PROTONS REFLECTION FROM LAYERED INHOMOGENEOUS SOLIDS

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Ion-Surface Interactions 2023

Introduction

The interaction of light ions with energy from hundreds of eV to several keV with solids has a number of features. Having relatively large runs, the ions lose a noticeable, and with a decrease in energy, the bulk of the energy as a result of elastic collisions. This leads to the development of radiation-stimulated diffusion of the light component into the heavy component of the target. The inability to create a developed cascade of collisions and knock out the target atom as a result of a direct impact leads to the dominance of the target sputtering process by an ascending reflected ion flow. The ions reflected from the first wall also determine the recycling process. It follows from the above that detailed information about the processes of reflection of light ions from stratified surfaces sheds light on a number of problems associated with the first wall of CTF installations.

Analytical theory

Energy spectra of light ions reflected from homogeneous surfaces [1] are determined by the formula:

$$R(\Delta,\mu_0,\mu,\varphi_0,\varphi)=\frac{\mu_0|\mu|}{\mu_0+|\mu|}\frac{(1-x^l)}{\Delta E_0}e^{-\frac{A}{\sqrt{1-\Delta}}}$$
$$\sum_l\frac{2l+1}{2}P_l(\mu_0\to\mu,\varphi_0\to\varphi)\left[e^{-\frac{\Delta(1-x^l)\xi}{(1-\Delta)^{5/2}}}-e^{-\frac{\Delta\xi}{(1-\Delta)^{5/2}}}\right]$$

The solution describing the energy spectra of light ions reflected from layered inhomogeneous surfaces is constructed according to the following scheme:

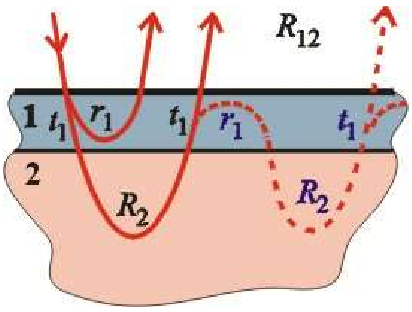

Fig.1. The scheme of light ions reflection from two-layer target

$$R_{12}=r_1+t_1\otimes R_2\otimes t_1$$

Thus the energy spectra of light ions reflected from two-layer surface taking into account the absorption of ions in a layer of thickness *d* are determined by the following formula:

$$R_{12}(\Delta)=R_1(\Delta)+t\left(d\left(\frac{1}{\cos\theta_0}+\frac{1}{\cos\theta}\right)\right)$$
$$\left(R_2\left(\Delta-\frac{\overline{\varepsilon}_1 d}{E_0}\left(\frac{1}{\cos\theta_0}+\frac{1}{\cos\theta}\right)\right)-R_1\left(\Delta-\frac{\overline{\varepsilon}_1 d}{E_0}\left(\frac{1}{\cos\theta_0}+\frac{1}{\cos\theta}\right)\right)\right)$$

Results

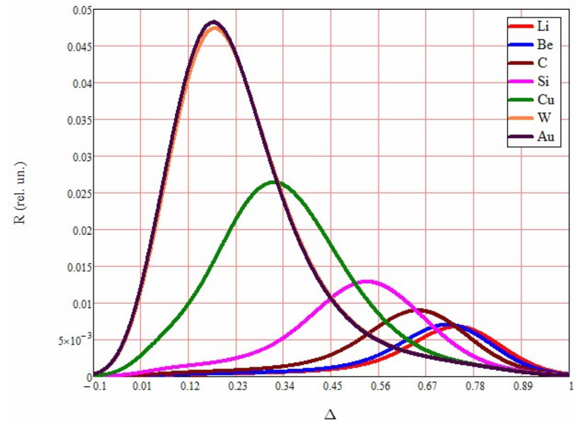

Fig.2. Energy spectra of protons reflected from homogeneous surfaces. Incidence angle 71°; reflection angle 109°. Initial energy 25 keV

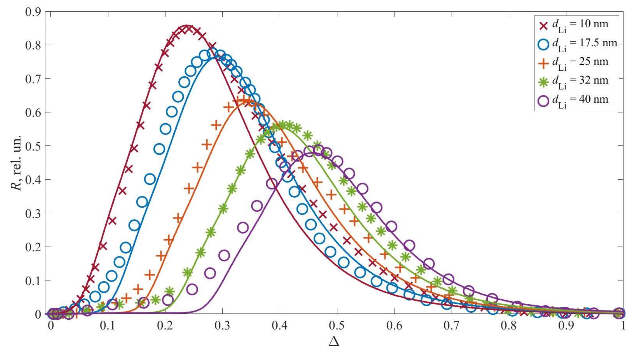

Fig.3. Energy spectra of protons reflected from a tungsten target coated with lithium layers of different thicknesses. Incidence angle 71°; reflection angle 109°. Initial energy 25 keV. Lines – calculation; symbols – experiment [2]

Conclusions

An analytical theory describing light ions reflection from layered inhomogeneous surfaces is constructed. This theory based on a boundary value problem solution for transport equation by means of invariant imbedding method in small-angle approximation. Calculation of energy spectra of protons reflected from a tungsten target coated with lithium layers of different thicknesses is carried out. Comparison of the analytical calculations with the experimental results shown the satisfactory agreement. Presented analytical theory points out on the possibility of describing the energy spectra of light ions reflected from any combination of layers.

[1] V. P. Afanas'ev, L. G. Lobanova Application of the Methods Used to Interpret the Electron Spectroscopy Spectra to Interpret Ion Spectroscopy Signals // Russian Microelectronics, 2022, Vol. 51, No. 4, pp. 210-219.
[2] D.G. Bulgadaryan, D.N. Sinelnikov, N.E. Efimov, V.A. Kurnaev Using the scattering spectroscopy of keV-energy protons to analyze the deposition of lithium on tungsten // Bulletin of the Russian Academy of Sciences: Physics, 2020, Vol. 84, No. 6, pp. 742-746