ELECTRON BEAM APPLICATION FOR MECHANICAL STRESS RELAXATION AND FOR SI-SIO$_2$ INTERFACE STRUCTURAL REGULATION

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1. INTRODUCTION

Silicon structure with dielectric isolation is one of the structures used for preparing integrated circles on the single chip. Significant internal mechanical stresses (IMS) created in the process of silicon structure production cause a bend deformation of the substrate that can be higher then the elastic limit for the silicon. Relaxation of the IMS leads to appearing structural defects on the Si-SiO$_2$ interface [1] and residual stress. The semiconductor-dielectric interface determines the quality of silicon based devices in many cases. Thus, investigation of the interface defects and their changing under different influence is strongly studded last time.

2. EXPERIMENT

In the present work the electron irradiation, for decreasing the IMS and for interface structural regulating, was used. The following systems are investigated: on the silicon plate (silicon substrate doped by boron with resistance 4.5Ω·cm and with plate thickness 200…400μm) placed is the oxide layer with a thickness of 1…1.5μm. The heterosystem was irradiated with the electron beam of an energy less than the threshold one (100…400keV) using the accelerator RUP-400 (electron current density 1μA·cm^{-2}) and with the electron beam energy 0.8…1MeV using another accelerator El.T-1.5(electron current density 1…5μA·cm^{-2}).

The region of localization of the plastic deformation was obtained using the method of curvature control with layer by layer etching from the oxide side.

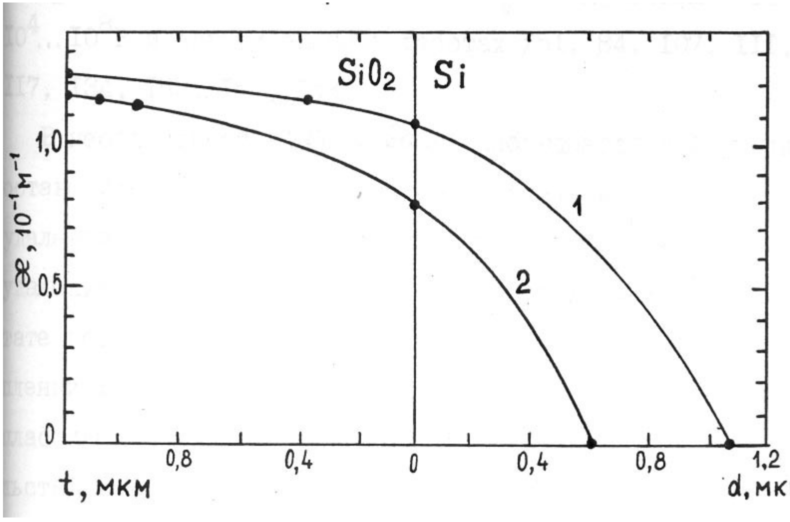

Fig.1 Heterosystem Si-SiO$_2$ curve versus the thickness during layer -by -layer etching, before (1) and after (2) electron irradiation with energy 1MeV.

3. RESULTS

Fig. 1 shows the changing of the structure curvature in the process of layer- by -layer oxide etching. The curve 1 pointed the unirradiated system and curve 2 – after irradiation by electron fluence (10^{14}cm^{-2}) with electron energy 1MeV. The substrate maintains the residual bend when oxide was etched out completely (Fig. 1 curve 1 for d = 0μm). The curvature was zero under subsequent etching of the silicon substrate. This result correlates with behavior of the curvature of the semiconductor-semiconductor heterosystem with the plastic deformation taking place in it [2, 3]. It was shown that after irradiation the curve has different shape (Fig.1 curve 2). The decrease of the plastic deformed layers in the substrate was observed after the electron irradiation. This means that the dislocation morphology was changed, i.e. the dislocation moved to the interface under irradiation and the interface Si-SiO$_2$ turned to the more equilibrium state.

Thus, the curve behavior of the irradiated heterosystems corresponds to the more equilibrium interface state [4, 5, 6]. Fig. 1 shows decreasing the region of plastic deformation in the silicon substrate after irradiation using the electron beam.

The electroreflectance spectra and Raman scattering (RS) spectra confirm the interface regulating in the heterosystem under electron irradiation. Electroreflectance and RS spectra were measured through the SiO$_2$ layers (see Fig. 2 and 3).

