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Nanomechanical Surface Characterization using Scanning Tunneling Microscopy with Berkovich Diamond Tip

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Abstract – combined technique for surface indentation and scanning using Scanning Tunneling Microscopy (STM) with Berkovich conductive diamond tip is presented. Purposely synthesized boron-doped single-crystal diamonds were used as a tip material. Nanoindentation and study of the indents on the Mo, Si, Au, and Cu were conducted. Experimental nanoscratching demonstrated the technique's capability to estimate thin films' adhesion.

We present combined technique for surface indentation and scanning using Scanning Tunneling Microscopy (STM) with integrated Berkovich conductive diamond tip. Although being limited to conductive surfaces, the proposed technique has significant advantages. The first advantage is related to the high stiffness of tunneling probe as compared to the stiffness of AFM cantilever. High stiffness and perpendicularity of the tip to the surface during indentation eliminates bending beam effects on the typical AFM and ensures machining effectiveness. The second advantage and originality of the instrument is in its ability to analyze each phase of nanocomposite surface separately. Purposely synthesized boron-doped single-crystal diamonds were used as a tip material. [1]. Boron dopants distribution in the tip's working zone was studied by measuring voltage-current characteristics of tunneling between the tip and reference surface. This allows authors to choose tips with the localized conductive zone comparable in size with single atoms. Resolution of the SPM surface scanning is 1 nm that considerably exceeds achievable by diamond tip-equipped AFM.

The results of nanoindentation and study of the indents on the Mo surface (Fig. 1), Si, Au, and Cu (Fig. 2) are shown. Silicon surface is characterized by the distinctive steps around indent that points out to the fracture of the oxide film during indentation. Quantitive estimation of the surface geometry after indentation has been performed. It was found that the volume of the material extruded from indent (pop-in) exceeds the volume of the indent. Experimental nanoscratching of the gold films deposited on the silicon substrate was performed. High-resolution scanning the resulting surface gives the estimation of the film-substrate adhesion.

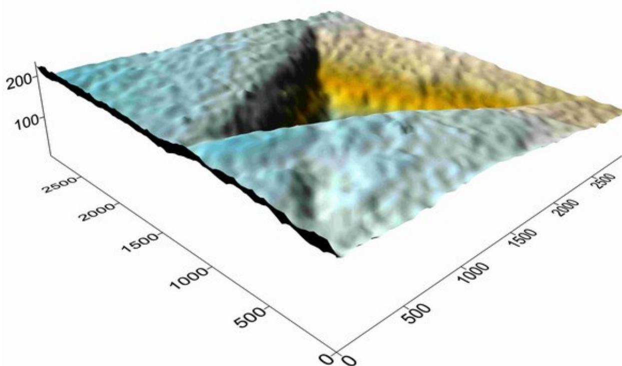

Fig.1. 3D image of the indent on Mo surface

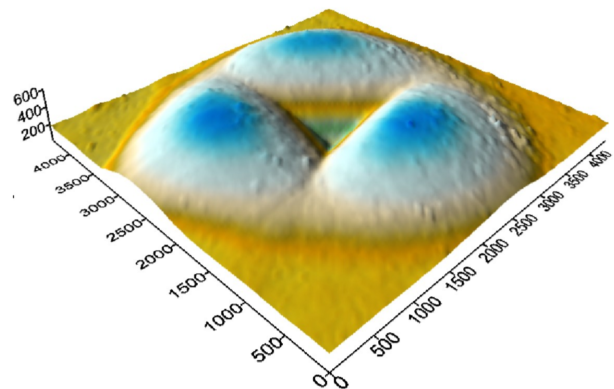

Fig.2. 3D image of the indent on Cu surface

[1] O.Lysenko, et al. Diamond & Rel. Mat. 17 (2008) 1316-1319.