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Laser generated Ge ions accelerated by additional electrostatic field for implantation technology

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ABSTRACT

The paper presents research on the optimization of the laser ion implantation method with electrostatic acceleration/deflection including numerical simulations by the means of the Opera 3D code and experimental tests at the IPPLM, Warsaw. To introduce the ablation process an Nd:YAG laser system with repetition rate of 10 Hz, pulse duration of 3.5 ns and pulse energy of 0.5 J has been applied. Ion time of flight diagnostics has been used in situ to characterize concentration and energy distribution in the obtained ion streams while the postmortem analysis of the implanted samples was conducted by the means of XRD, FTIR and Raman Spectroscopy. In the paper the predictions of the Opera 3D code are compared with the results of the ion diagnostics in the real experiment. To give the whole picture of the method, the postmortem results of the XRD, FTIR and Raman characterization techniques are discussed. Experimental results show that it is possible to achieve the development of a micrometer-sized crystalline Ge phase and/or an amorphous one only after a thermal annealing treatment.
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1. Introduction

In the last decade, the preparation of Ge nanostructures by means of controlled hot plasma (with temperature and densities of the order of tens of eV and 10^{17} electrons/cm^3) generated by irradiating a high purity germanium target by a nanosecond Nd:YAG laser, has attracted great attention [1–7]. However, there are many issues that limit its large-scale application yet to be clarified. Among them there must be mentioned the need to eliminate the contaminants always present in the projectile material and to narrow the energy spread of the ion beam in order to obtain the uniform implantation [6,7]. To reach both these goals, an electrostatic acceleration/deflecting system can be implemented in a conventional setup for material's implantation. Preliminary results were presented in Ref. [8,9] which gave information about the possibility of successful implementation of the electrostatic system into the implantation setup, without compromising the overall process but better improving the performance.

The novelty of this work originates from the attempt to optimize the Ge implantation method by means of a well established numerical simulation of the ion stream expansion, using the Opera 3D code. The experimental ion time of flight diagnostic response has been compared with the theoretical predictions. Finally, the structural properties of the so implanted Ge samples were investigated. The overall results suggest new starting points for further investigations to optimize the samples preparation process.

2. Experimental

A scheme of the laser-induced ion implantation is presented in Fig. 1. It consists of a repetitive Nd:YAG laser (wavelength λ 1.06 μm, pulse time t_{pulse} 3.5 ns, energy for pulse E_{pulse} 0.5 J, Repetition rate 10 Hz), a vacuum chamber with pressure of $\sim 10^{-6}$ mbar, and an electrostatic acceleration/deflection system. The germanium target, used as the projectile, has been irradiated by the focused laser beam with a power density of 10^{10} W/cm^2. The potential of the focusing electrode was controlled by an HV pulse generator and varied from 0 to +40 kV with a period down to ~1.5 μs. The ion currents were measured in situ by the mobile ion collectors located at different distance in respect to the focusing electrode. After the in situ measurements, the ion collectors were replaced by an holder on which are located some SiO_2 substrates. The Ge implantation into the SiO_2 substrates was

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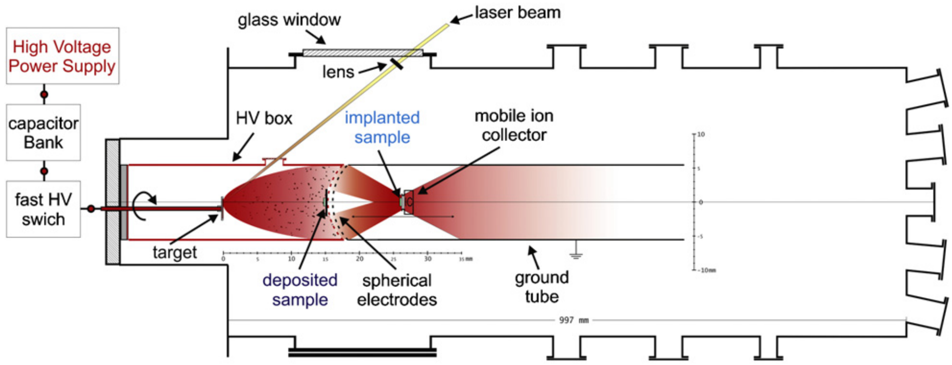

Fig. 1. Scheme of the experimental setup.