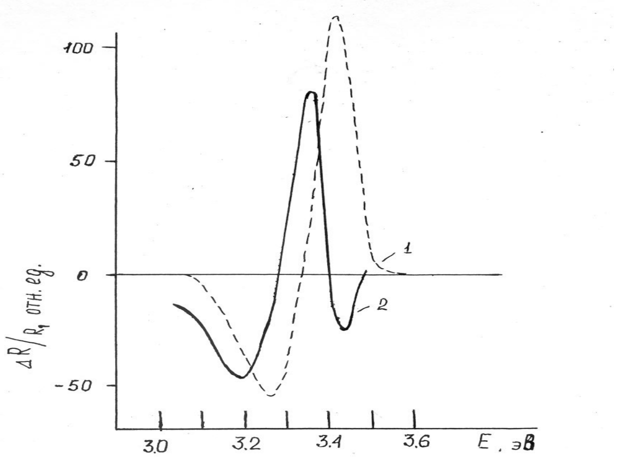

Fig.2 Electroreflectance spectra from the Si substrate in the initial system Si-SiO_2 (2) and after the irradiation (1).

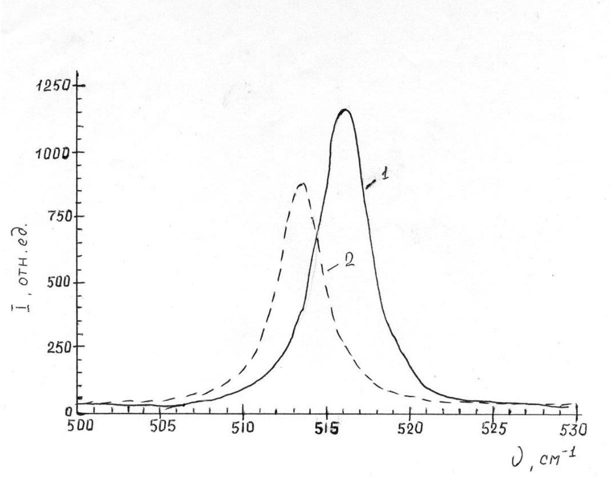

Fig. 3. RS spectra from the Si substrate in the initial system Si-SiO_2 (2) and after electron irradiation (1).

The electron irradiation leads not only to the blue shifting electroreflectance and RS spectra what means the decreasing the IMS like stretching in the silicon substrate but leads, also, to spectra narrowing (consequently, decreasing phenomenological parameter of broadening, increasing carrier mobility and life time of minority carriers [7]), what means the interface perfection growth (defects decontamination).

It was established that the integral electron fluence with high energy, that leads to interface regulating and decreasing the IMS, localizing the region of plastic deformation near interface, was by few order of magnitude less ($3.2\cdot10^{13}cm^{-2}$) than in the case under electron irradiation with the energy less then the threshold one, when such an effect was observed at a fluence not less then $1.6\cdot10^{16}cm^{-2}$.

The results obtained can be explained by that under irradiation the acceleration of the defect diffusion to dislocations (that exist in heterosystem) takes place. Irradiation with the electron energy less than the threshold one caused the volume ionization in the heterosystem near the interface region which was enriched with the structural defects like point or another kind. Defects that are localized near the interface become mobile due to action of ionization mechanisms. The defect flow to the dislocation creates a motive force leading to the change of defect place. In the result of irradiation dislocations have probability to break through the barriers or get round them. Dislocations that have an inclination are taken out of the system and dislocations that are placed parallel to the interface move in such a way that the total energy of the heterosystem gets minimum. The interface is cleared out from the technological defects that were created in the process of heterosystem preparation.

It is necessary to give to the system energy that is enough for overcoming or getting round the barrier to bring out the nonequilibrium heterosystem from the metastable state which corresponds to the local minimum of energy that is separated from absolute minimum by the energy barrier. Under electron irradiation with high energy the dislocations receive the possibility for overcoming the barrier and reaching the interface.

4.CONCLUSION

So, it is shown that:

(i) The energies of critical points in the zone diagram of the silicon substrate change under the radiation-stimulation relaxation of IMS that was shown by the shifting the electroreflectance and RS spectra;

(ii) The Si-SiO_2 interface structure is regulated under the electron irradiation that was shown by the compression of the location region of the plastic deformation to the interface region;

(iii) For IMS relaxation and structural regulation of the interface the electron irradiation with high energy is more effective than that with energy less than the threshold one for the silicon.

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