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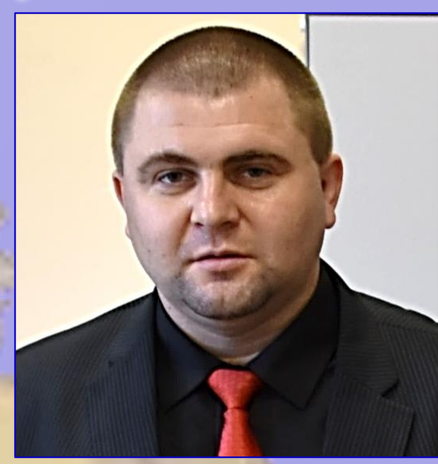


CFUV PhysTech

The Formation of Edge With Smoothed Profile for Epitaxial Iron-Garnet Films Using the Method of Ionic Etching

ABSTRACT. The paper presents the results of investigation of the possibility of forming a given 3D-profile of magnetic microstructures based on iron-garnet epitaxial films by ionic-plasma etching of the surface with mask. It is shown that when a mask with big thickness is applied, edge effects lead to the formation of an inhomogeneity of the plasma flow and the formation of a smooth edge of the film near the mask. The width of smoothed edge profile can be changed from units to hundreds micrometers by variation the height of gap between the edge of mask and the film due to effect of geometric half-shadow.

INTRODUCTION

To create highly sensitive magnetic field sensors (of the order of femtotesla), iron-garnets epitaxial films doped with rare earth elements can be used. Such films have a monocrystalline structure and a high degree of structural perfection. Large values of the magneto-optical Faraday effect in films based on Bi-substituted iron-garnet make it possible to record the magnitude of the magnetic field, but also to visualize its distribution. One of the factors which limiting the efficiency of dynamic remagnetization of such sensors (and which reducing the sensitivity of magnetic sensors based on them) is the appearance of edge domains near the edge of the film. To reduce the influence of the edge domains, the 3D-profile of the sensoric film disk must be smooth, close to ellipsoidal.

This work is devoted to the study of the possibility of forming structures with a smooth 3D-profile in epitaxial films of bismuth-substituted iron-garnets using ion-plasma etching of the surface through a mask.

