Experimental investigation of localization of field in blade structure based on nano-sized DLC film

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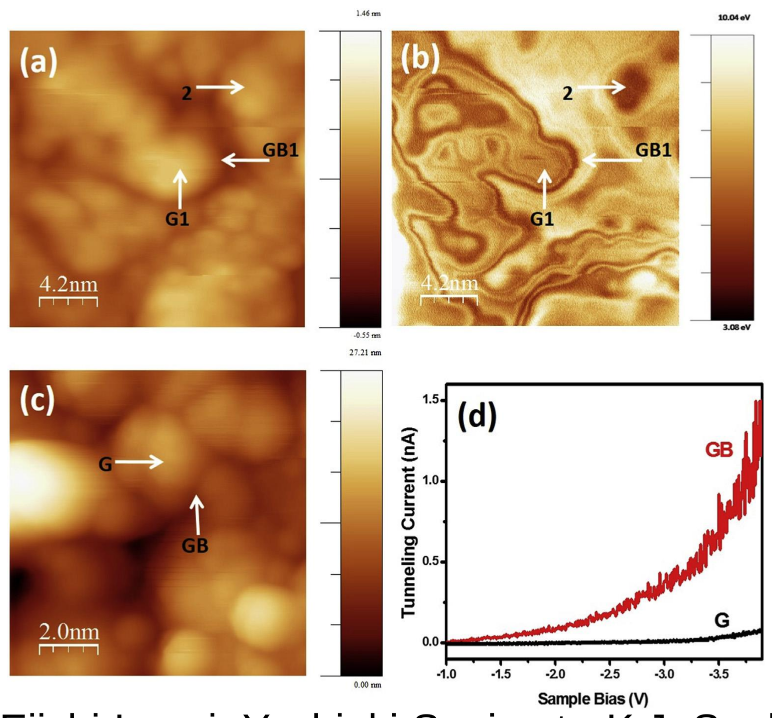
Abstract

A method is proposed for interpreting data from a field emitter surface study using a scanning AFM/STM to identify areas of electrostatic field localization and assess the degree of localization. The correlations are based on a comparative analysis of the results of numerical modeling of the effect of applied potentials on the local distribution of field strength and experimental results of AFM/STM (Agilent 5600 LS). The results of an experimental investigation of localization of field in blade structure based on nano-sized DLC film are presented.

Cold cathode materials with increased field emission (FE) properties have great promise for use in vacuum devices such as electron sources for electron microscopes, X-ray sources, high energy accelerators, cathode-ray tube monitors, microwave amplifiers and generators. Diamond is a good electronic candidate for solid-state electron emitters because of its negative electron affinity (NEA) and low effective work function surface. Ultrananocrystalline diamond (UNCD) film, which has ultra small diamond grain sizes of 2-5 nm with smooth surfaces, has recently attracted broad interest because of its excellent FE properties as compared to microcrystalline and nanocrystalline diamond films. The diamond or UNCD films have to be conductive, for the purpose of using it as a material for the fabrication of cold cathode/electron emitting devices. Up to date, few studies report the direct observation of emission sites by using STM to simultaneously map the surface topography and the emission sites on diamond surfaces.



