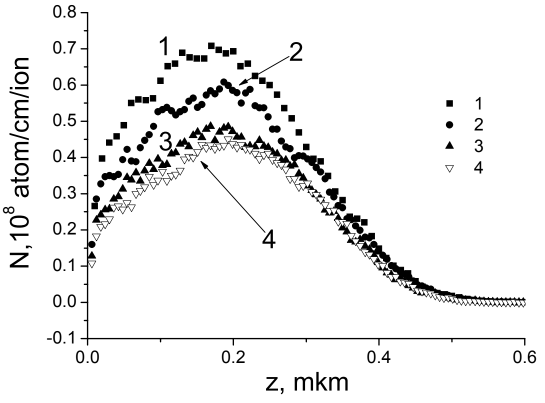

Fig. 4. Complete amount of impact stages of the Hg atoms N. The curve number is as in Table 1

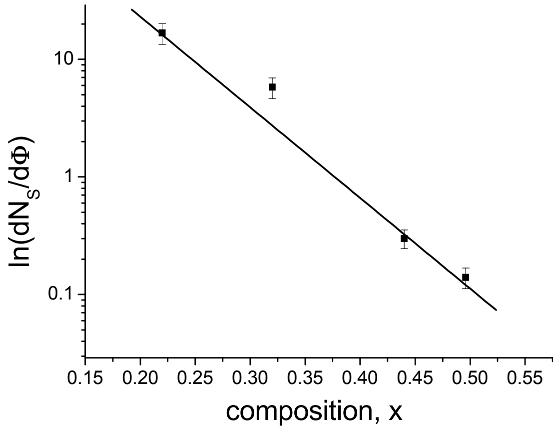

Fig. 5. The natural logarithm of the electrical active defects introduction speed vs material composition at R_p region

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 [4–6].

The dependences of the surface carrier concentration N_S vs radiation dose and energy of ions are presented in Figures 2 and 3. It is shown, that the monotonic increase of $N_S(\Phi)$ and $N_S(E)$ is observed for all samples. However for the same radiation dose and ion energy N_S are different for various sample series and the values depend on composition distribution near surface sample. For sample 1 the behavior of $N_S(\Phi)$ and $N_S(E)$ is like as in volume MCT crystals [4–6]. At reaching dose $\Phi_{sat}=10^{14}$ cm^{-2} the surface concentration attains maximal value $N_{Smax} = (0.9\div1)\cdot10^{14}$ cm^{-2}, and after that the saturation of the dependence $N_S(\Phi)$ with dose increasing is taken place. The values of Φ_{sat} and N_{Smax} in the saturation range correspond to the ones obtained at boron implantation in volume MCT. For the epitaxial films of a series 2–4 effects of the N_S dose saturation is not observed.

The analysis of the effective carrier mobility μ_{neff} behavior vs radiation dose and ion energies shows, that for samples 1 $\mu_{neff}(\Phi)$ and $\mu_{neff}(E)$ are monotonic decreased with dose and ion energies increase, but for the samples 2–4 the effect is inverse (Fig. 2, 3).

With increase of radiation dose and ion energy the difference between values μ_{neff} for samples of different series decreases.

Various behavior dose and ion energy dependences of electrophysical parameters for samples of the various series is possible to explain several factors. At first, different composition of implanted area for each epitaxial film may result indifferent ratios of primary generated RD in CdTe and HgTe sublattices. It is considered, that observable modifications of the MCT electrophysical properties after irradiation are caused by formation of mercury interstitial atoms which exhibit the donor properties [4–6]. The SRIM2003 program calculation of the complete amount of impact stages of the Hg atoms in epitaxial MCT films with a variable composition during boron irradiation has shown, that for series 4 samples amount of primary displacements are 40 % less, than for is series 1 samples (Fig. 4). As the amount of generated mercury interstitials are decreased, it is necessary to expect reduction of secondary damages formation rate as the rate is proportional to primary RD concentration. This deduction is also proved by experimental data analysis which shows, that for radiation doses less 10^{14} cm^{-2} the almost linear behavior of the surface electron concentration is observed. The analysis of then experimental data has shown that the natural logarithm of the electrical active defects introduction speed has linear dependence on material composition at R_p region (Fig. 5). The received results have shown, that electrical active defects accumulation dynamics is determined by composition distribution of the epilayer film in the implantated ions mean projective path region.

The second possible factor of differences in samples parameters is various thickness of n^+-layers after implantation, which mainly determined by medial projected range (R_p) of implanted ions and primary RD diffusion in depth of sample. However the SRIM2003 calculations show that e R_p differences no more than 3 % for all samples.

Third, the gradient of diffusion coefficient and intrinsic electric field may affect on primary RD migration. For an estimation of this effect contribution it is necessary to analyze observed in experiment spatial distribution of electron concentration in irradiated samples.

4. Conclusion

Experimental researches of the radiation defects accumulation dynamics at ion implantation of the MCT graded-gap epilayer has show that observable differences in implantation processing for an varied zone epitaxial MCT films are caused by various dynamics of electrical active radiation damages accumulation. The received results have shown, that electrical active defects accumulation dynamics is determined by composition distribution of the epilayer film in the implantated ions mean projective path region. For verification of the received deductions it is necessary to analyze observed in experiment spatial distribution of electron concentration in irradiated samples.

References

[1] V.V. Vasiliev, D.G. Esaev, T.I. Zakhariyash, A.G. Klimenko, A.I. Kozlov, I.V. Marchishin, V.N. Ovsyuk, N.Kh. Talipov, Yu. G. Sidorov, S.A. Dvoretsky, Instrument&Data Process, **4**, 22 (1998).

[2] A. Rogalski, "Infrared Detectors", Gordon and Breach Science Publisher, 2000.

[3] H. Ryssel, G. Lang, J.P. Biersack, K. Muller, W. Kruger, IEEE Transaction on electron devices, **ED-27/1**, 58 (1980).

[4] S.P. Kozyrev, L.K. Vodopyanov, Fiz. Tekh. Polupr, **17/5**, 893(1983).

[5] C. Bahir, R. Kalish, J. Appl. Phys. **54/6**, 3129 (1983).

[6] A.V. Voitsekhovskii, A.P.Kokhanenko, Russ. Phys. J., **1**, 101 (1998).

[7] A.V. Voitsekhovskii, A.P.Kokhanenko, D.V. Grigor'ev, A.G. Korotaev, D.V. Leont'ev, N.A. Kul'chitskii, Mater. Electr. Tekh., **2**, 60(2004).