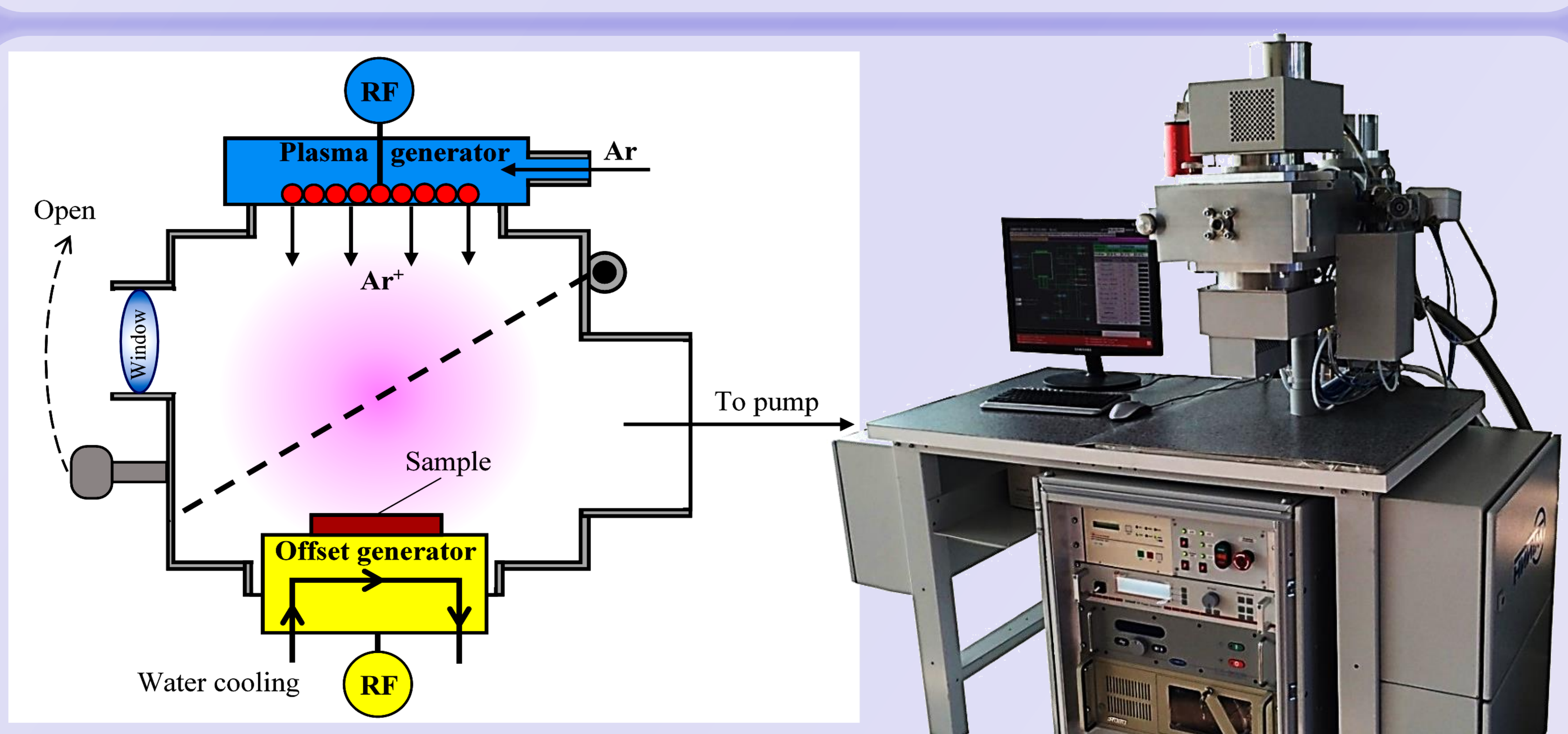

Fig. 1 –The scheme of the reactor chamber and general view of the vacuum machine for ion-plasma etching "MVU TM Plasma 06"

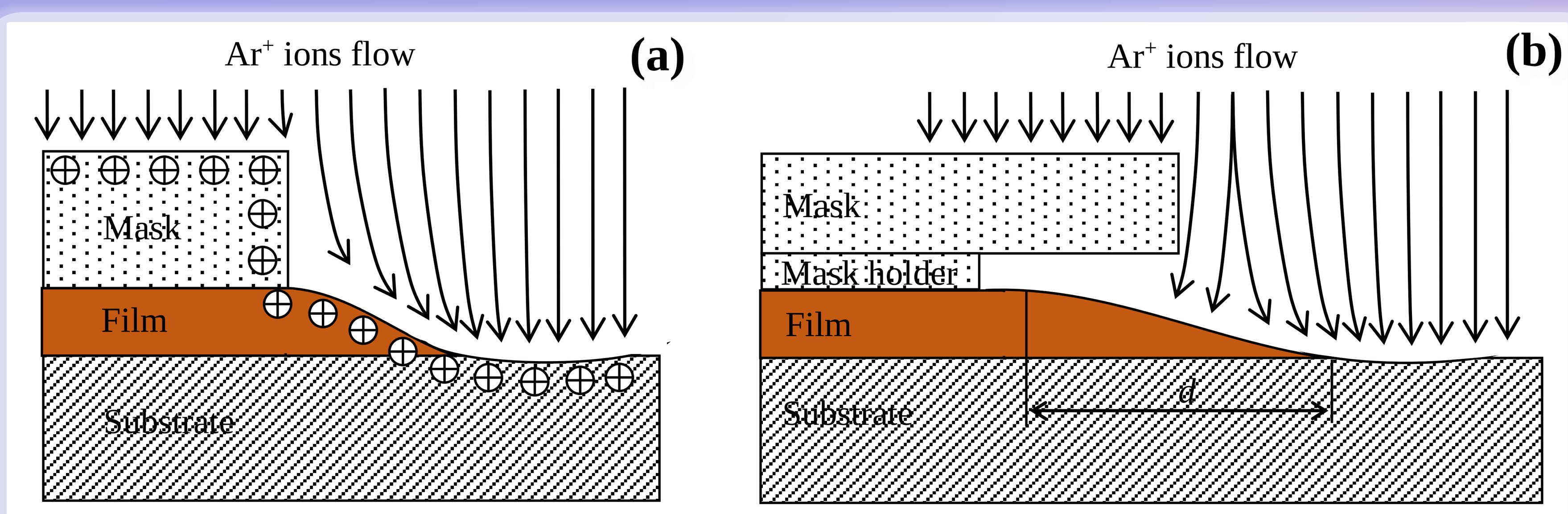

Fig. 2 – The scheme of the formation of a smooth 3D-profile on the film edge: a - the mask is located on the film surface; b - the mask is located above the film surface.

EXPERIMENTAL TECHNIQUE

Samples of bismuth-substituted iron-garnet epitaxial films (IGEF) has been obtained by liquid-phase epitaxy from a solution-melt with the nominal composition $(BiY)_3(FeAlGa)_5O_{12}$. Plates with a thickness of 500 μm from a polished single crystal of gadolinium-gallium garnet $Gd_3Ga_5O_{12}$ (GGG) with a surface orientation (111) has been used as a substrates. The thickness of the IGEF/GGG films was about 150 nm.

