channeling stopping power of MeV He\(^{+}\) ions in 4H- and 6H-SiC.

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I. INTRODUCTION

The energy loss of energetic ions along the major directions of crystals has been the subject of many studies. In fact, this phenomenon has relevance in several fields as nuclear physics, ion beam analysis and material modification by ion implantation. Thin self-supporting targets and transmission experiments are the traditional approach to the stopping power measurement of swift ions in crystalline materials. In spite of the many advantages of this method, the experimental results strongly depend on the preparation of the self-supported thin crystals, which must be planar and with homogeneous thickness to give accurate and reliable data. In the last decade alternative approaches have been proposed. All of them used thick targets and backscattering experiments. These targets were bulk crystals or substrates with on the top a perfect crystalline film. Generally, the simulation of the back scattering channeling spectra was used to derive the channeling stopping power values by assuming a known dependence of the dechanneling function on the ion energy. The best fits between the spectrum yield and the spectrum energy edges were used to evaluate the channeling stopping power that played as variable parameter in the simulation process.

In the panorama given above, the literature concerning SiC is limited to experiments of the more recent type and to the use of bulk SiC polytypes. But, times are mature to perform experiments also by using thin crystalline SiC films. In fact, now days, such films of the 4H and 6H polytypes are manufactured from bulk SiC wafers by the Smart-Cut® process. These SiC film have electronic quality, are few hundred nanometer thick, lay on the top of a thick SiO\(_2\) layer that lay on the top of a Si wafer. Such a structure is called “Silicon Carbide On Insulator” or SiCOI.

This paper presents the <0001> axial stopping power measurements both in 4H- and 6H-SiC done by using SiCOI wafers and Rutherford Back Scattering (RBS) experiments.

II. EXPERIMENTAL

<0001> on axis 6H-SiC and 8° off axis 4H-SiC SiCOI wafers were used for this study. The SiC films had nominal thickness \(\leq 350\) nm and 50 mm diameter, while the Si wafer had 100 mm diameter and the SiO\(_2\) layer was thicker than 1 \(\mu\)m.

The Rutherford Back Scattering Analysis chamber of the “Istituto Nazionale di Fisica della Materia” installed on one of the beam line of the accelerator AN2000 of the “Laboratori Nazionali di Legnaro” (Italy) was used. This chamber was equipped with a four axes (two rotational and two transitional) goniometer able to host a whole SiCOI wafer and few reference samples. The angular scan precision was \(\pm 0.01°\), the sample translation precision was \(\pm 10 \mu\)m. Channeling and random Rutherford Back Scattering (RBS) experiments were done with 0.9 – 2.3 He\(^{+}\) ion beams. The beam spot was 500 \(\mu\)m, the beam divergence was less than 0.03° and the beam current was in the range 20-80 nA. The analysis chamber was electrically insulated. The ion charge per measurement was evaluated by integrating the beam current over the measure time. A solid state detector placed at 170° from the beam direction was used to measure the energy spectrum of the back scattering ions. The detector aperture was about 2 \(10^{-3}\) sr and was measured by using a calibrated thin Ta film or the amorphous Si yield. By this equipment absolute measurements are possible and spectra recorded during different runs can be compared once their yields had been normalised per solid angle, unit charge and unit energy.

The stability of the crystalline 4H- and 6H-SiC thin film of the SiCOI wafers against radiation damage, as well

![FIG. 1: RBS spectra in <0001> channeling and random geometry for the 6H-SiCOI wafer. Different energy edges correspond to different interfaces in the SiCOI structure. For a given interface, arrows and labels indicate, respectively, the backscattered ion energy and the atoms responsible of the same backscattering event.](image-url)
as their structural quality and uniformity across the wafer diameter were checked. The film stability against ion damaging in axial and planar alignment for increasing ion fluence was found similar to that measured for the corresponding bulk polytypes. Once determined the He\(^+\) beam alignment with respected to the SiC film structure in a given point of the wafer, this was verified to be the same in any other point of the wafer, as it had to be in the case of large area single crystal SiC film. Major axial and planar spectra, as well as their minimum yield values, were equal to those measured for the bulk polytypes. Finally, the thickness homogeneity of the SiC film was measured by using RBS random spectra in many different positions and it was found within 3% for 4H-SiC and 0.5% for 6H-SiC across the 50 mm wafer diameter. The ensemble of all these features made these SiCOI wafers eligible to be used for stopping power measure in back scattering geometry.

### III. RESULTS

Fig. 1 shows the random and <0001> axis spectra measured for the 6H-SiCOI wafer at 2.0 MeV He\(^+\) energy and 170° back scattering angle. The random geometry corresponded to a 360° azimuth scan of the SiCOI wafer by steps of 0.5° and a fixed 3° angle between the He\(^+\) beam and the <0001> axis. C and Si edges corresponding to scattering events at the sample surface appear at the same energy value in both spectra and are indicated by single arrows. O and Si edges due to scattering events at the SiC/SiO\(_2\) interface appear in the axial spectrum at energy values higher than those of the corresponding events in the random spectrum and are indicated by double arrows. The same was expected for scattering events from C atoms at the SiC/SiO\(_2\) interface. But, due to the weak C Rutherford cross section and the reduced yield consequent to the channeling alignment, the C signal is not visible in the axial spectrum and a dashed line instead of two arrows was put in Fig. 1. Spectra as those in Fig. 1 were measured for He\(^+\) ions in the energy window 0.9 - 2.2 MeV. The minimum energy value was limited by the need to have well separated Si and O edges from the SiC/SiO\(_2\) interface, while, the maximum energy value was limited by the accelerator performances.

Random and axial spectra were measured in adjacent positions and a fresh area was used every ion beam energy value. The differences in the arrow position for scattering events due to Si atoms at the SiC/SiO\(_2\) interfaces were used to evaluate the ratio between the <0001> axial and random stopping power. In Fig. 2, the vertical error bars were determined by the precision in positioning the interface energy edges, that was \(\pm 1.5\) keV. First, the energy position of the Si edge at the SiC/SiO\(_2\) interface in the axial spectrum was determined. The results of such an evaluation versus the primary He\(^+\) beam energy averaged along the in going ion path are shown in Fig. 2 for the two polytypes. These energy values have error bars corresponding to the He\(^+\) ion energy loss between the sample surface and the SiC/SiO\(_2\) interface. Such a choice stresses the fact the evaluation presented here is a first approximation that assumes the channeling to random stopping power scale factor constant over any studied interval of energy, that it is not the case, as the same trend of Fig. 2 shows.

The thicknesses of the SiC films measured by the RBS random spectra were in the window (360 + 2) nm and (270 + 8) nm for the 6H-SiC and 4H-SiC wafers, respectively. The local thickness measurement had a precision of \(\pm 1\) nm.

### IV. CONCLUSION

Original data concerning the <0001> axis stopping power for MeV He\(^+\) ions in 4H- and 6H-SiC are given as results of preliminary studies done by using SiCOI wafers and Rutherford Back Scattering experiments [2].

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