FOCUSED ION BEAM IMPLANTATION OF Er-IONS IN NON-CONDUCTING SOLIDS

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The implantation of single Er-ions in dielectrics is a very promising tool for the creation of future quantum information processing devices. In the following, the influence of surface charges on the focused ion beam is investigated. Different fluences were used and the current on the sample during implantation was measured. As not definite results were obtained, further methods will be provided.

Introduction

Recently, rare-earth elements attract much interest in solid-state physics. They find good application quantum electronics perspective investigations [1]. The most interest in this case has Erbium. It has a number of properties useful for quantum memory applications. The first is providing the telecom wavelength of 1550 nm, the second is long life times. Most of Er doped YSO crystals are made using Czochralski technique [2]. The most interest in the cases was a high density of Er-ions to obtain good laser-systems.

It was also discussed [3] that the charge produced on a dielectric surface by electrical discharges is the result of trapping of electrons at impurity or defect sites in the material. This charge also influences the behavior of secondary electrons. Figure 1 demonstrates the way of influence of the surface charge on the secondary electrons. But it was also shown [4] as electrons a trapped by ions on the curtain distance from the beam falling point.

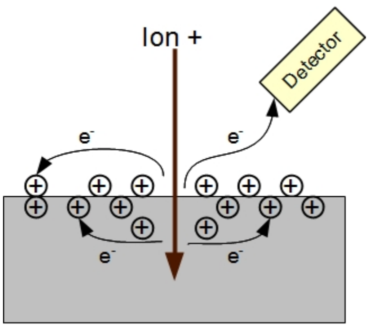

Fig. 1. Surface charge influence on secondary electrons

As charge forms an electric field in above the surface, it can influence the focused ion-beam energy (slow it down or speed it up).

Experimental

Two kinds of samples were prepared: p-type Si:B (Bor) with a 90 nm thermally grown SiO_2 layer was taken as the host material.

Two of the samples were covered by 20 nm Al layer to get a conducting surface. Er-ions were implanted in the bottom of the SiO_2 layer (Figure 2). Evaporation of Al was provided in vacuum. It is possible that a few nm layer of Al oxide is formed in air, but this layer is thin enough to be neglected.

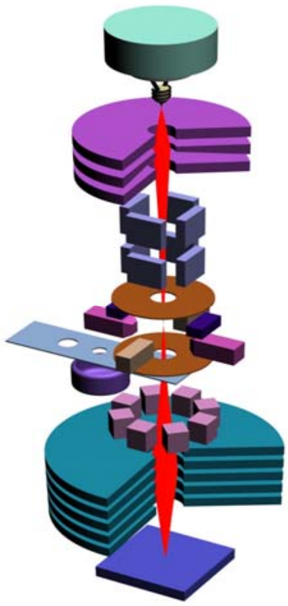

Fig. 2. FIB unit schematics

The Er was implanted in the SiO_2 layer. The implantation process was modeled in the SRIM software. The Er-ion energy in the case of Al layer was 210 kV, in the case without Al it was 180 kV. The energy was decreased to place the Er-ions inside the silicon dioxide layer.

Focused ion beam unit schematics is presented in Figure 3. Ion-beam is formed from ion-source (Er-Au-Si) by applying accelerating voltage up to 100 kV. Number of lenses is used to form the narrow beam. Implantation was provided for two type of fluences: lower one and higher one. Er^{3+} ions were filtered using E×B-masfilter. Ion-current was measured with Faraday cup. Current on the sample was measured during implantation via grounded ammeter (Figure 4).

After implantation samples rapid thermal annealing process was used. Samples were annealed at 1005°C, 5 minutes.

Results and discussion

Current measured on the sample is normally twice higher than the current measured on Faraday cup. This happens due to the large number of secondary electrons and displaced ions. For all samples with Al, the current on the sample was high

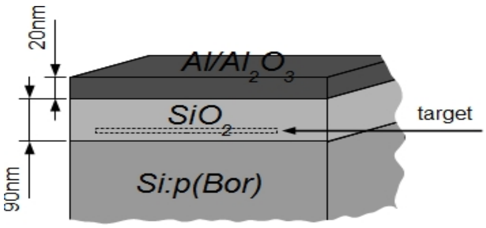

Fig. 3. Schematic drawing for sample covered with Al

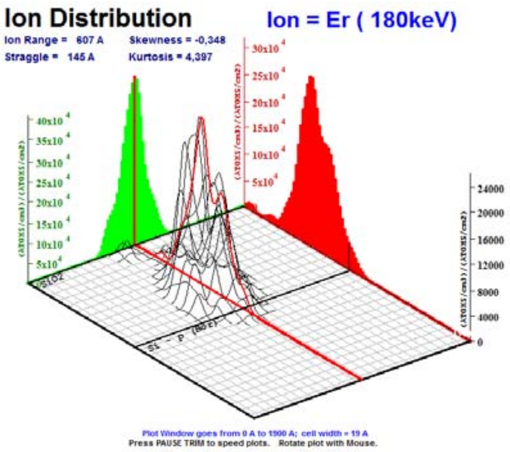

Fig. 4: Er distribution profile for sample without Al layer

Table 1. Current on the sample for different fluences

	Fluence, cm^{-2}	Current on Faraday cup	Current on sample
#2/SiO_2	$1{,}28{\cdot}10^{11}$	1,8 pA	3,5 pA
#4/SiO_2	$8{,}54{\cdot}10^{10}$	1,4 pA	0,7 pA
#5/SiO_2	$1{,}36{\cdot}10^{14}$	140 pA	180 pA
	$4{,}55{\cdot}10^{13}$	140 pA	310 pA

up to 3,5 pA. For uncovered samples with low fluence it was lower in the very beginning of implantation process and most time decreased down to 0,7 pA, what is lower then ion current itself. For uncovered samples with higher fluence current was high enough – (180 – 310) pA. Simulation of implantation processed promised to get our ions in the SiO_2 layer. Obtained Er profile is shown on Figure 5. Most of Er ions are placed in silicon dioxide layer in the depth of (40 – 80) nm.

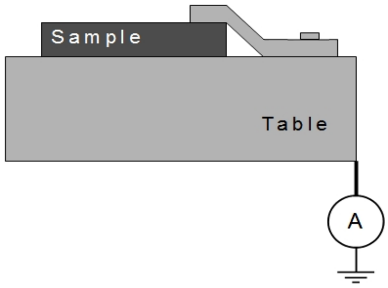

Fig. 5. Measurement of current on sample

Conclusions

Current measurements on the sample showed not definite results, it is not obvious to say if the surface charge has influence on the focused beam on the current stage. But it is clearly seen, that for lower fluence current of charges leaving the surface is much lower than normally expected. In order to obtain more clear results further investigations of prepared samples will be provided. Measurements of Er-ions locations in crystals and comparison of experimental data with those simulated theoretically will show existence of the extra-factor of surface charges.

References

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