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SPECIFIC CHARACTER OF THE ^{119}Sn THIN FILMS GROWTH ON AMORPHOUS Si BY THE CBPLD METHOD

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The research of the ^{119}Sn thin films growth on amorphous Si that is important for the multilayer periodical spin-tunnel nanostructures creation have been investigated in this paper. The ^{119}Sn mono-isotopic thin films on the silicon substrates (100) had been received by crossed-beam pulsed laser deposition method (CBPLD). Similarly the [Fe/Si/Sn/Si] multilayered periodical structures have been deposited. The received samples were investigated by atomic-force microscopy, electronic microscopy and X-ray reflectometry methods. It has been established that at ^{119}Sn film thickness up to 3 nm it is possible to received atomic-smooth surfaces with 0.5 nm roughness.

1. INTRODUCTION

Using an electron spin properties in data transmission devices and storage devices is rather actual for one of the important directions of the materials nanotechnology – spintronics [1-3]. From the fundamental physics point of view main problems here are electron polarization mechanisms, polarized electrons injection from ferromagnetic in semiconductors through interface border, electron mean free path with conservation of spin polarization (polarization dispersion), relaxation time of domains magnetization. One of precision research methods of such processes is Mossbauer spectroscopy which allows registering spatial distribution of spin polarization via a superfine interaction by the introduction of the probe isotopes (^{57}Fe, ^{119}Sn, ^{151}Eu, etc.) as an interlayer or directly in a semiconductor layer [4]. As control samples the [Fe/Si/Sn/Si] multilayer films of type ferromagnetic metal – the semiconductor with ^{57}Fe and ^{119}Sn Mossbauer isotopes are used. It is possible to measure an ultrathin field and to define degree of electron polarization and its penetration depth placing Mossbauer atoms-probes (for example diamagnetic ^{119}Sn) on distance from interface border.

For the qualitative multilayer structures production (with distinguished and smooth interface border) research of the specific character of the ^{119}Sn thin films growth on amorphous Si has been done. The crossed-beam pulsed laser deposition method (CBPLD) in the high vacuum conditions was used for the thin films deposition [5-8].

2. EXPERIMENTAL SETUP

Experimental setup scheme is presented on fig. 1. Deposition was performed in the vacuum chamber 9 at 10^{-6} Torr residual pressure received by turbo-molecular pump 11, the ^{119}Sn targets 4 were ablated by λ=1.06 µm laser radiation 1 at $5\cdot10^8$ W/cm^2 power density on the targets. Pulse repetition frequency was equal 10 Hz.

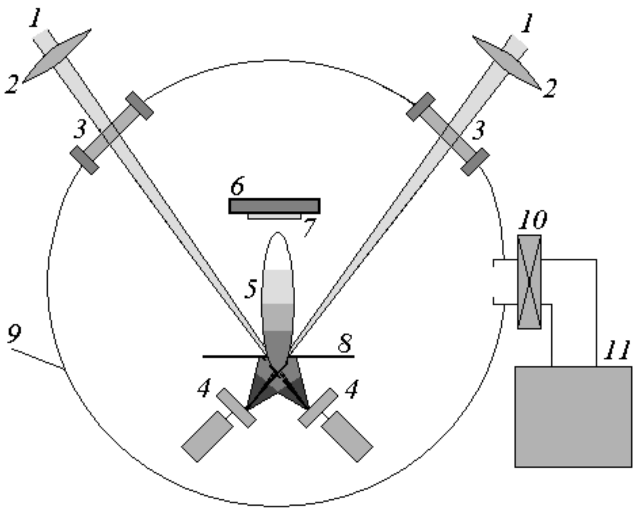

Fig. 1.1. YAG:Nd^{3+} laser radiation, 2 – focusing lenses, 3 – window of the vacuum chamber, 4 - targets, 5 – plasma plume, 6 – substrate heater, 7 – substrate, 8 - diaphragm, 9 - vacuum chamber, 10 - vacuum seal, 11 – turbo-molecular pump.

3. RESULTS AND DISCUSSION

The (100) silicon for microelectronics was used as substrates. The roughness of the substrates surface was 1 nm. Preliminary on the silicon substrate (from which the layer of natural oxide did not remove) the 40 nm amorphous silicon film was deposited. After the amorphous silicon deposition the surface roughness made 0.5 nm [9]. Surface quality was defined by the atomic-force microscope (AFM). Various thickness ^{119}Sn films were deposited on received amorphous Si surface without of unvacuumization procedure.

