Ion Beam Implantation in GaSb single crystal and RBS and RBS/C measurements

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Ion Beam Implantation in GaSb single crystal for doping purpose

Among III-V semiconductor compounds, gallium antimonide (GaSb) is of a special interest as a substrate material due to the lattice parameter match to solid solutions (ternary and quaternary) whose band gaps cover a wide spectral range from 0.8 to 4.3μm [1]. Regarding devices perspectives, GaSb have shown applications in laser diodes with low threshold voltage [2], photodetectors with high quantum efficiency [3], high frequency devices [4] or to high efficiency thermophotovoltaic (TPV) cells [5]. In this view, GaSb is a III-V semiconductor compound with zinc blende crystal structure and has an energy gap of 0.726 eV and is worth to mention that the structure GaAs/GaSb had set a record for solar cell efficiency of 35% opening a new era for photovoltaics applications. We can say that the GaSb photosensitive structures offers the possibility of an almost total conversion of sun energy from visible spectrum to heat transform in electricity by TPV effect. At this status, the GaSb compound study is of interest due to effort for understanding material preparation and processing in order to develop a competitive technology for optoelectronic devices and metal-insulator-semiconductor (MIS) devices.

Ion-implantation has been used in III-V semiconductors as an important doping technique. It has the advantage of being a low temperature process that allows accurate control of the dopant profile with good reproducibility. This technique is ideally for selectively doping either in semi-insulating or semiconducting layers for potential device applications [6]. The damage removal process in III-V compounds is more complex than in elemental semiconductors due to the comparatively lower solubility of implanted species in the former; with different problems associated with defect-related compensation of electrically active dopants. Ion-implantation is an attractive method to achieve a local doping layers for example in optoelectronic devices. It is worth to mention that early studies ('80 years) reported an anomalous behaviour of GaSb areas exposed to ion bombardment appeared to be "swollen". This phenomenon was observed both on GaSb and InSb crystals irradiated with very energetic light ions and it seems that GaSb presents some implant properties similar to that of InSb, with a research accent to be characterized on swelling of implanted GaSb. In this work, ion implantation will be investigated as an alternate technique for doping GaSb and with an essential effort to understand the production and removal of the radiation damage. In literature, are reported damage produced by implantation of Te, Er, Hg or Pb ions into undoped (100) GaSb single crystals and recovery treatments by annealing at 600^0C for 30 sec (in case of Te implanted samples). The implantations of 10^{13}-10^{15} ions/cm^2 in GaSb were realized at liquid nitrogen temperature at energies corresponding to the same projected range of 447Å [7]. Residual damage was observed to be in the form of dislocation loops and microtwins. The threshold dose for amorphization is low in the range 1x10^{14}/cm^2 and 1x10^{16}/cm^2. This experiment tends to use ion implantation for p-type doping in GaSb, in order to delimitate an area of *n/p* homojunction starting from an n-type GaSb substrate. Typically, group IV atoms such as Si, Ge and Sn (1.40Å) are well known amphoteric dopants of III-V compounds; they can incorporate on group III lattice sites as donors or on group V lattice sites as acceptors. The covalent radius of Sb (1.40Å) is larger than of Ga (1.24Å), group IV atoms tend to occupy Sb sites. In this view Si(1.16Å) and Ge (1.21Å) prefers occupation of the larger Sb site over the more closely matched Ga site, so Ge is an acceptor in GaSb since their covalent radii are larger than Si[8]. We propose an implantation of shallow acceptors in GaSb as Ge, Li and Si.

Former experience of our group in n-GaSb(100) Si^+ implanted was presented at EU PVSEC-Conference, Amsterdam The Netherlands 2017 [9]. Some data regarding the experiment are presented in the general aspect of the implanted surface before and after recovery treatment is presented in **Fig.1 (a,b)**, as AFM images. The surface details are in the same observations characteristics as presented in literature [9], the effect of thermal treatment being visual observed. We notice that there exist a structural modifications after ion implantation due to radiation damage, some of them being lattice defects. The effect of recovery treatment was also putted into evidence by the modification in photo-current in the sense of its increase, from I= 2μA, to I= 3 mA

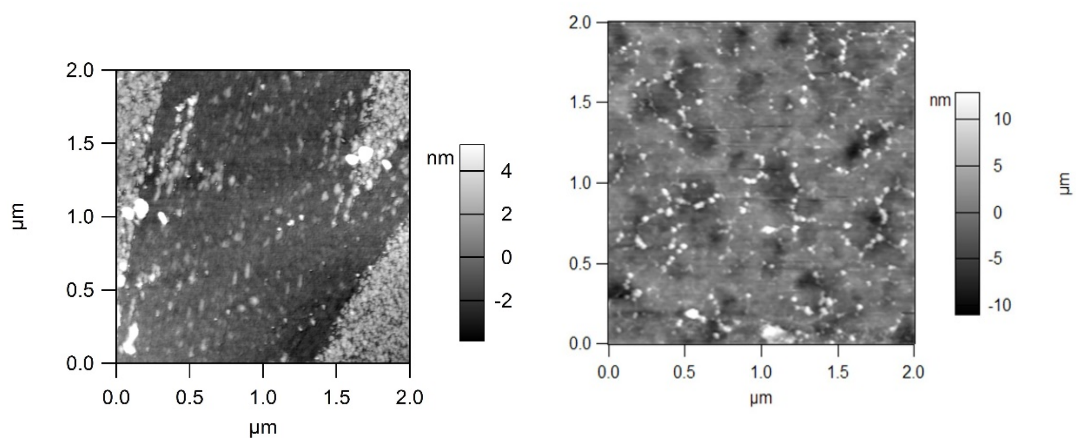

Fig.1 AFM image of Si^+/*n-GaSb* for as implanted sample (a) and after recovery treatment (b)

The as-implanted n-GaSb(100) wafers were processed in specific semiconductor technological procedure and a final result is represented by the obtaining of an active IR photosensitive structure as presented:

We intend to implant 1 MeV Si ions in single crystals of n-GaSb(100) at various fluences between 10^{13} at/cm^2 and 10^{15} at/cm^2. RBS and RBS/channeling will be used to determine implantation profile and damage profile.
Also, we intend to implant 1 MeV Si ions in single crystals of p-GaSb(100) at various fluences between 10^{13} at/cm^2 and 10^{15} at/cm^2. RBS and RBS/channeling will be used to determine implantation profile and damage profile. For such a low energy damage is mainly attributed to energy transfer to the atomic structure, which result in target atoms directly displaced from their lattice sites and defects being produced via atomic collision cascades. The damage induced by implantation will be studied using Rutherford backscattering spectroscopy in channeling geometry (RBS/C). The damage profile will be measured by two beam approximation.
A RBS analysis for thin films of PdGeAu and Ag deposited on n-GaSb and p-GaSb will be performed.

We need 8 days (24 shifts) at the 3 MV Tandetron accelerator.

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