Sputtering of Metals in the 100 MeV Range ◊

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Sputtering of materials with ions in the keV range is well understood and established as technological tool. The basic physical process is nuclear scattering with subsequent collision cascades which finally can result in particles leaving the surface. Typical sputtering yields are 1–10 atoms/ion in agreement with model calculations. Sputtering with MeV–energies is contrary to the keV–range much less studied and understood. At these high energies electronic effects dominate the slowing down of ions and may also influence the sputtering yields, which is of general as well as technological interest. Measurements on insulators have shown enhanced yields but little is known on metals. Therefore, we have started a project to determine sputtering yields of metals using heavy ions up to the highest tandem energies.

The main experimental problem of sputtering measurements at these energies is the low particle current which has to be used. This is on one hand necessary to avoid thermal effects and on the other hand limited by the tandem accelerator. Assuming nuclear sputtering only and 250 MeV Au ions incidenting on Ti at 20^o to the surface a sputtering yield of about 1 atom/ion is expected from theory. A reasonable Au current of 1 particle nA results within 3 hours in a total dose of nearly 10^{14} Au ions which corresponds to 1/10 of an atomic Ti mono-layer sputtered. It is obvious that this kind of measurements has to be done in an UHV system, where the metal surface can be cleaned in–situ and monitored during the irradiation. The newly installed UHV–setup described elsewhere in this report [1] meets these requirements.

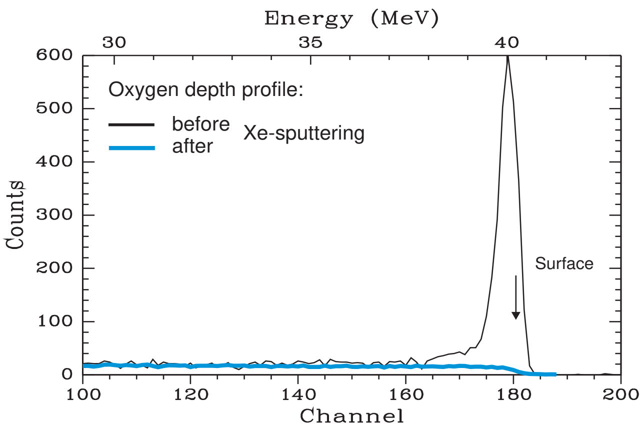

Fig. 1: Oxygen depth profile of a Ti sputter target

In fig. 1 an example is shown of a sputtering experiment with 230 MeV Au on Ti evaporated onto Si (A. Wenzel, Uni Augsburg). The oxygen depth profile measured in–situ with ERDA before and after sputter cleaning of the Ti surface with 8 keV Xe ions clearly demonstrates the benefit of cleaning as well as of UHV conditions. The surface contamination of oxygen can be reduced by sputter cleaning to the low bulk concentration level of about 0.2 %. Within the 3 hours sputtering time which is integrated in the spectrum no surface buildup of oxygen could be detected. Thus one can exclude interfering effects from surface oxides.

A second consequence of the low possible dose is the very sensitive technique which has to be used for detection of the sputtered atoms. Especially from metals most of the sputtered atoms are neutrals with typical energies of some eV. The most used (and simplest) technique is to catch the sputtered atoms on ultra pure materials and subsequently determine the thickness of the deposit. From the estimation above a thickness of 10^{13} atoms/cm^2 can be deduced which can be detected by heavy ion RBS [2].

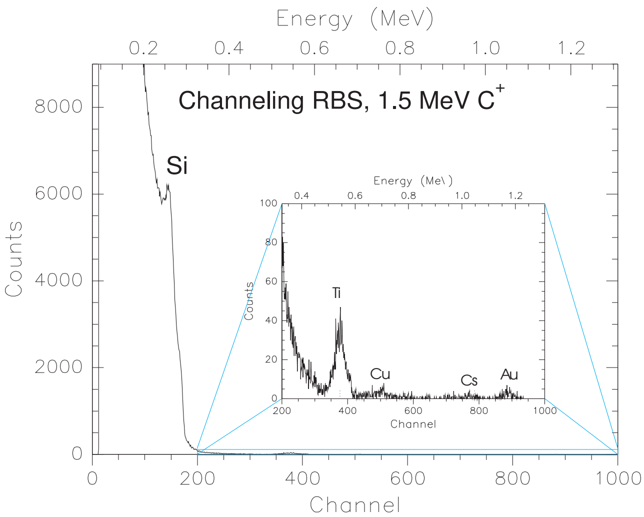

Fig. 2: RBS spectrum of a Si catcher used in Ti sputtering

We have used single crystalline Si wafers as catchers to further increase the sensitivity by the channeling effect. Fig. 2 shows a typical spectrum of a Si catcher used during Ti sputtering which was measured with 1.5 MeV C ions in channeling conditions (Lst. Stritzker, Uni Augsburg). The Ti peak corresponds to about $5*10^{13}$ atoms/cm^2 which would be covered by pulse pile up from Si signals without channeling. Note the Cu, Cs and Au contaminations in the 10^{11} atoms/cm^2 range which can be held at this low level only with careful catcher cleaning and strict protection in the catcher box.

References

[1] H. D. Mieskes *et al.*, this report p. 104
[2] M. Brodale, diploma thesis, LMU München, 1997

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