It has been established that at ^{119}Sn film thickness up to 3 nm were received atomic-smooth surfaces with 0.3-0.5 nm roughness (fig. 2).

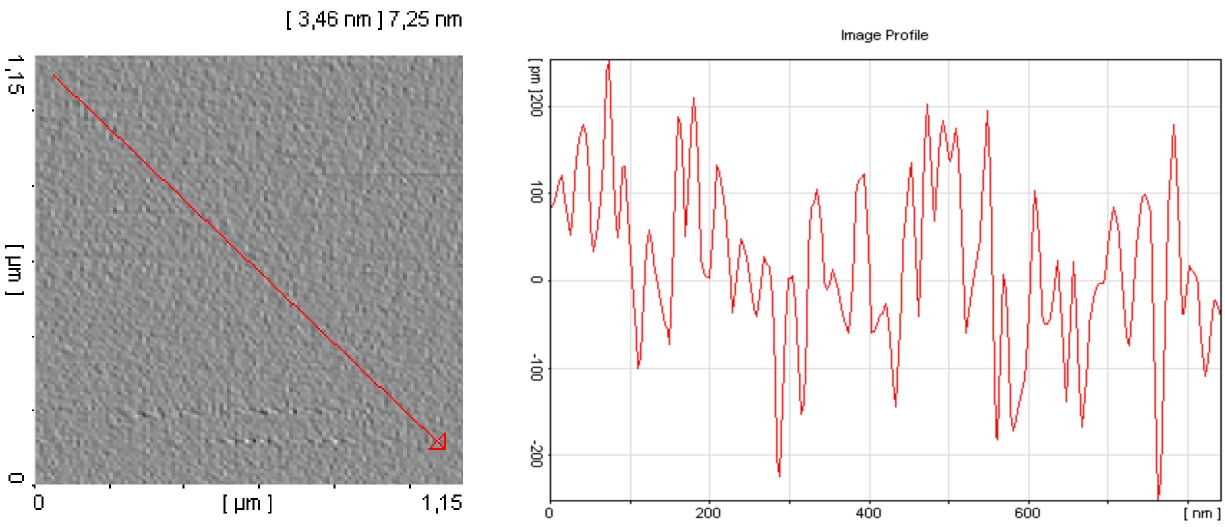

Fig. 2. AFM image and surface profile of the 3 nm thickness ^{119}Sn film.

At the thickness increase of the ^{119}Sn deposited films to 6 nm qualitative change of the surface morphology was observed. In fig. 3 it is visible that on the film surface start to be formed small local mountainous formations by separate groups with the lateral sizes about 50 nm and height to 20 nm. Thus the flat surface roughness of the film remained unchanged. At thickness increase of the deposited films to 9 nm groups started to unite and their height increased to 50 nm.

It is possible to connect the appearance of such changes with films flaking but film surface observation with the course of time hasn't revealed morphology changes though in the films flaking case such changes should increase.

