Nanostructuring of pollycrystalline FeSi alloy by means of ion beam

B. Šetina Batič[1], M. Jenko[1]

1. Institute of Metals and Technology, Lepi pot 11, 1000 Ljubljana, Slovenia

barbara.setina@imt.si
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Polycrystalline Fe-2%Si alloy was chosen as a model system for studying sputter induced topography modulations due to its properties: each grain, ranging few µm in size and of different crystalline orientation, behaves as a single-crystal surface that sputters independently of the surrounding grains.

Thus, it is possible to experimentally include a large amount of grains of different crystallographic orientations in the same experimental run. Samples of FeSi alloy (composition given in Table I) with added Se as surface active element were polished to achieve a smooth starting surface and subjected to Ar^+ ion beam irradiation of different energy, angle and ion dose to obtain a complete set of experimental data on ion induced morphology changes.

The samples were characterized using a multitechnique approach: Field Emission Scanning Electron Microscope (FE-SEM, Jeol JSM 6500-F) was used for the determination of different structures that formed in individual grains and to visualize a larger area of the sample, while Atomic Force Microscope (AFM, Veeco) gave detailed information on corrugation, individual ripple wavelengths, pit depths and other morphological details.

Results show that the surface exhibits grain-orientation dependent patterns, ranging from well-defined ripple structures to terraces, pits, or pyramidal structures. The characteristic length of these structures is in the order of a few hundred nanometers.

Figure 1 shows typical morphologies obtained at 6 keV ion beam energy and off-normal sputtering angle of 60°, where it can be clearly seen that different grains exhibit different patterns. The grain boundaries act as strong boundaries also for the pattern formation and each grain behaves as an isolated unit. Additional electron backscattered diffraction (EBSD) experiments will be performed to correlate the orientation of the crystallite with the corresponding pattern.

Atomic force microscopy gives an additional insight in pattern formation. Figure 2 shows morphological details in a single grain as seen by SEM and AFM. Sputter-induced roughening was observed on some grains, along with smoothing on the others. Average RMS roughness values vary between 1.5 for the smooth surfaces and 10 nm for the rough surfaces.

Regular ripple like patterns, which are characteristic for amorphous materials, were not observed. Instead, we were able to see facet-like formations with steep and smooth edges, as is clear from AFM cross sections in Figure 3.

In conclusion, we have observed Fe-Si alloy surface modifications under the combined action of surface active element doping and ion beam nanostructuring. The results show pattern evolution of each grain is governed by the crystal orientation of it. Smoothing as well as roughening of the surface was observed. Instead of ripples, facet-like morphologies with steep and smooth ridges formed.

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Fe	Si	Al	C	P	Mn	S	Se
balance	1,66	0,83	0,035	0,0029	0,199	0,0028	0,05

Table 1: Chemical composition of the FeSi alloy (weight %)

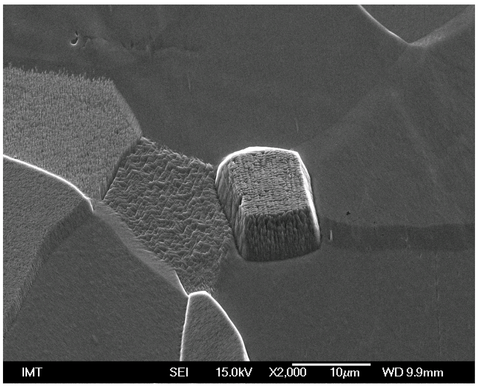

Figure 1: Typical morphologies obtained at 6 keV ion beam energy and off-normal incidence angle of 60°.

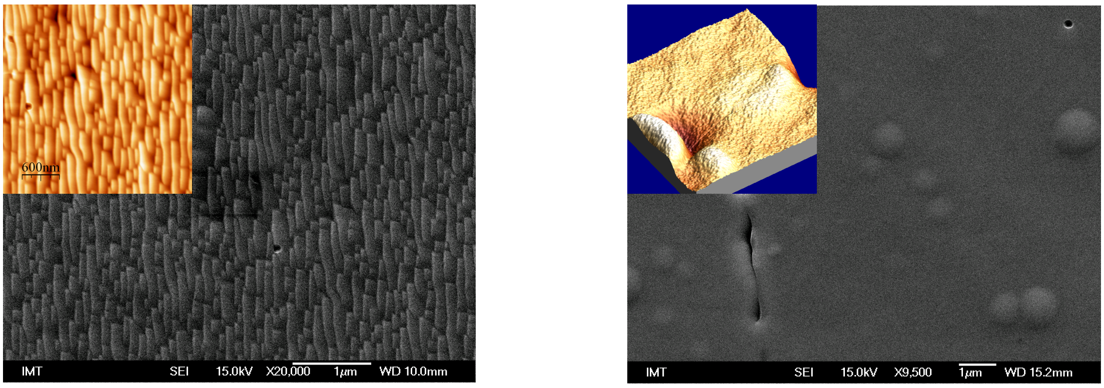

Figure 2: Morphological details within one grain as observed by SEM and AFM. Left image: facets (average RMS roughness 8 nm); right image: smoothening of surface has been observed (average RMS roughness: 2 nm).

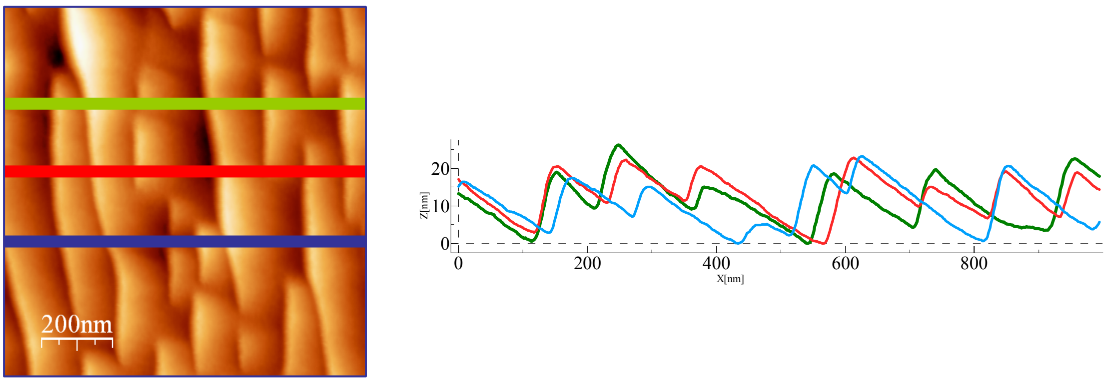

Figure 3: Facet-like morphological features. Left: AFM image with marked lines; right: AFM profiles along marked lines.

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