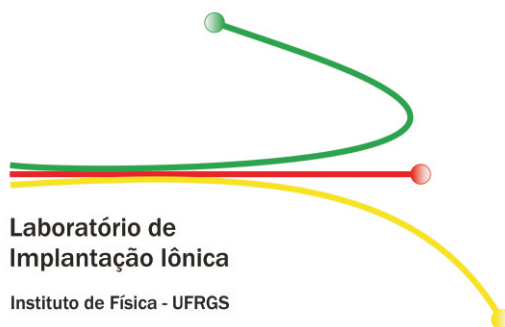




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Pedro Luis Grande

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Neutralization and wake effects on the Coulomb explosion depth profiling

L. F. S. Rosa¹, P. L. Grande¹, R. C. Fadanelli¹, J. F. Dias¹

¹ Instituto de Física, Universidade Federal do Rio Grande do Sul , Brazil

Corresponding author: lucio_efe@hotmail.com

Depth profiling of heavy elements in thin films is a requirement in the modern materials science. One of the most used techniques is the Rutherford backscattering spectrometry (RBS) due to its simplicity and reliability. The RBS gives depth in units of length assuming the knowledge of the density of the target, otherwise “depth” stands as an abbreviation for the number of atoms per unit area. But in the case of thin films the atomic density can be quite different from its bulk or nominal value.

In [1] we proposed the use of Coulomb explosion (CE) as an alternative way to determinate the absolute value of thickness of thin films (from 0.1 to 20 nm). The depth information is obtained from the broadening of the energy-loss distribution of the H⁺ fragments under quasi-Coulomb explosion after the molecular break-up. For H₂⁺ ions with a few hundreds keV, the complete dissociation takes place at the first atomic layers and the energy-loss straggling can be disentangled from other energy-loss fluctuations and converted to time or penetrated depth. This conversion is straightforward as long as neutralization, multiple scattering and wake potential effects are of minor importance, which is the case for energies larger than 150 keV/u.

In this work we exploited this technique at much lower energies and determined the effects of neutralization, screening under non-central wake forces and multiple scattering. For this sake, we measured the energy loss spectrum of H₂⁺ and H⁺ at 50 keV/u to 150 keV/u in thin TiO₂ films using MEIS (Medium Energy Ion Scattering) as a function of the incidence angle. The results at 150 keV/u yield thicknesses different from the nominal one obtained by the standard MEIS analysis using the bulk density of TiO₂ but are in good agreement with thicknesses obtained by TEM measurements. This is a consequence of the actual density of the film being smaller than the bulk one by 20%. The same results can be obtained at much smaller energies only if neutralization effects are correctly taken into account. In addition, the effect of the screening due to non-central wake potential is very important and is discussed using the dielectric formalism with a linear combination of Mermin dielectric functions [2] to describe the electronic structure of TiO₂.

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