Probing the nano-scale Schottky barrier of metal/ semiconductor interfaces of Au (or Mo)/Bi_2Se_3 by Kelvin probe atomic force microscopy

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The effectivity of the thermoelectric materials could be increased by the presence of the metallic nano-inclusion used for electron energy filtering. This type of the nano-composite (metallic 1D/2D nano-particles on the surface of the highly organized layered crystal) could be hardly evaluated by the macroscopic techniques for their "averaging" of the effect for nano-particles of different sizes.

Kelvin probe force microscopy, one of the electric modes of the atomic force microscopy, enables measuring of electrical surface potential of each separated nano-particle and thus we can predict the behavior of the nano-composite in the bulk form with respect to the size and the chemical composition of the inclusions.

To verify this theory, we prepared the set of the Au nano-particles (Au-NP) on the cleaved surface of the layered semiconducting Bi_2Se_3 by the magnetron sputtering. The Au-NP height was 5 – 70 nm. The surface potential of the Au-NP decreased by -40 mV in comparison with the clean Bi_2Se_3 and the magnitude of the decrease correlated with the height of the Au-NP (Fig. 1).

We observed different behavior of Au and Mo metallic films. While Au diffused to the matrix forming mechanic mixture, Mo diffused forming nano-inclusion of the $MoSe_2$ due to the strong Mo-Se chemical bond. The metallic film was exposed by the e-beam lithography for local patterning. The exposed area (6x10 μm^2) topologically expanded over original surface for dozens of nm as the result of the diffusive reaction of Se with metallic nano-particle (Fig. 2). After exposition, the surface potential of the Au layer decreased for -62 mV in comparison with the initial Au surface. However, Mo layer after the similar exposition exhibits increase of the surface potential for 110 mV due to the formation of the $MoSe_2$ nano-inclusion.

Figures

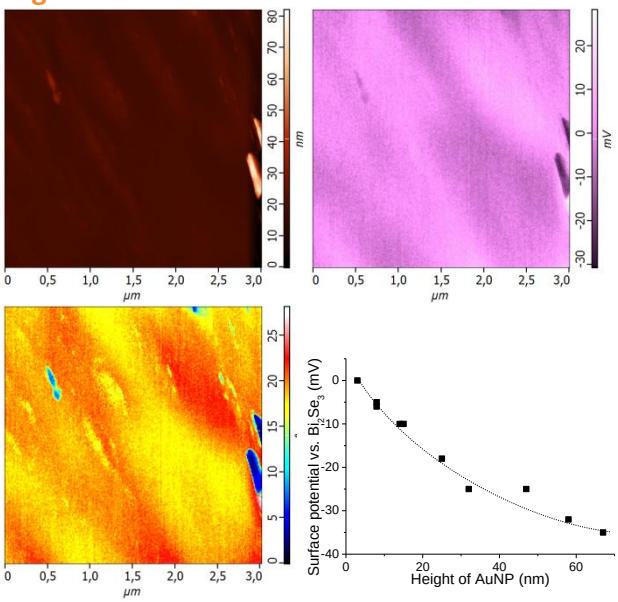

Figure 1. Nano-particles of Au on the Bi_2Se_3 surface detected on the map of the topology, surface potential (KPFM), mechanical behavior (phase-shift) and the correlation of the surface potential over Au-NP height

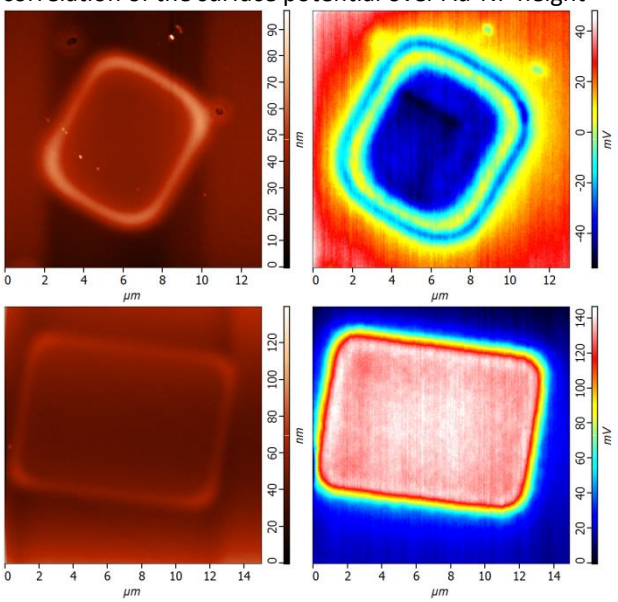

Figure 2. Topology (left) and surface potential map (right) maps of the Au(30 nm layer)/Bi_2Se_3 (upper row) and Mo (10 nm)/Bi_2Se_3 after local e-beam lithography