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Mechanical Behavior of the Patterned Copper Lines

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The effect of geometrical confinement on mechanical response of the material was investigated. We used AFM technique (instrumented nanoindentation) for nanohardness (*H*) and Young's modulus (*E*) measurements of the polycrystalline thin films of Cu (99.999%) film deposited on silicon substrate and patterned into 3-8 μm lines. The *H* and *E* values were calculated on the base of Oliver, Pharr's procedure [1]. The *H* and *E* dependence on a distance from the line edge was studied. This approach allowed us to vary systematically only one of two line size limiting parameters, since the film thickness was constant. The load-displacement *P(h)* curves and corresponding indent images for different loads and different distances from the line edge were made with the DI Dimension 3100 and Hysitron Triboscope™ nanoindenter.

The results of the work demonstrate the edge effect in nanoindentation of Cu lines. The size effect manifests itself in increased plastic compliance and decreased "apparent" Young's modulus for the indents in the close vicinity of the line edge.
It was found that starting from some threshold distance (which is determined by the load applied) the indentation compliance decreased with decreasing distance between indent center and the line edge (see Fig.1 a, b). For indents centered approximately at the strip edge the indentation compliance was by a factor of 2-3 lower than the one far from the line edge. Correspondingly, plastic deformation increased as indents approached the strip edge and reached a very high value just at vicinity of the strip edge. Unloading parts of the *P(h)* curves of the indents in the vicinity of line edge were different from those measured for indents far from strip edge and showed significant influence of restoring forces.

AFM images of the indents revealed characteristic behavior of the material at the line edge. Necking and fracture of the thin walls separating the indent from the strip edge were observed on the nanometer scale (See Fig.2 a, b). The critical indentation parameters were determined and the results obtained are discussed in the terms of the microscopic deformation mechanisms describing the interaction of the elastic-plastic boundary beneath the indenter with the edge of the line [2-4].

References

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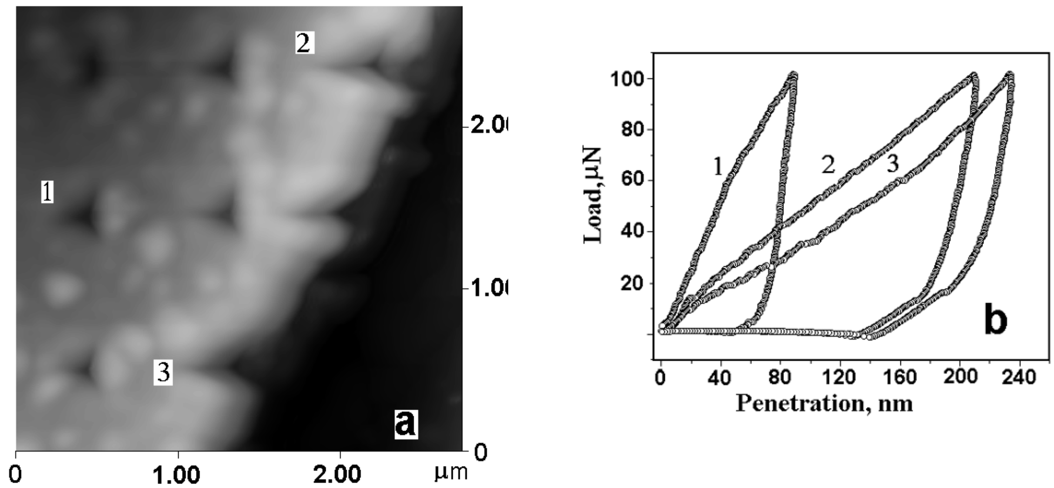

Fig.1 A SPM image of the edge region of the Cu line with the indents produced by cube corner indenter (a) and the corresponding load-displacement curves (b).

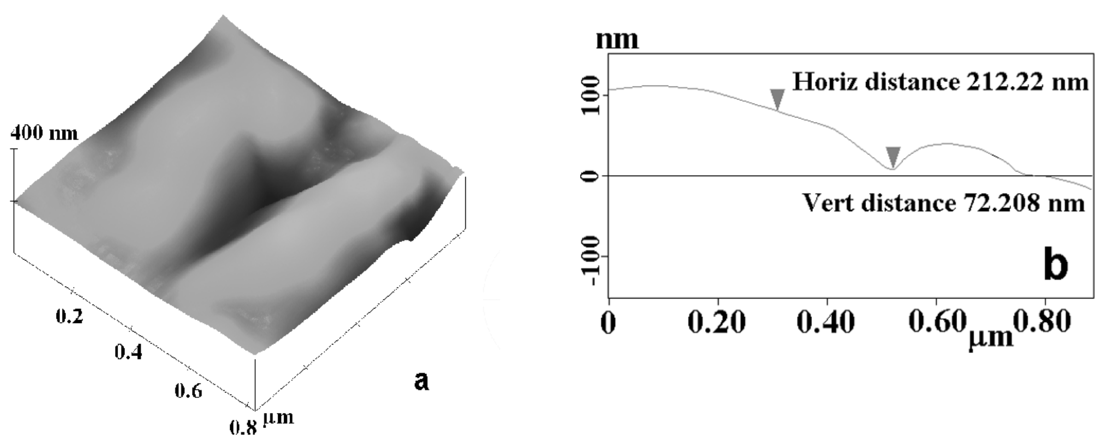

Fig.2 AFM image of the indent N2
a - 3D topography image, b - The depth and half-width of the indent N1

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