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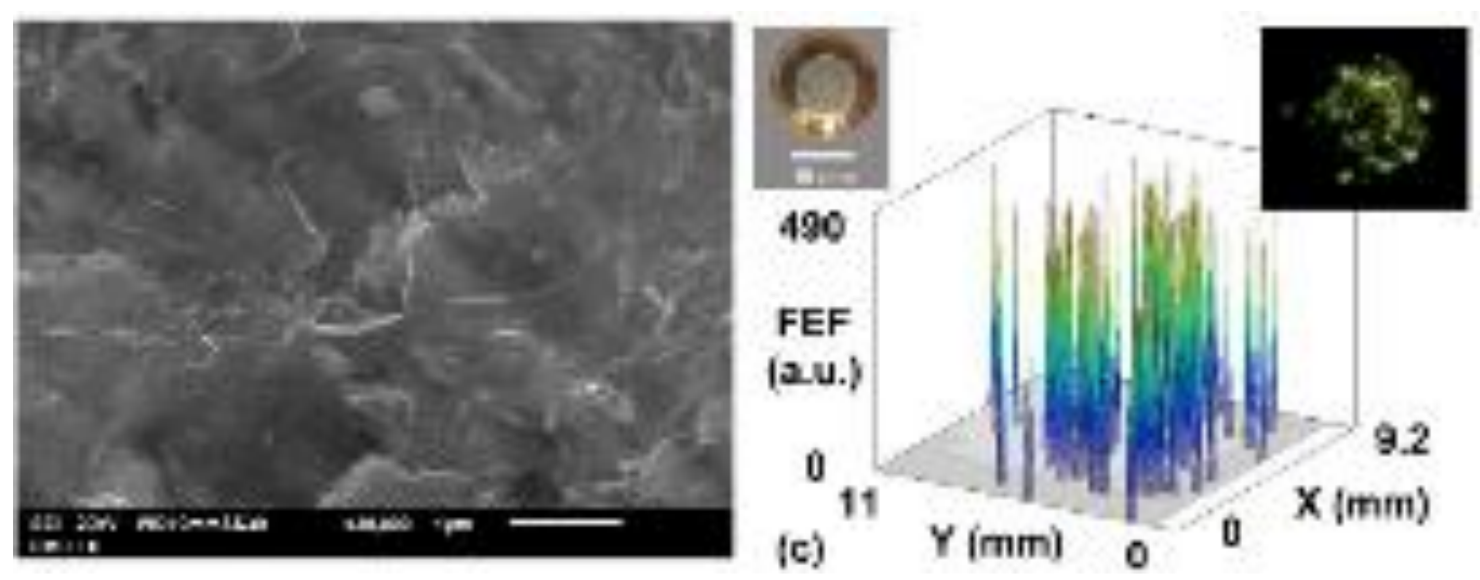

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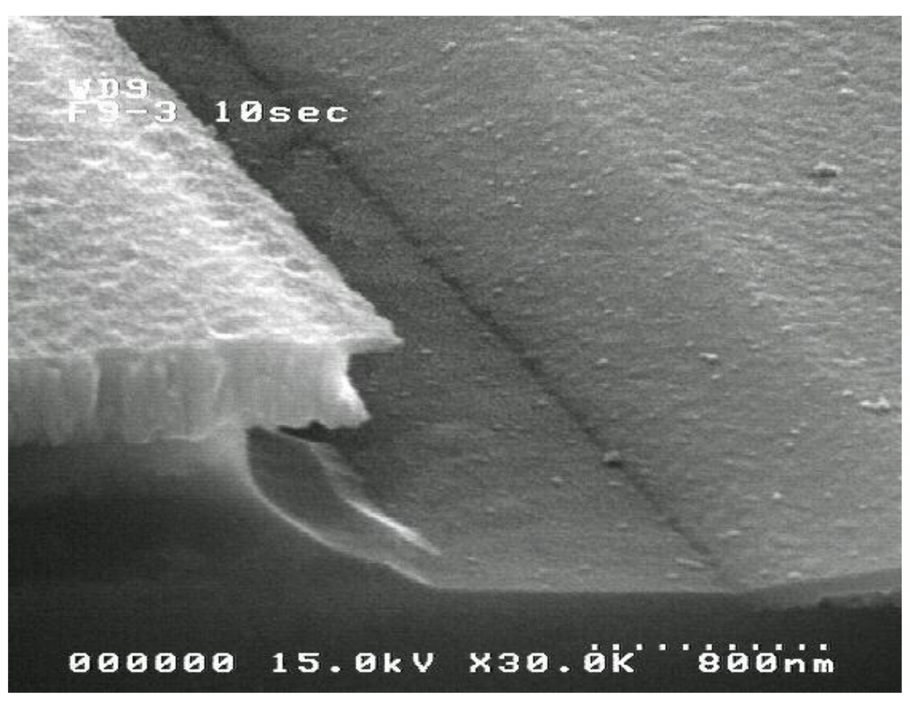