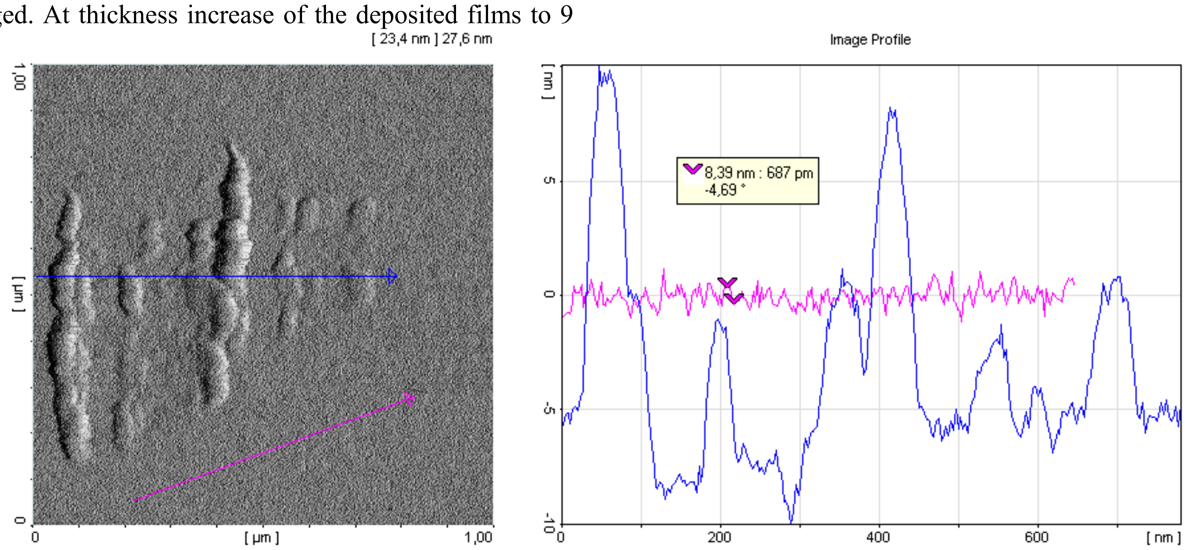

Fig. 3. AFM image and surface profile of the 6 nm thickness ^{119}Sn film.

In the 20 nm thickness films surface quantitative and qualitative changes increase even more. In fig. 4 it is visible that quantity of the mountainous formations increase and the height of some from them reaches 80 nm at 20 nm film thickness on flat areas.

At the films thickness increase to 40 nm all surface got close-packed granules character. In fig. 5 it is visible that granules height makes from 20 to 30 nm and lateral sizes makes 80-90 nm.

At the films thickness increase to 100 nm the granules size increases and on the average makes 100 nm. Fig. 6 shows scanning electronic microscope image of such film surface. On fig. 6 insert demonstrates high resolution SEM image of the film area etched to the substrate on which separate granules are clearly visible.

Similar research of the film surface morphology change with the thickness increase has been conducted at the amorphous silicon thin films deposition. Research hasn't revealed specific character of the films growth with increase in the film thickness. The surface roughness of the received amorphous silicon films of on the average improved to 0.5 nm at the 1 nm initial roughness of the single-crystalline silicon (100) substrate surface. In fig. 7 demonstrated AFM research results of 20 nm thickness amorphous silicon film. Research of the Fe thin films surface morphology change with the thickness increase also hasn't demonstrated specific character of the films growth with increase in the film thickness.

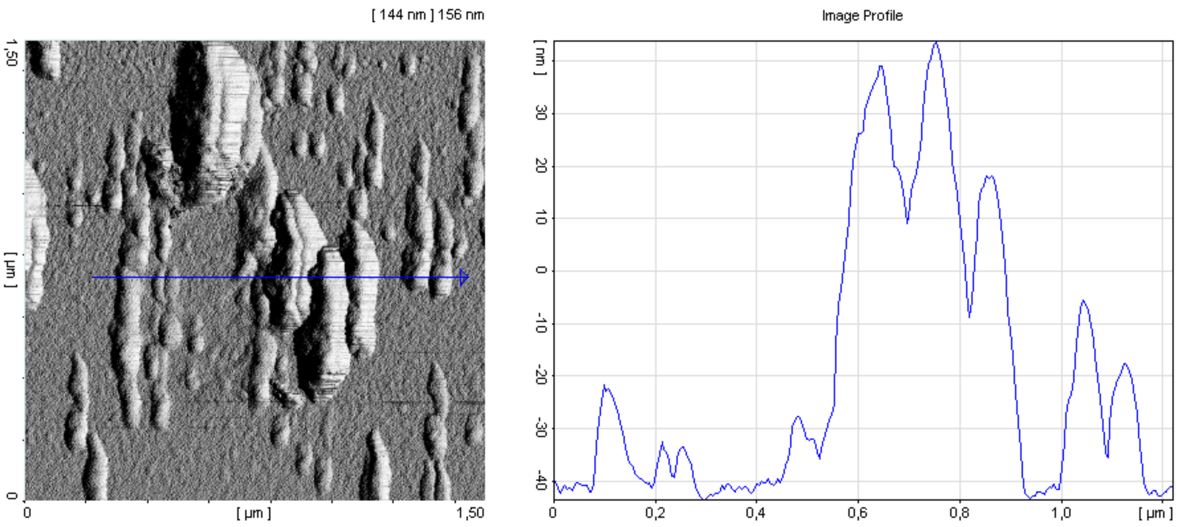

Fig. 4. AFM image and surface profile of the 20 nm thickness ^{119}Sn film.

