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Ion-stimulated Diffusion on "Film-substrate" Interface During Ionic Sputtering of Film Surface

ABSTRACT. *In present work the results of analyzes of chemical elements distribution on "film-substrate" interface of deposited ferrite-garnet films before and after thermal annealing are presented. It's shown the role of both thermal stimulated diffusion and ionic stimulated diffusion for formation of profile of elements distribution. It has been proposed the method of reconstruction of "real" form of interface profile before the ionic beam influence.*

INTRODUCTION

The physics of micro- and nanostructures often determined by properties of their surface. The surface can be free (as rule it contacted with a gases or a vacuum), or it can be an interface (as rule between two condensed matters, for example the interface between film and substrate). So the formation of the surface with specified physics and chemical properties is the one of the key problems in micro- and nanoengineering.

The present work is about investigation and analysis of influence of different diffusion mechanisms on the formation of profile of chemical elements distribution on the "film-substrate" interface. It was shown the possibility of reconstruction of "real" profile of elements distribution (before interaction with ion beam).

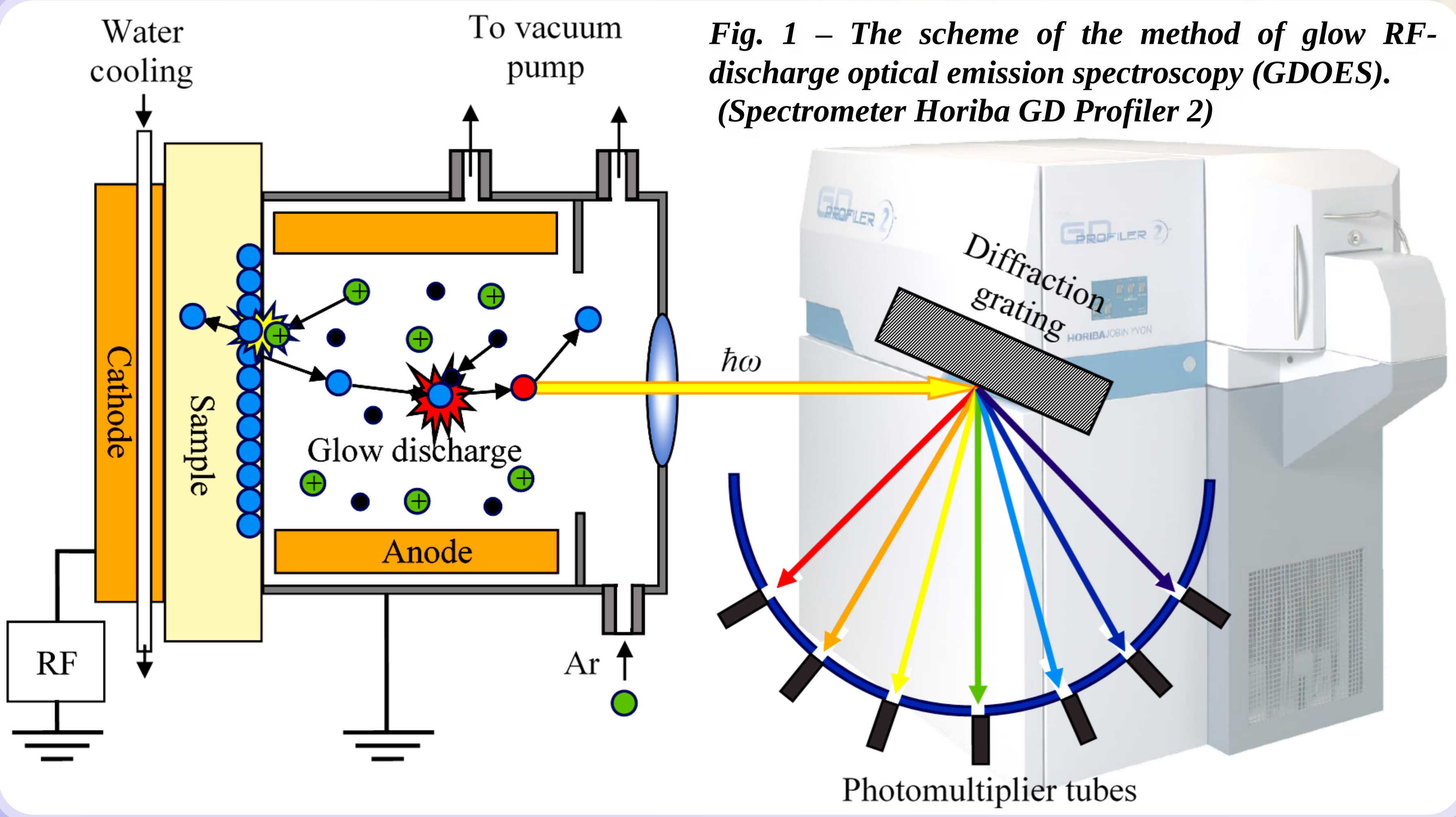

Fig. 1 – The scheme of the method of glow RF-discharge optical emission spectroscopy (GDOES). (Spectrometer Horiba GD Profiler 2)

