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Applications of MeV ion beams and microscopy to non-destructive surface analysis of materials

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Man has been developing a wide range of surface analysis techniques, involving e.g. ion, electron and photon beams interacting with a solid target. The techniques are, generally, complementary and provide target information for near surface depths. Nuclear techniques, which are non-destructive, provide for analysis over a few microns close to the surface giving absolute values of concentrations of isotopes and elements. Applications have been given in areas such as scientific, technologic, industry, arts and medicine, using MeV ion beams [1-7]. Tracing of isotopes with high sensitivities is possible by nuclear reactions. We use ion-ion reactions and the energy analysis method. At a suitably chosen energy of the incident ion beam, an energy spectrum is acquired of ions from the reaction, coming from several depths in the target. Such spectra are computer simulated and compared with experimental data, giving target composition and concentration profile information [4-7]. Elastic scattering is a particular and important case. A computer program has been developed in this context, mainly for flat targets [4-6]. The non-flat target situation arises as an extension.
Successful applications of the method are given using the $^{18}O(p,\alpha_0)^{15}N$ reaction and elastic scattering of $(^4He)^+$ ions for three types of samples. SEM is used as a useful complementary technique.

One sample (S1) was obtained by sequential high temperature oxidation of austenitic steel in C $^{16}O_2$ and C $^{18}O_2$ gases. An ^{18}O diffusion concentration profile was expected. SEM has shown a reasonably flat oxide (Fig. 1). S1 was analysed by the $^{18}O(p,\alpha_0)^{15}N$ reaction at E_p=1.78 MeV, 165°. A complementary error function profile of ^{18}O was found, due to diffusion, and the diffusion coefficient was determined. The second sample (S2) was a self-supported target of anodic aluminium oxide obtained by aluminium anodization at 200 V, with an expected thickness of 0,2740 µm. S2 was analysed by elastic scattering of α particles at E_α =2.0 MeV, 135°. An oxide with excellent uniformity and thickness X_1= 0.2460 µm was found. Sample S3, labelled Al/Ag/Au, consisted of two thin layers of Ag and Au obtained by sequential vacuum deposition of Ag and Au onto a thick flat Al substrate; film thicknesses of X_1=0.0648 µm and X_2=0.1333 µm were initially expected for Au and Ag, respectively. It was analysed at E_α =1.5 MeV, 165°. Uniform concentration profiles were used along X_3=0.55 µm for Al, X_2=0.125 µm for Ag and X_1=0.061 µm for Au (Figs. 3 and 4). A further analysis at a higher bombarding energy, E_α=2.9 MeV, permitted to conclude that the sample is better described by a structure Al/Ag/(Au,Ag) where the surface film consists of a mixture of Au and Ag due to the sequential vacuum evaporation, with a relative atomic density C_{Ag}/C_{Au} of 5.6%. The results of the present work are illustrated for samples S1 (Figs. 1 and 2) and S3 (Figs. 3 and 4).

The combined use of nuclear techniques and SEM microscopy has shown to be a highly powerful analytical tool for surface analysis of materials.

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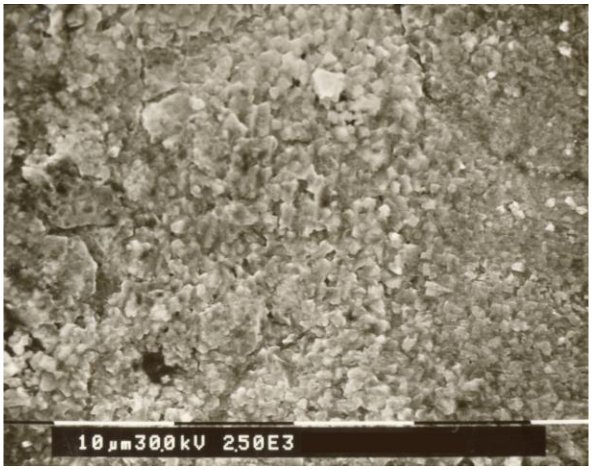

Figure 1. SEM image of the thick oxide sample (S1).

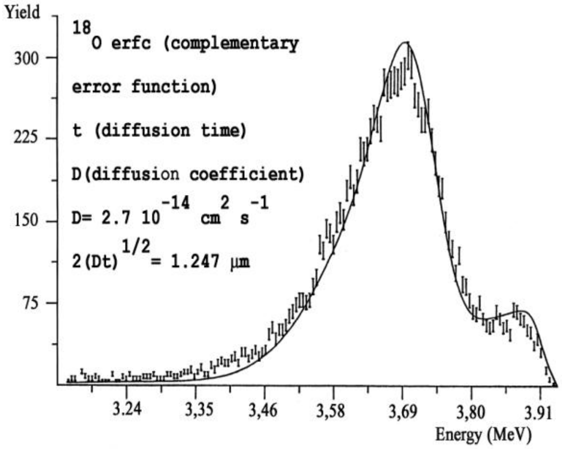

Figure. 2 Computed fit to the spectrum of sample S1 at E_p=1.78 MeV, 165°.

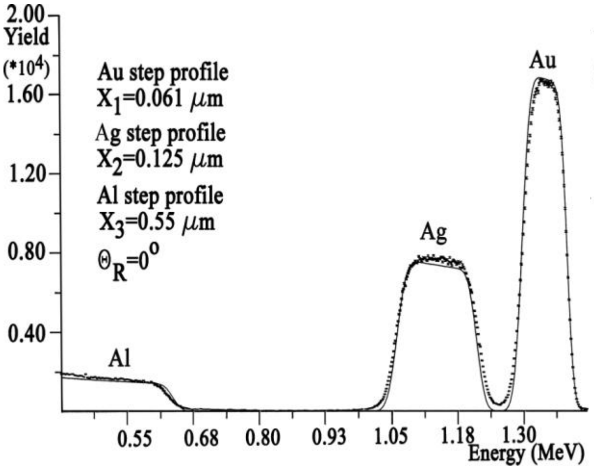

Figure. 3 Computed fit to the α elastic scattering data from the Al/Ag/Au sample, S3, for E_α=1.5 MeV, 165°.

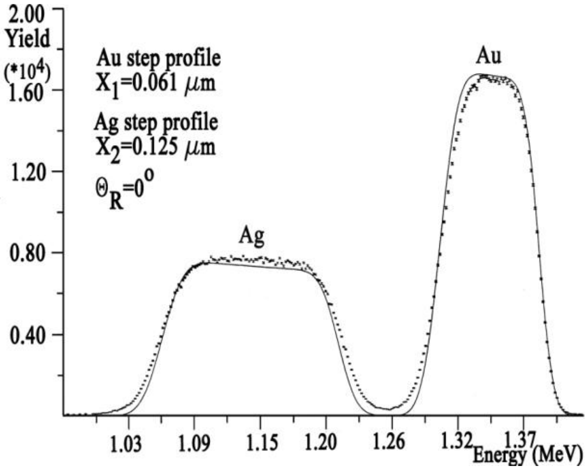

Figure. 4 Computed fit to the α elastic scattering shapes from Ag and Au in the Al/Ag/Au sample, S3, for E_α=1.5 MeV, 165°.