

High-Energy Elastic Recoil Ion Detection Analysis

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Elastic recoil detection analysis (ERDA) with heavy ions has become a powerful tool for stoichiometrical analysis of multifaceted samples. The method uses the information of atoms elastically scattered out of the target in forward direction. These ejectiles are analyzed concerning their atomic number and energy, the latter reveals the depth of the scattering collision inside of the sample. The differential cross section for scattering the target atom into the detector is:

$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2 (M_1 + M_2)}{8\pi\epsilon_0 M_2 E_1} \right)^2 \cdot \frac{1}{\cos^3\phi} \quad (1)$$

with the scattering angle ϕ . Especially with heavy ions, (e. g., Xe or heavier), element specific depth profiles for atomic masses up to Cr, Fe and Ni, the components of steel, can be obtained easily.

ERDA as a standard analytical tool in research and in industry is typically performed with projectile energies below 1 MeV/u at small electrostatic accelerators.

In recent years, ERDA has been tested at the high charge state injector using 1.4 MeV/u Xe ions [1]. In 2012 a similar setup was installed at the M3-branch of the UNILAC. Here, we have performed ERDA for the first time with 3.6 MeV/u Au ions. At this energy the Coulomb threshold is not reached and thus, the necessary elasticity of the binary collision is still guaranteed.

The figures show qualitative results, demonstrating the promising capabilities of high energy-ERDA. Various samples were probed under an incident angle of 67.5° to surface normal. The scattered atoms have been analyzed under 45° with respect to the incident beam by a $\Delta E/E_{rest}$ -telescope similar to the one used in [2]. The detector consists of an ionization chamber working with isobutane at 30 mbar pressure, decoupled from the experimental vacuum by a $1\mu\text{m}$ mylar foil and a silicon detector for E_{rest} . It has a solid angle of 1.7 msr and an acceptance angle of 2.8° in scattering plane.

From eq. 1, the difficulty of high energy-ERDA is visible, as the differential cross section goes down with the energy square. This problem is mitigated by choosing Au as projectile and a longer measuring time as compared to [2].

Within the limited beamtime available, we concentrated on the depth profiling of non-evaporable getter (NEG) coatings on stainless steel as a well known system [2]. Furthermore NEG getters are of active interest because of their use in the FAIR project [1] and the LHC.

Figure 1 shows the raw ERDA data of a getter-coated stainless steel target. All elements are clearly resolved in the plot. The getter layer consists of Ti, V, and Zr and has a

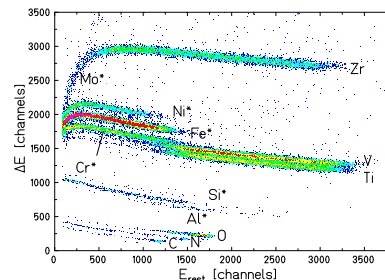


Figure 1: Raw data plot of the NEG getter sample.

thickness of roughly $1.2\mu\text{m}$. Under the getter layer, the steel substrate is clearly visible. The substrate composition and cleanliness of the interface is essential for the life time of the getter coatings. The data illustrate the capability and impact of high energy ERDA to investigate buried layers and interfaces of layer samples to the substrate.

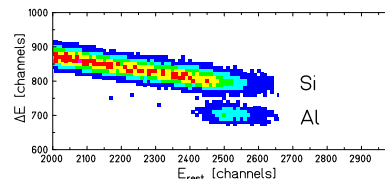


Figure 2: Zoomed into raw data plot of an Al layer on Si.

Figure 2 shows a zoomed area of the $\Delta E - E_{rest}$ plot of Si covered by a 100 nm thick Al coating. The neighboring elements Si and Al are clearly resolved. However, the 100 nm thickness of the Al layer is distributed on roughly 100 channels of the acquisition chain. With respect to the gauss-shaped borders (front and back edge) of the layer, the depth resolution of the system is towards several 10 nm, being yet poor as compared to low energy ERDA systems [3]. We are presently working on improvements for the depth resolution. This includes the elimination of the binning combined with minimization of noise in the analog signal chain of the electronics. Moreover, an improved E_{rest} -detector with a better energy resolution should be used. Lastly, the implementation of kinematic correction is necessary to eliminate the haziness in energy due to the acceptance angle in scattering plane.

References

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