EXPERIMENTAL TECHNIQUE

The samples of bismuth-substituted iron-garnet (BiIG) films was obtained by method of ion-reactive sputtering of target with $Bi_{1.0}Lu_{0.5}Gd_{1.5}Fe_{4.2}Al_{0.8}O_{12}$ composition in Ar (25 %mol.) + O_2 (75 %mol.) athmosfere with pressure P = $8.7\cdot10^{-2}$ Pa (residual gases pressure is not warse then P = 10^{-3} Pa). As the substrates the 500 µm thick plates of polished gadolinium-gallium garnet ($Gd_3Ga_5O_{12}$, GGG) monocrystal with (111) surface orientation was used. The thickness of BiIG/GGG films was 100 ± 5 nm. The films crystallization was carried out by method of thermal treatment in air at 700°C during 20 min.

For investigation of chemical elements distribution profiles on the "film-substrate" interface the method of glow RF-discharge optical emission spectroscopy (GDOES) by Horiba GD Profiler 2 spectrometer was used. The scheme of GDOES is demonstrate in Fig. 1.

For analysis of thermal-activated diffusion processes on the "film-substrate" interface the numerical evaluation of one-dimension diffusion equation was carried out.

$$\frac{\partial}{\partial t}C(x,t)=-\frac{\partial}{\partial x}\left(-D_x\frac{\partial}{\partial x}C(x,t)\right)=-\frac{\partial}{\partial x}\varphi(x,t)$$

This equation was solved with approximation of time-domain discretization. In this case the change of chemical element concentration ∂C in domain ∂x during time ∂t was determine as the difference of diffusion flows $\partial\varphi$ on the borders of domain (flow gradient).