Figure 1

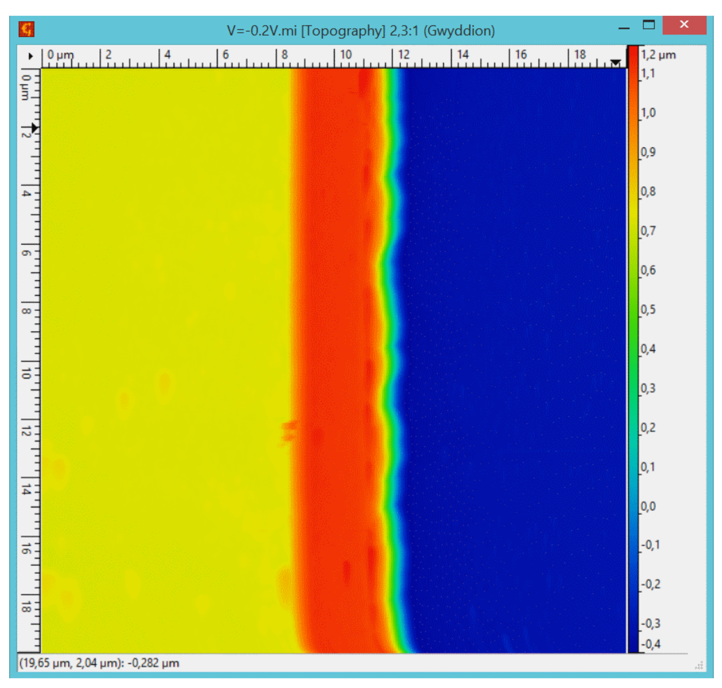

Figure 2

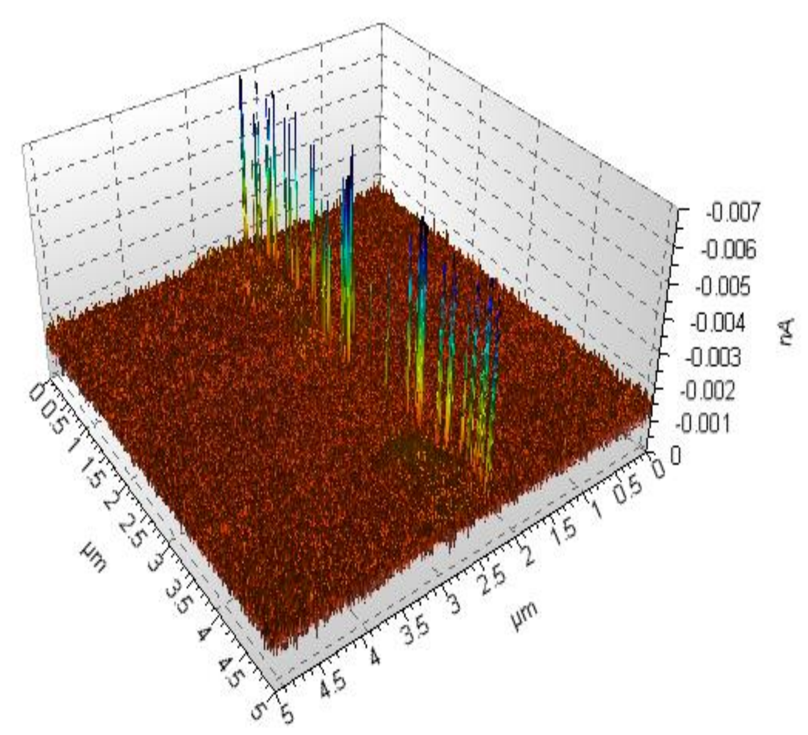

Figure 3

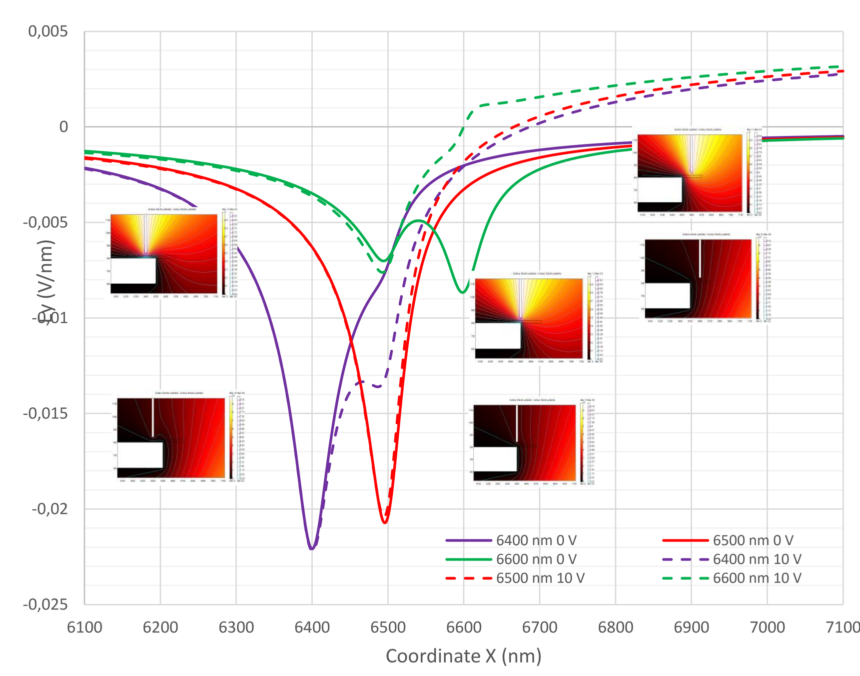

Figure 4

Figure 1 is a 3D STM image of planar blade structure in which a molybdenum emitter is coated with a thin layer (30 nm) of diamond-like carbon (DLC) film.
Figure 2. is a 2D topography of diamond-like carbon (DLC) film measured Agilent 5600 LS AFM.
Figure 3. is a 2D topogram of local current from DLC film measured using Agilent 5600LS AFM with conductive probe in CSAFM mode.
Comparison of data in Figure 2 and Figure 3 allows precise identification of the topology of the field localization zone.
The curves in Figure 4 are the distribution of the component Ey of the electrostatic field strength normal to the surface of the DLC film, calculated under the following conditions:
potential on probe 1 V; potential on the molybdenum substrate of the emitter 0 V; potential on the gate electrode 0 V (solid curves) or 10 V (dotted curves); the position of the probe Xzond = 6400 nm (lilac curves), 6500 nm (red curves), 6600 nm (green curves). For definiteness, the distance between the tip of the probe and the DLC film is assumed to be 20 nm - this is the gap for the appearance of a tunnel current.
The topograms of the distribution of the equipotentials of the electrostatic field, corresponding to the considered positions of the probe and the potentials applied to the gate electrode, are given on the insets (0 V - on the upper topograms, 10 V - on the lower ones).
The obtained numerical results are in qualitative agreement with the experimental ones.

Conclusion

A method is proposed and described, including the AFM sensing technology in combination with a conductive probe in CSAFM mode, which was used to study the field localization in a flat blade structure with a molybdenum emitter covered with a thin layer (30 nm) of DLC film. Numerical modeling of the electrostatic field strength on the surface of the DLC film showed that the use of AFM, STM technologies, as well as taking into account the found non-linear dependence of tunnel current on the field, make it possible to clarify information about the topology of the investigated surface.

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