Materials Research with Heavy Ion Beams

W. Assmann, H. Huber, T. Reichelt, I. M. Yesil, and S. A. Karamian [a]
[a] FLNR JINR Dubna

More than 300 samples have been analyzed with heavy ion beams, 40 samples with 25 MeV ^{16}O ions by RBS, and 265 samples with 210 MeV ^{127}I ions typically by ERDA (elastic recoil detection analysis). Almost all RBS samples were YBCO high T_c superconductors produced at the TU Munich and the ICR (Interd. Research Centre in Supercond., Cambridge). The strength of the ERD technique with particle resolution is light element detection without background from heavier components. Therefore in most of the ERDA samples light element components or contaminants were of interest. Examples were composition of TiN_xO_y and AlCuFe solar absorbers, stoichiometry of TiN, FeC and CN surface coatings (Univ. Augsburg), or diffusion processes in glass (FZ Rossendorf). The additional solid state detector in our ionization chamber was used for analysis of Hydrogen in Kapton foils (GSF Munich) and a-C:H coatings (MPI-IPP Munich, see this report p. 78).

To improve the understanding of surface roughness effects in ERDA depth profiles the simulation program SURF was developed. The program has been tested with well defined periodic surface structures made by ion etching in Si (Lst. Kotthaus, Univ. Munich). The characteristic structures in the measured energy spectra are simulated satisfactory as well as spectra of surfaces with random roughness.

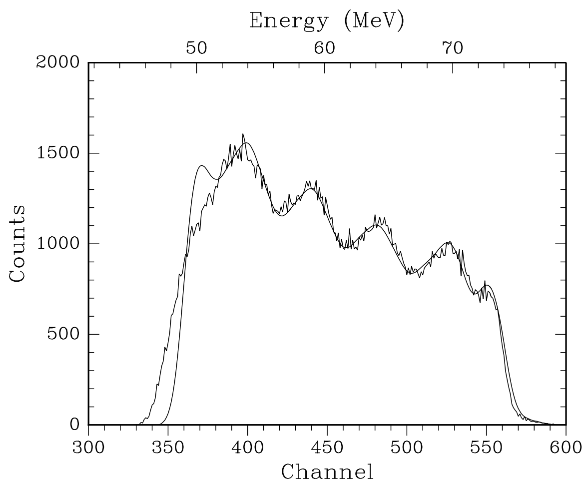

Fig. 1: Energy spectrum of Si recoils from a Si wafer measured with 200 MeV I and 5 ° incidence angle to the surface. The wafer surface had a grid structure with 1 μm period, 0.5 μm width and 175 nm depth. Solid line is a simulation with the program SURF

With our position sensitive ionization chamber blocking patterns of recoils from crystalline samples can be detected. The phenomenon of changing from blocking to channeling behavior for recoils from larger depth has been further investigated on thin Si foils. [1].

The blocking technique has been used to measure in situ radiation damage with different heavy ion beams. Crystalline metals (Cu, Cr), semiconductors (Si, Ge) and insulators (MgO) were studied with Au, I, Ni, and S ions. In one of these measurements we used the highest terminal voltage so far at our Tandem accelerator, 15 MV, to produce 285 MeV Au^{18+} ions. Thin YBCO superconductor films were also irradiated with light ions from the Tandem accelerator at the Demokritos institute (Athens), where the radiation damage was detected by RBS-channeling and Raman techniques [2].

During these irradiation studies we have found radiation induced deformation in some materials, e.g. Ge has shown a surface swelling up to 2 μm. The temperature increase in these experiments at room temperature was measured to be negligible corresponding to the small particle flux used. In cross section REM and TEM pictures (TU Munich and FZ Rossendorf) a highly damaged sponge-like zone could be seen around the projected ion range. Probably voids are created with a maximum diameter of 100 nm surrounded by amorphous material which increased the volume typically by a factor of 2. This damage seems to be solely caused by nuclear effects. The region where more than 90% of the total energy is damped by electronic energy loss shows according to the blocking measurements only minor crystalline defects. Au ions produce an additional strange structure at the Ge surface which consists of some 100 nm amorphous material. Surface swelling has been found also in Al_2O_3 and $SrTiO_3$.

After irradiation of thin Si foils with heavy ions in transmission geometry a distortion of the irradiated area in beam direction could be detected. This phenomenon is known in the literature for light ion irradiation and was called dimpling [3]. It seems to be a very sensitive measure for volume expansion by defects. To study this dimpling phenomenon in the presence of very high electronic energy losses Si foils of 1.5-12 μm thickness and 10 mm^2 area were irradiated with 210 MeV I ions at different fluences. The Si membranes were prepared by electro chemical etching (FZ Rossendorf, B. Schmidt). Distortions up to 15 μm were measured with a laser interference microscope (Fraunhofer Inst. (FIT), Munich). Additionally the beam spot area appeared black due to higher absorption of light. This dark area and the distortion disappeared completely after annealing at 650 °C for 30 min.

Well defined amorphous structures were produced parallel to the surface of crystalline materials by heavy ion irradiation at a glancing angle of 1 °. These ion tracks could be seen with REM on thin YBCO films after irradiation with 285 MeV Au ions and a fluence of 10^{11} Ions/cm^2. They have a typical size of 2-3 μm length and 50 nm width. Tracks were also found on Al_2O_3 and $SrTiO_3$ substrates.

References

[1] Jahresbericht 1994, p. 159
[2] R. Vlastou et al., Proc. of 4^{th} Europ. Conf. on Accelerators in Applied Research and Technology, Zürich, Aug. 1995
[3] R.L. Meek et al., Rad. Eff. **11** (1971) 139