Angular Distribution of Elastically Backscattered Electrons and the Depth of Electron Penetration

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In Elastic Peak Electron Spectroscopy (EPES), the information on electron transport in the surface region of solids is derived from the probability of elastic backscattering in a given direction in space. Using Monte Carlo methods, it is possible to simulate the electron trajectories inside the sample. In the present work, the angular distributions are visualized in 3D plots, and comparison is made between different analyzers and different experimental configurations.
From computer simulations, the sampling depth of analysis can be derived. The EPES method is sensitive to the surface two monolayers, where most of electrons are backscattered.

Introduction

Elastic Peak Electron Spectroscopy (EPES) is a method dealing with the elastic backscattering of electrons[1-2], and is very sensitive to the surface region of the samples. Experimental percentage η_e of elastically backscattered electrons is usually associated with Monte Carlo calculations. In the present work, three dimensional graphs showing the outside distribution of electron emission have been elaborated.

Monte Carlo simulations

We have used two kinds of Monte Carlo methods. One is based on layered structures (code A [3]) and the other code is applicable to uniform solids (code B [4]).
The computer programs need, as input parameters, the elastic cross section and the inelastic mean free path of electrons in studied materials. For a good statistical results, we have used 10^6 electron trajectories inside the samples in a single run. Code A is implementing only the non-relativistic cross sections calculated within a partial wave expansion method[3-5]. The relativistic elastic scattering cross sections were used in the Monte Carlo program code B. They were taken from NIST Database 64 [6]. Furthermore, the differences in elastic scattering cross sections originating from two sources did not affect noticeably the calculated

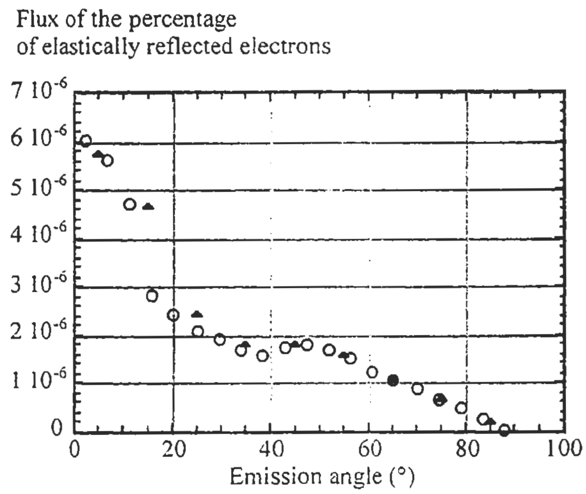

Figure 1: Comparison of the results obtained by two different computer simulations with Au sample and E_0 = 200 eV. (▲) code A, (O) code B