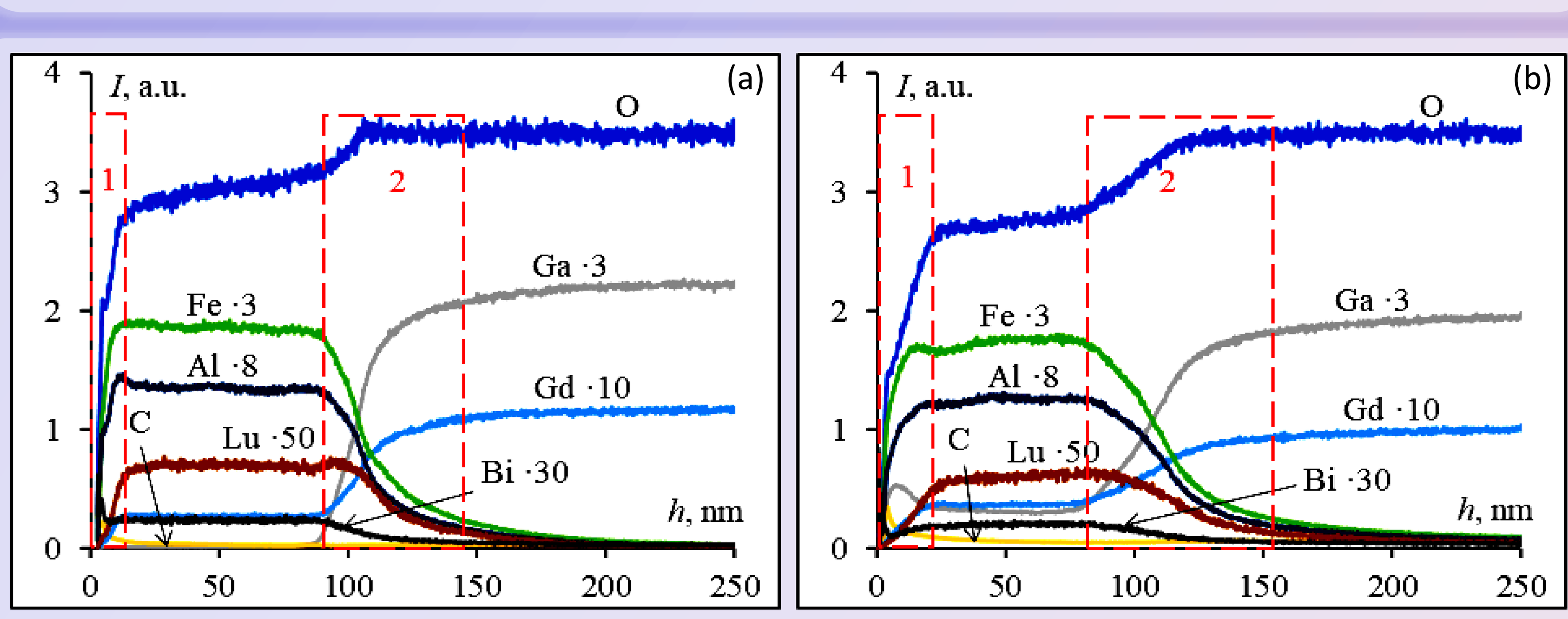

Fig. 2 – The profile of chemical elements distribution in BiIG/GGG film depth: a) after deposition on the room temperature substrate; b) after thermal treatment on air at 700°C during 20 min.
(The multiplier of spectral line intensity increasing is shown in the elements signature)

ACKNOWLEDGMENTS

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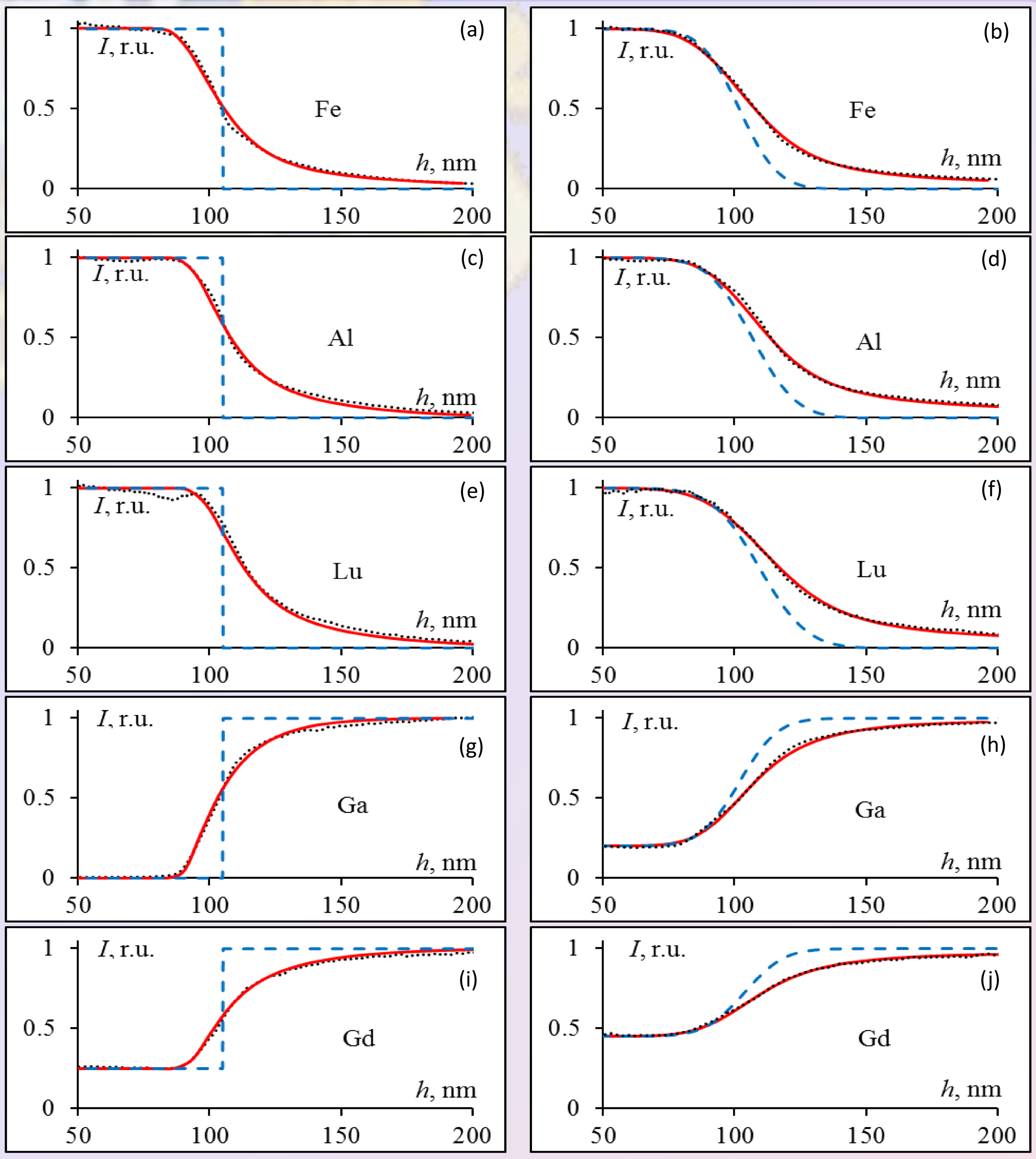