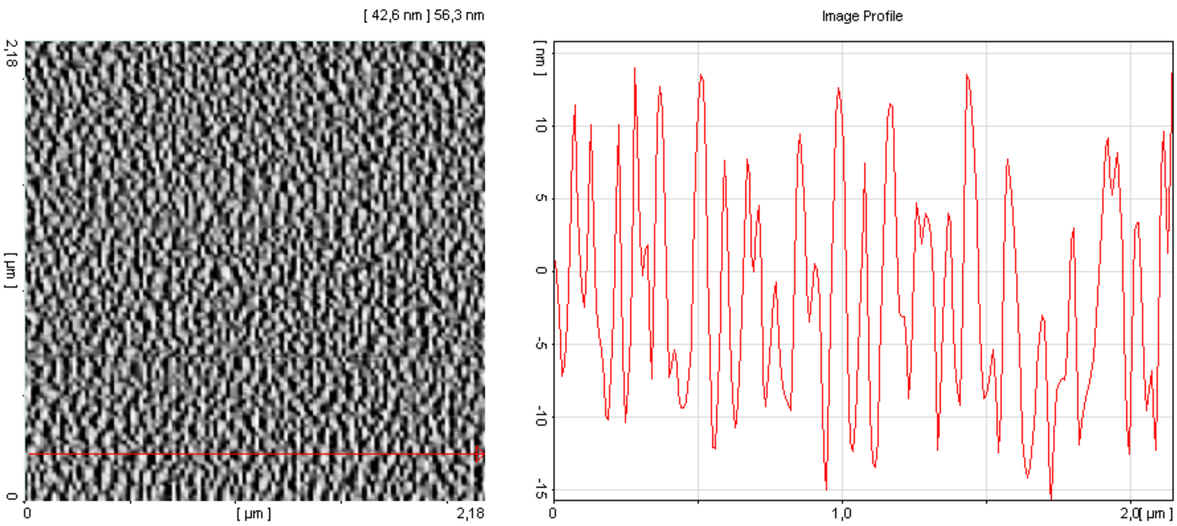

Fig. 5. AFM image and surface profile of the 40 nm thickness ^{119}Sn film.

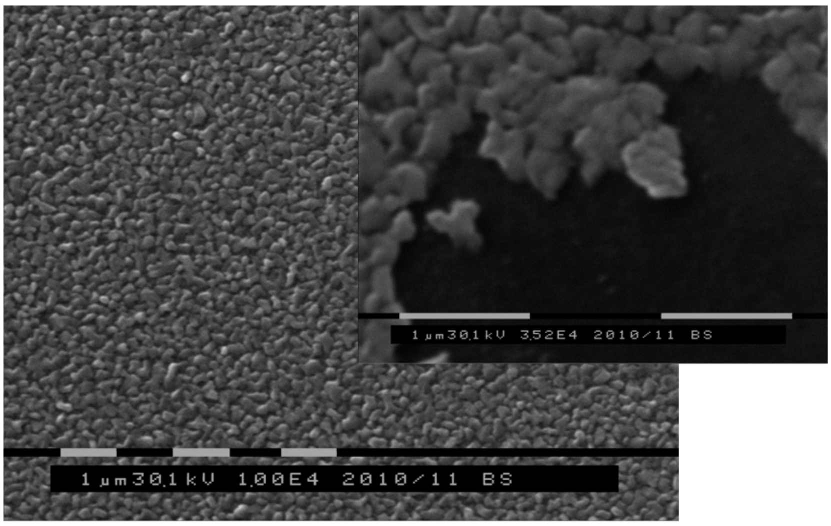

Fig. 6. SEM image of the 100 nm thickness ^{119}Sn film. On insert demonstrates the film area etched to the substrate on which separate granules are clearly visible.