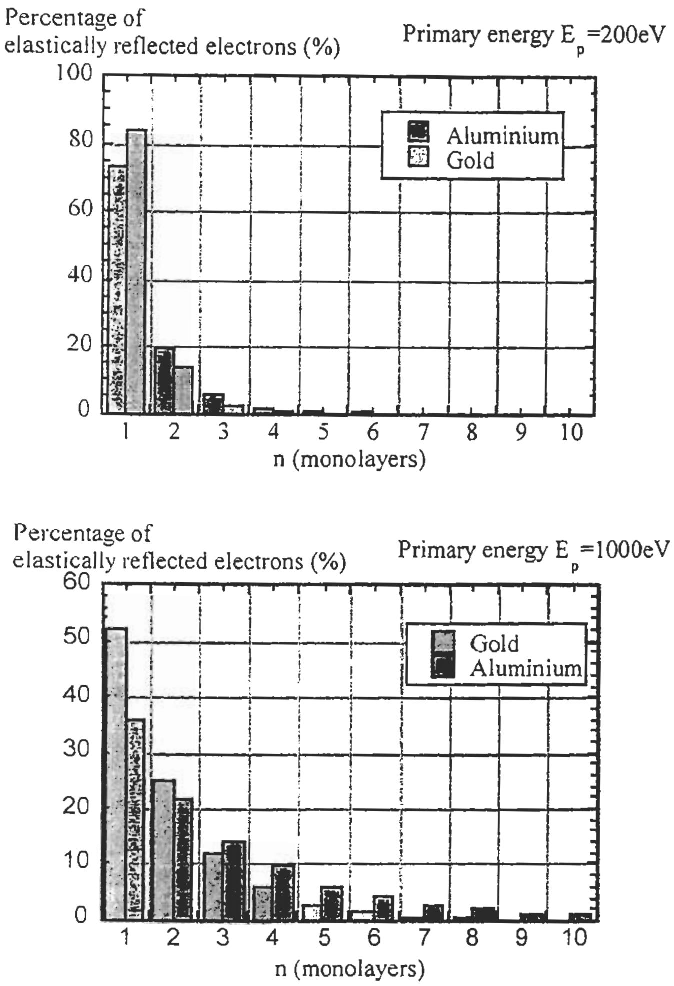

Figure 2: Diagrams of penetration depths of elastically reflected electrons for Al and Au substrates and for two values of the kinetic energy of incident electrons (E_0=200 eV and E_0 = 1000 eV).

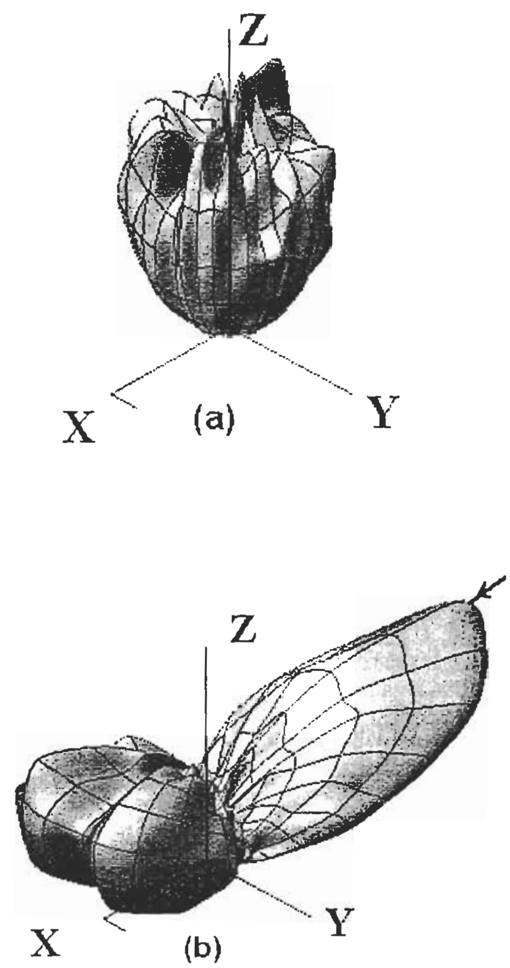

Figure 3 : Three dimensional pictures of the density of current elastically reflected from Al sample at E_0 = 200 eV. Impinging beam direction: (a) $\theta = 0°$. (b) $\theta = 70°$.

intensities.
Substrates are considered as amorphous. As we can see in the figure 1, these two methods give quite similar results. For the following results, we have used the code A.

The penetration depth

In surface studies, the depth of analysis is an important parameter which is depending on primary energy E_0 and substrates. Figure 2 displays the percentage of reflected electron for Au and Al targets for two primary energies. For E_0 = 1000 eV the penetration depth is greater than for E_0 = 200 eV.

Nevertheless, in both cases, practically all electrons (80%) are elastically reflected from the first overlayers. Thus, the EPES technique is very sensitive to the surface of the samples.

3D pictures

We have developed a computer program that gives three dimensional pictures based on the flux ($d\eta_e/d\Omega$), which shows the percentage of elastically reflected electrons from targets.[7] View angles can be chosen for a quasi realistic vision. The 3D plots result from calculations in which the solid is assumed as amorphous. Thus, the peaks on the 3D plots are