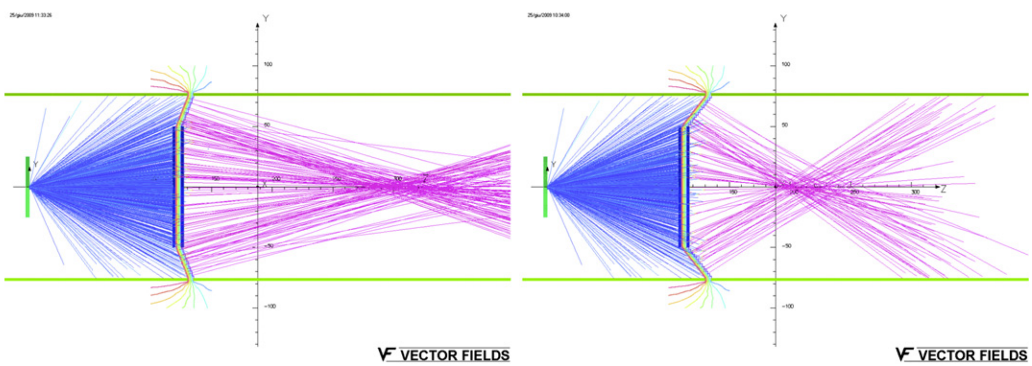

Fig. 2. Simulated data on the influence of the grid inclination on the ion traces.

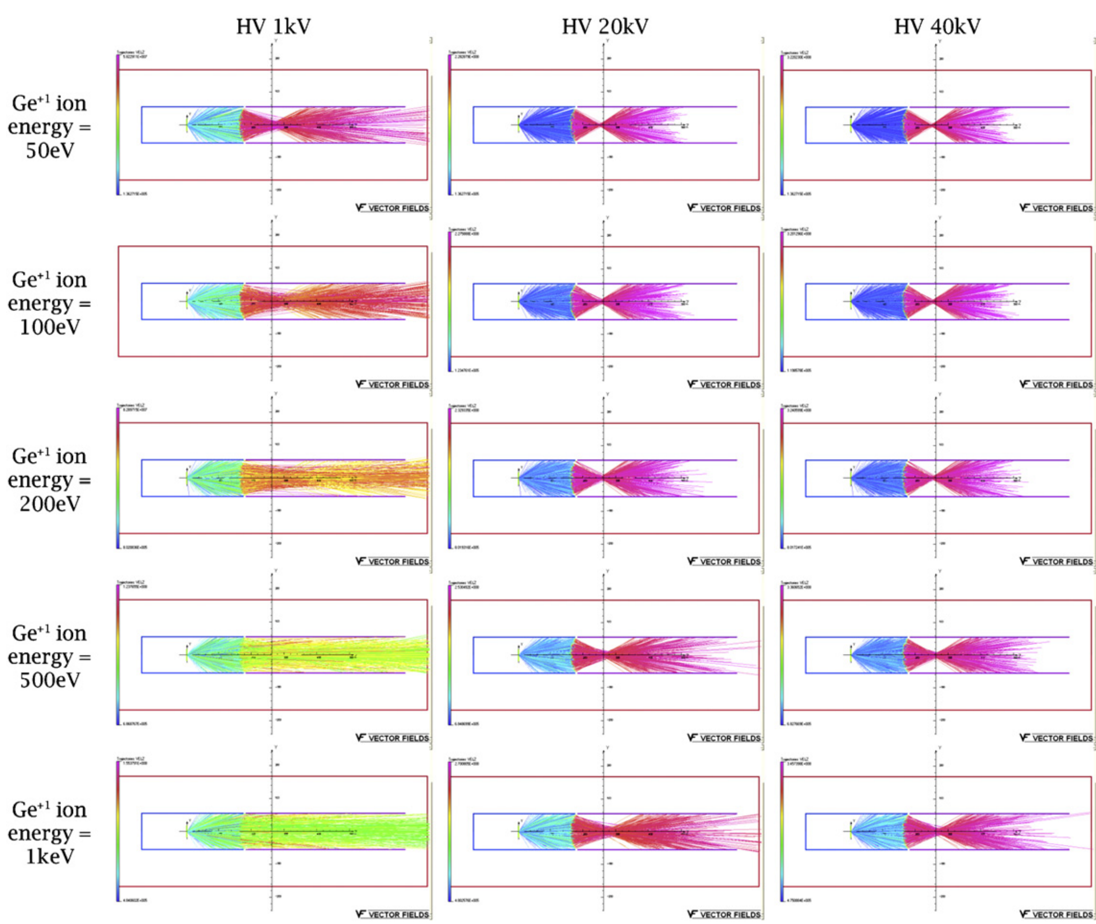

Fig. 3. Simulated results about the focusing of the ion beams by the accelerating/deflecting potentials of 1 kV (left) and 40 kV (right). The mean ion energy increases from up to bottom.

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