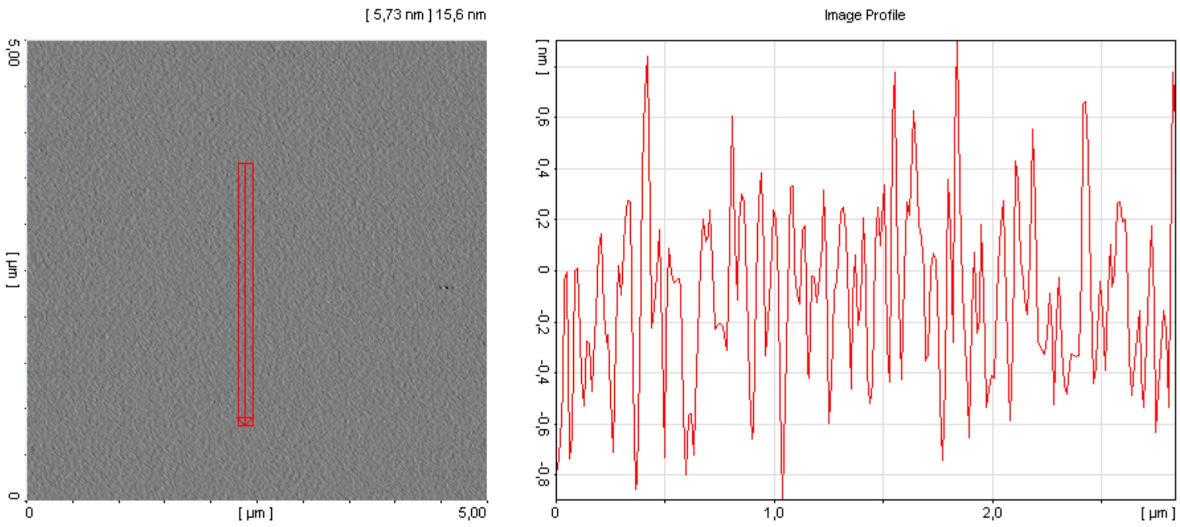

Fig. 7. AFM image and surface profile of the 20 nm thickness amorphous silicon film.

