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Epitaxial growth and characterization of 4H-SiC for detection applications

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Silicon Carbide (SiC) is a compound semiconductor, which is considered as a possible alternative to silicon for particles and photon detection. Its characteristics make it very promising for the next generation of nuclear and particle physics experiments at high beam luminosity.

Silicon carbide shows a large variation in crystal lattices according to the stacking sequence of the atoms in the crystalline lattice. Among all the SiC polytypes, 4H-SiC is considered to be the most appropriate for high-power, high-frequency, and high-temperature applications in microelectronics, and also it has the widest bandgap and an almost isotropic electronic mobility [1]. Moreover, SiC based detectors are more resistant to the ionizing radiations than Si ones. Then, they can be used in high level radioactive ambient where the temperature and the radiation environment preclude the use of conventional microelectronic semiconductors [2-3].

Some studies based on the effects of neutron, proton and heavy ions irradiation on SiC diodes evidenced the high radiation hardness of this devices [4], that maintain their performances after irradiation at doses as high as 20 MGy [5-6]. Therefore, for all these characteristics the use of these detectors is particularly interesting for all those activities where high particles flux must be detected.

The high-quality material used for device application is typically grown epitaxially by a Chemical Vapor Deposition (CVD) process. Epitaxy allows a highly precise control of thickness, doping and homogeneity of crystal films. The epitaxial growth of SiC films is typically realized in horizontal hot-wall reactors in a low-pressure regime and, for 4H SiC polytype, temperatures ranging from 1550 to 1650°C [7]. Nowadays 4H-SiC can be growth on relatively large area (150 mm wafers) with thickness until 250 μm and a low density of defects.

A new field of application of the solid state detectors is a neutron detection in harsh environment such as thermonuclear fusion. The Single-Crystal Diamond (SCD) detectors are used on this field, but high cost, the small dimensions of the wafers and a low availability of commercial monocrystalline diamond allow the use of alternative materials like SiC. From a previous paper [8] it has been observed that the resolution of SCD detectors 150 micron thick is better than the resolution of 100 micron thick SiC detector. Furthermore, the resolution of the SCD detectors increases increasing the thickness. Then to increase the resolution of the SiC detectors is necessary to increase considerably the thickness of the epitaxial layer.

The purpose of this work is to grow a 250-micron epitaxial layer of 4H-SiC material through a CVD process and a Chemical Mechanical Polishing (CMP) process at the end of growth. We have characterized our sample optically through Photoluminescence (PL) and Raman (i-LOPC) spectroscopy for defects distribution and carrier lifetime evaluation. We obtained a PL map and his relatives signal of 4H-SiC with 250 μm of epitaxial layer. At this step our sample presents some defects, but most of them are located on the edges of the wafer. This effect is connected to the presence of the off-axis of the substrate towards the [11-20] directions. We compared the 250 μm thick epy layer with two other samples having an epitaxial layer thickness of 100 μm which we obtained with two different growth rates, 60 and 90 μm/h respectively. Furthermore, we started with the manufacturing process, then we want to study its behavior under working conditions through simulations and irradiation under neutron beam of 14 MeV.

We have been measured the carrier lifetimes through the Raman shift of the LO phonon-plasmon-coupled mode (LOPC) [9]. Given that the LO phonon-plasmon coupling is obtained thanks to the free carriers generated by the high injection level induced by the laser, this technique is named induced-LOPC (i-LOPC). Moreover, there are some processes to increment the carrier lifetime and, as a consequence, the diffusion length for 4H-SiC. These post growth processes, such as oxidation and passivation processes, could increase these values thanks to the decrement of carbon vacancies [10]. Hence a possible increase of lifetime and diffusion length after a high temperature oxidation process will be evaluated.

We also compared the influence of different types of stacking faults (SF) defects on the carrier lifetime values and how, following the LO shift in Raman analysis, the decrease in laser power shows a gradual decrease in the difference in LO shift ON-SF and OUT-SF, until the peaks overlap, obtaining the same duration values for both areas. The analysis of the thick epitaxial layer is necessary to understand if this epitaxial material could be used in order to fabricate devices for neutron detection. A considerable effect of the growth process and of the laser power on the carrier lifetime is observed and will be explained at the conference.

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