Ion etching was carried out on a vacuum machine "MVU TM Plasma 06" (NII TM, Zelenograd) in Ar plasma at a pressure of 1 Pa (residual pressure of atmospheric gases is not worse than $5 \cdot 10^{-3}$ Pa). In this machine, plasma is generated by an RF glow discharge (13.6 MHz). The etching of the sample surface occurs due to the RF offset on water-cooled samples holder from an independent generator (13.6 MHz). The general scheme of the reactor chamber of the machine for ion-plasma etching is shown in Fig. 1.

Fig. 2 shows a method for forming a smooth 3D-profile of the film edge. For this, during ion etching, a "massive" (about 500 μm thick) mask of a nonmagnetic dielectric (quartz, GGG) is applied to the film surface.

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Edge effects at the mask boundary (including the field interaction of Ar^+ ions with an induced surface charge) lead to the curvature of the ion flux and to the formation of an etching rate gradient. Thus, a film edge with a smooth 3D-profile is formed near the mask border. The width d of the region of a smooth 3D-profile on the film edge can be changed from units to hundreds micrometers when creating a gap between the mask and the film, as shown in Fig. 2, b. The change of gap height effect on the probability of plasma flow penetration under the mask and as the result on the width *d* of edge area with smoothed profile.

The experimental investigation of geometric form of film edge 3D-profile was carried out by Linnik micro-interferometer MII-4 with block of digital analysis. For investigation the green light filter with wavelength λ = 532 was used.

The width of smoothed profile area was determined using a scale bar in micro-interferometer eyepiece (1 division = 30 μm).

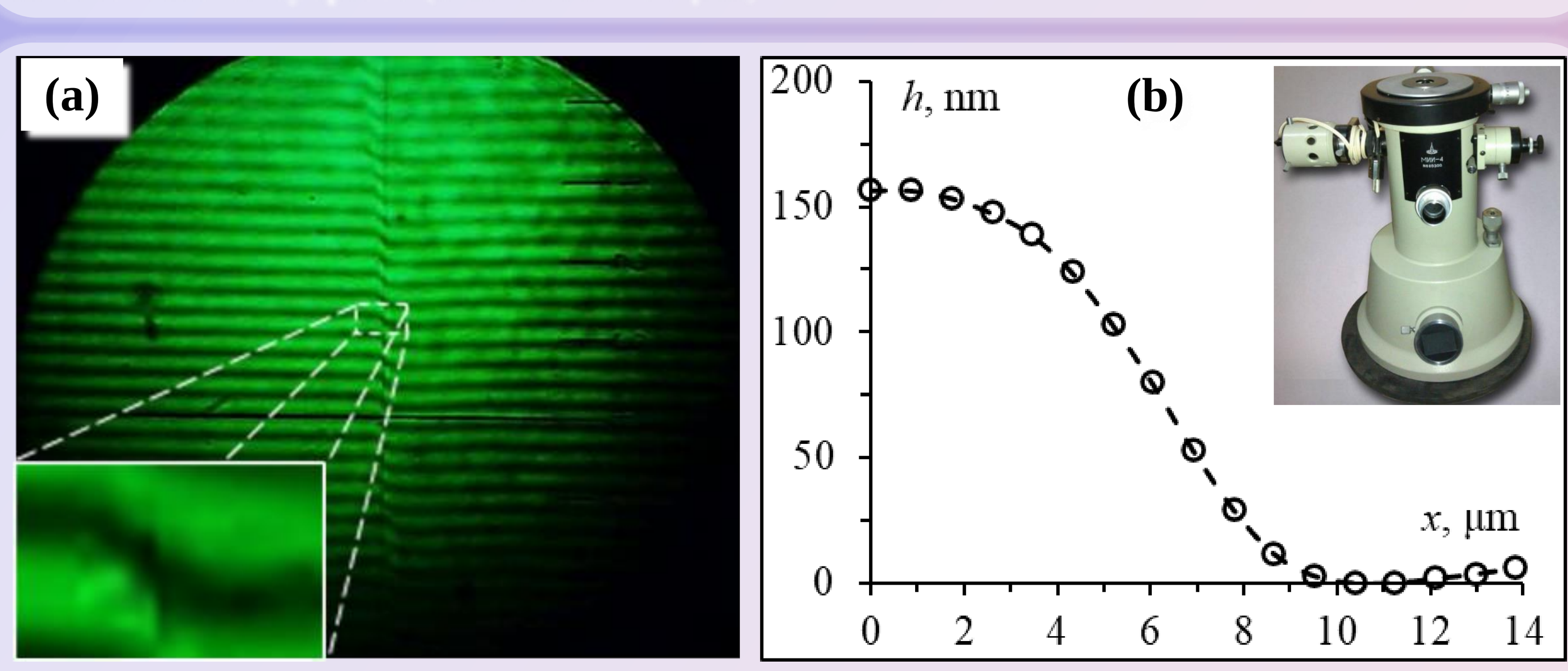

Fig. 3 – Film edge profile after ion etching (mask on the film surface): a - photo of the interference pattern at the boundary of the etching region (monochromatic radiation λ = 532 nm); b - the form of the profile of the film edge.