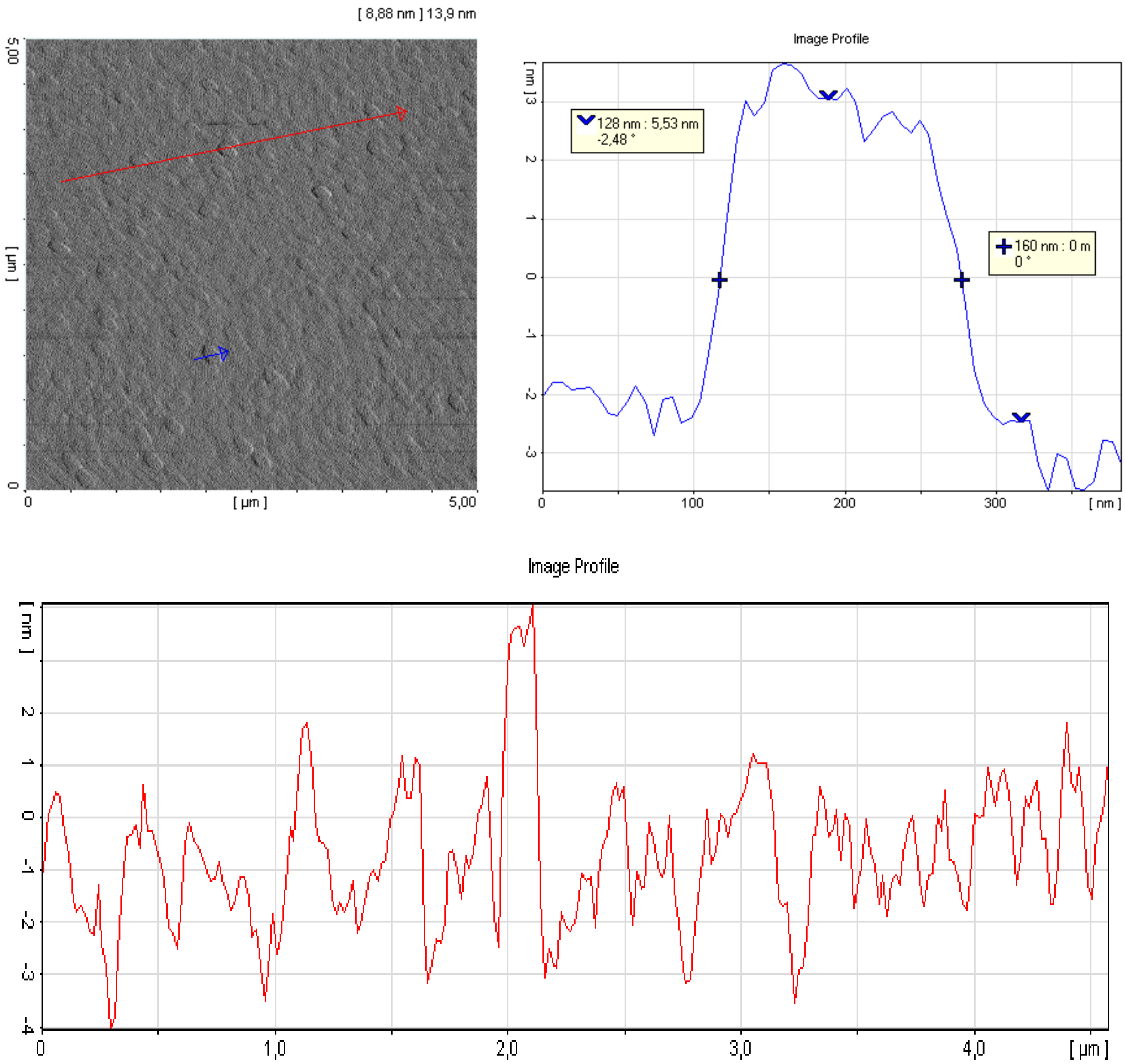

Fig. 8. AFM image and surface profile of the [Fe/Si/Sn/Si] multilayer periodical structure (Fe-10 nm, Si-5 nm, Sn-5 nm, Si-5 nm (3 periods)).

The [Fe/Si/Sn/Si] multilayer periodical structures with various layers thickness have been deposited subject to results of the specific character of the Fe, Si and ^{119}Sn films growth research

Fig. 8 shows the structure with Fe-10 nm, Si-5 nm, Sn-5 nm, Si-5 nm (3 periods) layers thickness. It is visible that the surface is covered by areas with lateral sizes about 5 nm and width to 160 nm. As Si and Fe don't show surface morphology changes at the deposition observation of such structures on the surface can be connected only with the specific character of the ^{119}Sn thin films growth.

At the multilayered structure deposition with Fe - 9 nm, Si - 3 nm, Sn - 3 nm, Si - 3 nm (6 periods) layers thickness the surface was smooth without presence of any formations (fig. 9), the average roughness the surface according to AFM data made 0.5 nm. It has been established that the interface layers roughness also made from 0.2 to 0.5 nm at research of the given sample by the X-ray reflectometry method.

According to the X-ray reflectometry data at the entering into multilayer structure layers thickness decrease to Fe – 3 nm, Si – 2 nm, Sn – 1 nm, Si – 2 nm (6 periods) the interface between Fe and Si appears indistinct that is possibly caused by the Fe and Si interaction with formation of iron silicide (fig. 10). It is confirmed by agreement theoretical reflectometrical curve shape with experimental curve shape at replacement pure iron on the $FeSi_3$ silicide in calculations.