Fig. 3 – Analysis of chemical elements distribution profiles on the "film-substrate" interface:
a, c, e, g, i – before thermal treatment; b, d, f, h, j – after thermal treatment;
(Dots – experimental data, solid line – simulation data, dashed line – "real" form of profile without ion-stimulated diffusion accounting)

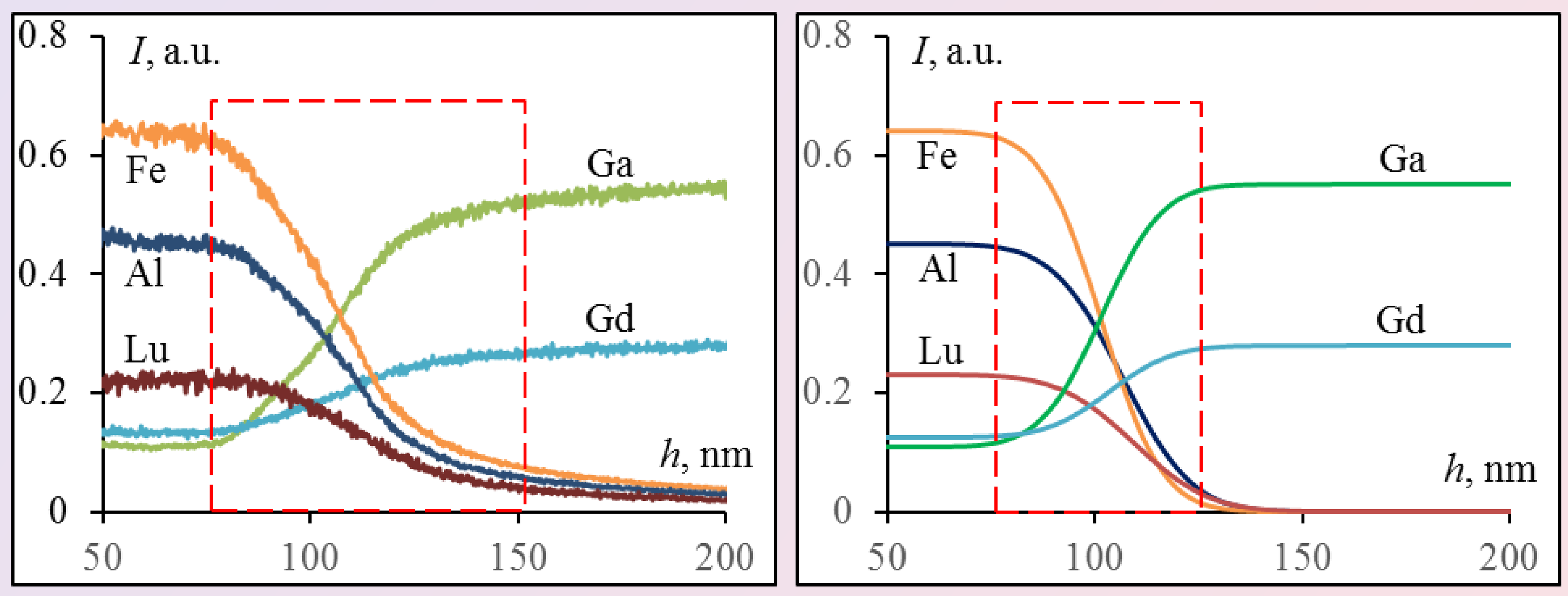

Fig. 4 – Comparison of chemical elements distribution profiles on the "film-substrate" interface:
a – experimentally measured profiles; b – reconstructed "real" form of profiles without ion-stimulated diffusion accounting.

CONCLUSIONS

For deposited bismuth-substituted iron-garnet BiIG/GGG films the contribution of different diffusion mechanisms on the formation of *elements distribution profiles on the interface* was analyzed.

It was shown that the directed ion-stimulated diffusion is occurs during the sputtering of the sample surface by high-energy ions Ar⁺. It lead to distortion of experimentally observed *elements distribution profiles on the interface in comparison of "real" profile. It has been proposed the methodology of theoretical analysis of experimentally obtained profiles, which allows to reconstruct the "real" form of interface profile without ionic beam influence (the integral artefact of investigation method)*. It was shown that *the investigation of BiIG/GGG film (with thickness 100 ± 5 nm after thermal treatment at700°C during 20 min.) demonstrate the experimentally observed profile with the width of "film-substrate" interface bigger in 1.5 times then the theoretically reconstructed "real" profile.*

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