Ultrasharp tips formation based on amorphous tungsten cantilever coating.

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To meet the challenge of state-of-the art requirements in atomic force microscopy there is a need for the development of novel probes which will fulfil the customer requirements in resolution improvement and tip life time. Traditional silicon cantilevers produced by the batch-fabrication technology satisfy the most user requirements, but a tip radii leaves much to be desired. There are a number of methods which allow to decrease a tip radii of curvature, one of them is bombing of silicon tip by rare heavy gas. In this way if the tip gets side hit, then a heavy rare atom takes a few Si atoms and this complex separates away from a tip. If tip gets axial hit, that cause to the elastic collision and the rare atom reflects back. By using such the sharpening procedure it is possible to create long high aspect ratio tip with about 5nm radii of tip curvature. Other solution for making sharpen tips is using carbon nanotubes attached on the cantilever tip end. It is well investigated, that carbon nanotubes could have diameter 2-3 nm and up to a few micrometers length.

In this work the possibility to produce sharpened tips of silicon cantilever with conductive coating by using electro-migration effect is described. It is well known that in metal wires under high current densities the effect of electro-migration could be observed [1]. In our case if we operate in contact AFM mode with simultaneous current measurements and using conductive cantilevers due to small radii of the contact between tip and surface current densities could be up to 10^8 A/cm^2. With regard to such high current densities we assumed that if we will lift up a tip, the conducting coating will flow down and form a sharpened tip fig(1).

A commercial SPM Solver P47 was used for experimental setup. As initial we used stiff silicon cantilevers with coatings based on tungsten amorphous films ~ 5-10nm thickness. The ultra-thin amorphous tungsten films were deposited by cathode arc deposition method [2]. Then we realized the approach to the surface of high ordered pyrolytic graphite with force about 200nN. After the approach we applied negative voltage on tip respectively to the surface in the range of 5-10V and move tip up by reducing of a high voltage on Z plate.

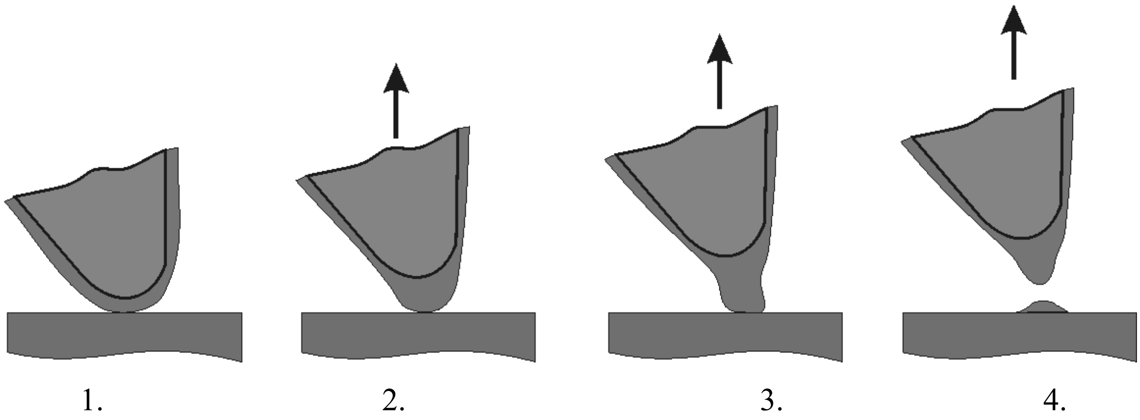

Fig.1 The schematic diagram of the tip sharpening process.

The typical surface morphology of HOPG surface obtained by traditional conductive cantilever is shown on figure 2a, and image of the same surface region after electro-migration tip treatment is shown on figure 2b.

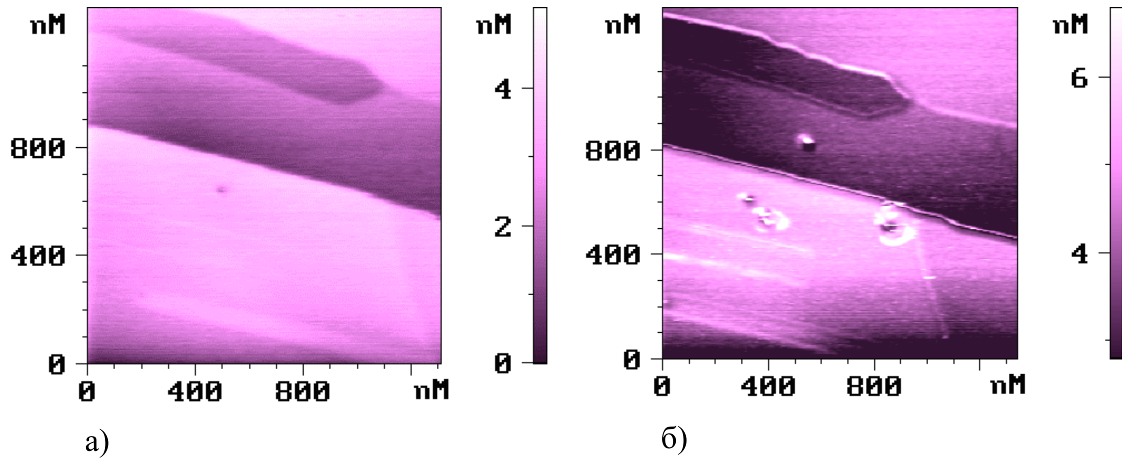

Fig. 2 AFM image of HOPG surface obtained in resonant mode by traditional conductive cantilever (a), and image of the same region after electro-migration treatment.

It is clear to see that a resolution of the image obtained after tip sharpening is better. For example at left bottom part of the image on fig. 2a we can see one thick line on smooth substrate, but on fig.2b we can resolve three separate lines.

The effect of tip sharpening under electro-migration effect we connect with using amorphous tungsten films. We assumed that under high current densities a amorphous tungsten coating not only flow down but also due significant heating its can form mono-crystalline phase and make some kind of whisker.

It has shown that electro-migration effect can be used for conductive tips sharpening and this effect is repeatable. The tips have produced by described way could be successfully used in AFM measurements.

1. Huntington H.B. During forces for thermal mass transport.// J. Phys. Chem. Solids. 29(5), 1968, p. 1641-1651
2. Boxman R. L and Goldsmith S. // Surf. Cout. Technol. 43/44, (1990), p. 1024