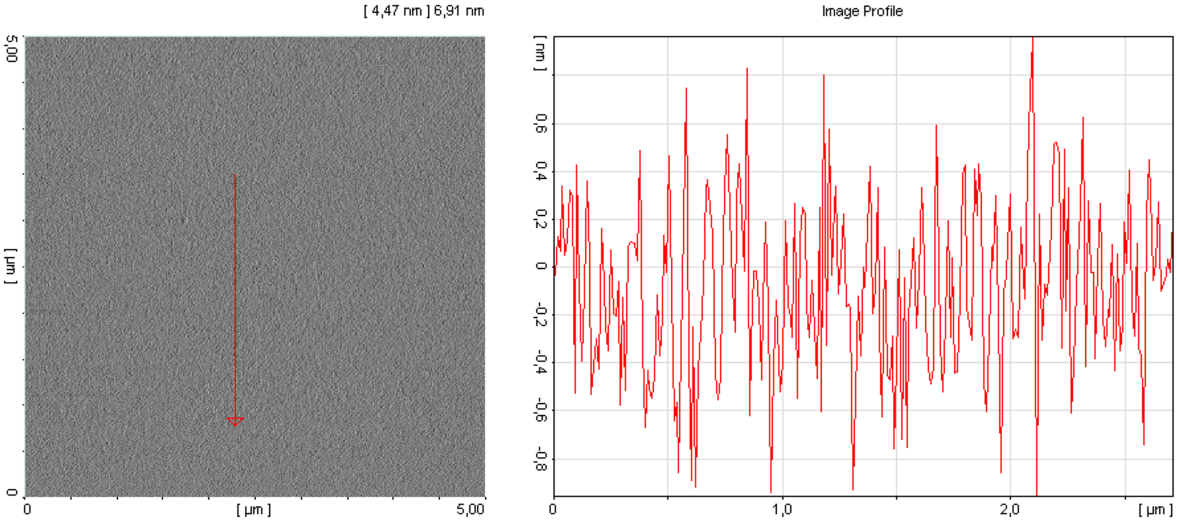

Fig. 9. AFM image and surface profile of the [Fe/Si/Sn/Si] multilayer periodical structure (Fe - 9 nm, Si - 3 nm, Sn - 3 nm, Si - 3 nm (6 periods)).

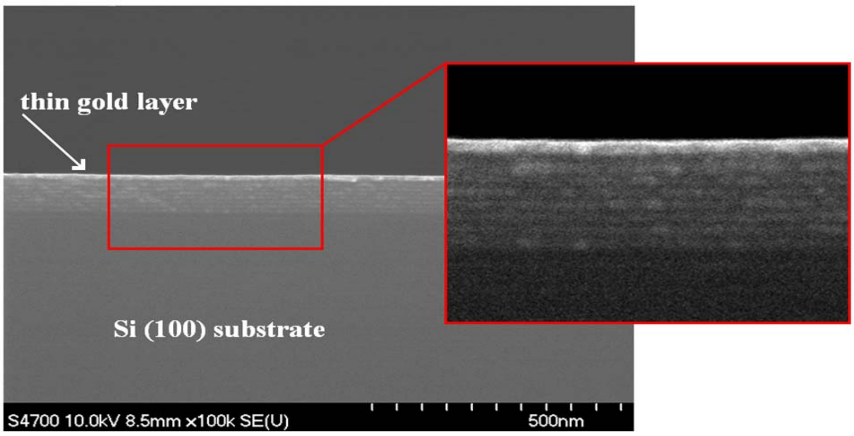

Fig. 10. SEM cross-section image of the [Fe/Si/Sn/Si] multilayer periodical structure (Fe – 3 nm, Si – 2 nm, Sn – 1 nm, Si – 2 nm (6 periods)).

The received samples of spin-tunnel nanostructures with various layers thickness will be used for the further studying by the magnetometry and Mossbauer spectroscopy methods with attraction of the electric, x-ray and other measurements results in the wide temperature and magnetic field ranges. By these results the specific nanodimensional systems properties information such as degree of electron polarization and its penetration depth through interface border, size and energy of anisotropy nanoparticles distributions, relaxation time of magnetization will be received.

4. CONCLUSIONS

The research of the specific character of the ^{119}Sn thin films growth on amorphous Si by the CBPLD method has been done for the [Fe/Si/Sn/Si] multilayer periodical spin-tunnel nanostructures of type ferromagnetic metal – the semiconductor with the ^{119}Sn Mossbauer isotope production.

It is established that at ^{119}Sn film thickness up to 3 nm were received atomic-smooth surfaces with 0.3-0.5 nm roughness. At the thickness increase of the ^{119}Sn deposited films to 6 nm qualitative change of the surface morphology not connected with films flaking was observed. On the film surface were formed small local mountainous formations by separate groups with the lateral sizes about 50 nm and height to 20 nm. At the films thickness increase to 100 nm all surface got close-packed granules character with 100 nm on the average granules size.

The [Fe/Si/Sn/Si] multilayered periodical structures with various layers thickness are demonstrated. It is established that at the ^{119}Sn layers thickness from 1 to 5 nm it is possible to receive qualitative multilayered structures (with distinguished and smooth interface borders) suitable for Mossbauer spectroscopy as control samples.

5. ACKNOWLEDGMENTS

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