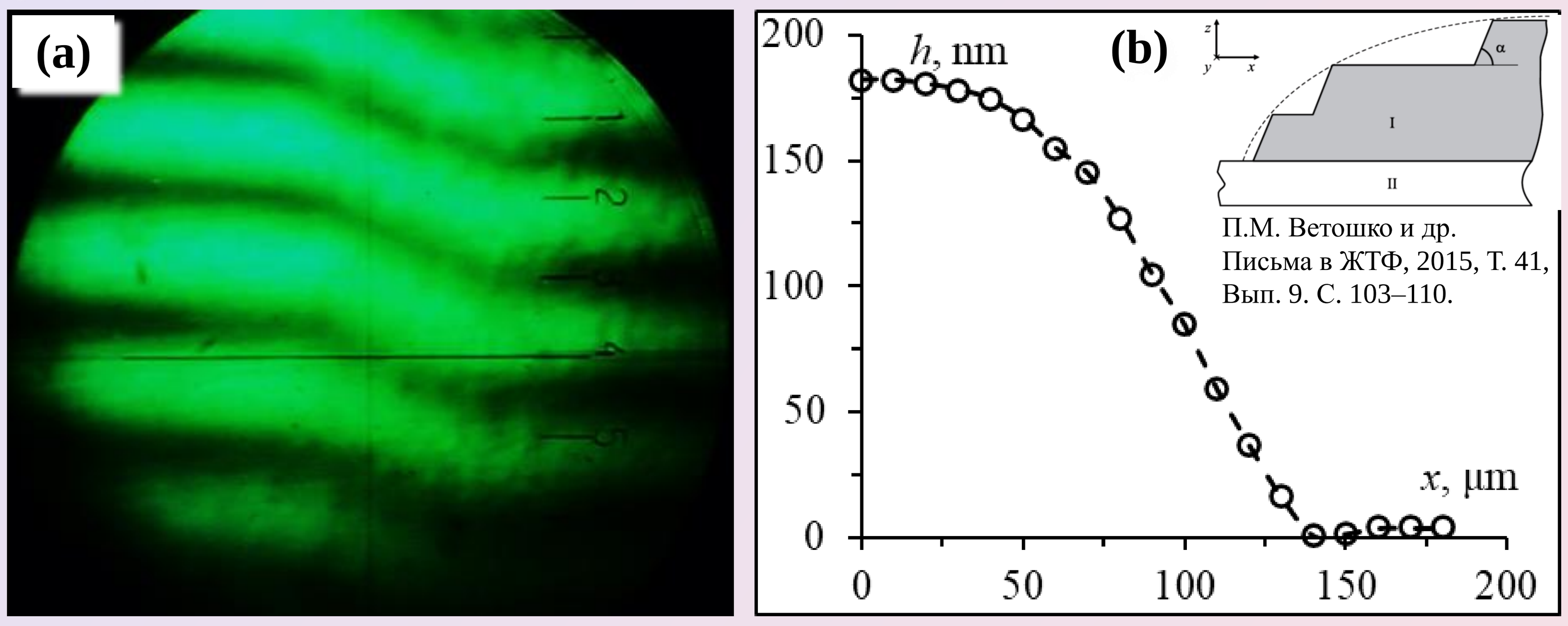

Fig. 4 – Film edge profile after ion etching (mask above the film surface): a - photo of the interference pattern at the boundary of the etching region (monochromatic radiation λ = 532 nm); b - the form of the profile of the film edge.

The height of profile in the investigation point h(x) was determined as the interference pattern shift using equation:

$$h(x) = \frac{A(x)}{2B}\lambda$$

where $A(x)$ – the magnitude of interference pattern shift in the investigation point x, B – the distance between two adjacent interference maxima or minima (interference period), λ – light wavelength.

CONCLUSIONS

So, it was experimentally showed the possibility of creating a specified smoothed edge 3D-profile in rare-earth iron-garnets films using ionic etching through a mask in one "masking-etching" technology cycle. The width d of the region of a smooth 3D-profile on the film edge can be changed by creating the regulated gap between mask and film, in this case the specified smoothed 3D-profile forming due to different etching speed as the results of geometric half-shadow effect.

It is shown that when the mask 500 μm thick locate on film surface the width of etching smoothed profile is about 10 μm with the etching depth of 160 nm. When the mask locate above the film surface on height of 300 μm the width of etching smoothed profile is about 140 μm with the etching depth of 180 nm.

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