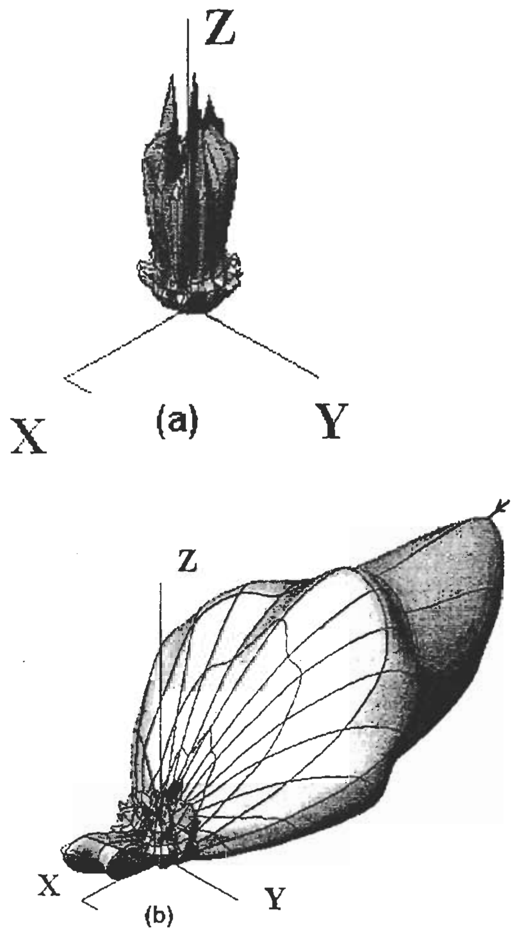

Figure 4 : Three dimensional pictures of the density of current elastically reflected from Au sample at E_0 = 200 eV. Impinging beam direction: (a) θ = 0°. (b) θ = 70°.

entirely due to statistical uncertainties.

For E_0 = 200 eV, one can see the influence of the impinging angle of the primary electron beam (figure 3 and 4). Clearly, the spatial distribution of backscattered electrons is different for Al and Au samples.

EPES and different analysers

The recorded elastic peak is dependent on the analyzer aperture as well the position of the sample and the incidence angle of the primary beam.
This is evident from the above 3D pictures which show the dependence of the intensity in spatial directions.

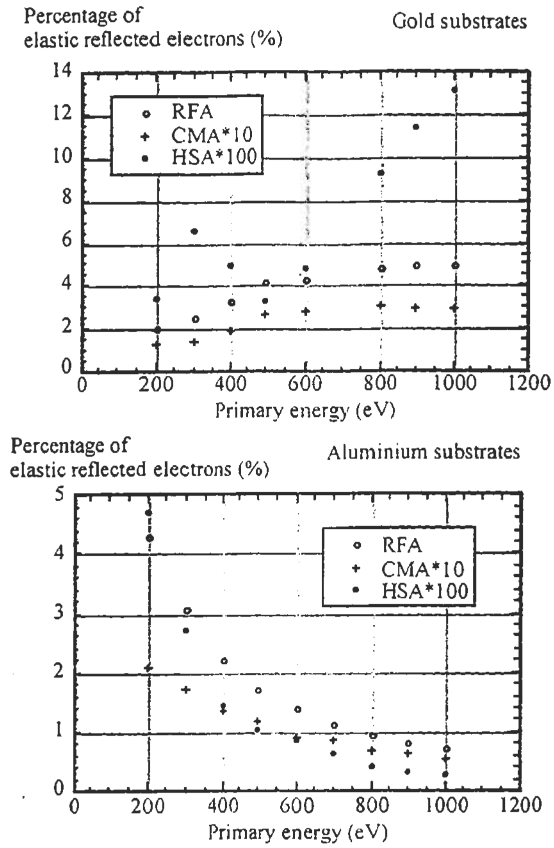

Figure 5 : The theoretical variation of the percentage η_e of the elastically reflected electrons entering the solid acceptance angle of the three analyzers from Au and Al samples

In the figure 5 using an incidence angle equal to 0°, we have presented results for three typical spectrometers:
-retarding field analyzer (RFA) : θ = 0-55°, φ = 0-360°.
-hemispherical analyzer (HSA) : the collection window is about 2x18mm and the angle between the electron beam and the analyzer is 64°.
-cylindrical mirror analyzer (CMA) : θ = 42° ± 2°, φ = 0-360°.
As one can see, differences in the experimental configuration lead to dramatic differences in the energy dependence of the probability of elastic reflection.

Conclusion

EPES technique is based on elastically reflected electrons from substrates. This

method is very sensitive to the surface of the samples and must be completed with Monte-Carlo simulations.
Computer results allow to drawn 3D visual representations of the electron current spatial intensity.
We have found that this method is dramatically dependent on the geometrical experiment.

Acknowledgement

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