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Electric Field Observation around a FEG-Emitter Tip Using a Conventional TEM

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The electric field distributions around field emission gun emitters (FEG-emitters) have an important role in the property of FEG. However, there are limited numbers of observation of the electric field distribution around a FEG-emitter under an applied voltage [1]. We have developed a simple and quick method [2] to observe the electric/magnetic field distribution near a specimen using a conventional transmission electron microscope (TEM). The electric field distribution around a FEG-emitter tip has been observed by using our method.

TEM observation has been performed in a Hitachi H-9000NAR operating at an accelerating voltage of 300kV. The Kamino holder [3] that has two electrodes was used our experiment. To apply a voltage externally to the specimen, a special specimen cassette was developed. The cassette consisted of two metal plates and a metal stem. One of the metal plate was fixed to the stem inserting an insulator in between (A) and the other was fix using a conducting silver paste (B) with a spacing of about 500μm between two electrodes as shown in Fig.1. A narrow tungsten needle taken from a commercial cold FEG-emitter was fixed to electrode A of the specimen cassette and then the cassette was fixed to the specimen holder. The electrode A is connected to the ground earth, and the external voltage was applied to the electrode B. A holey carbon film (Quantifoil R2/2) with holes in a diameter of 2μm arranged in a square lattice pattern with a spacing of 4μm was placed at the position of a selected are diffraction (SAD) aperture. The distortion of the shadow image of the aperture was observed as the electric field distribution around the specimen.

The positions of the shadow images of the square lattice arranged holes were compared before and after applying external voltages to the FEG-emitter as shown in Fig.2. The shift of the hole is proportional to the horizontal part of the electric field along the trajectory of the electron beam [2]. The spacing between the grounded electrode and the tip of FEG-emitter was 20μm, and the applied voltage between the electrode and the emitter was 20V in Fig. 2. An uniform shift of the shadow image of holes that is indicated by a dotted arrow was observed far enough from the emitter needle. The shift is thought to correspond to the uniform electric field formed between the electrode A and B.

The solid lines indicate the deviation of the shadow image shift form the dotted arrow, i.e. the true shift of the shadow image at each position is the summation of the dotted arrow and the thick line. There is non-uniform distortion of the electric field near the emitter needle, which corresponds to the electric field distribution around the FEG-emitter. An asymmetry of the field was observed. As shown in Fig. 2, the needle was tilted 8 degree to the line perpendicular to the edge of the electrode A, that will explain this asymmetry. The asymmetry of the field was enhanced with the increase of applied voltage to the FEG-emitter.

In summary, the electric field distribution around a FEG-emitter was observed in a conventional TEM. An asymmetric field distribution and its enhancement depending on the applied voltage which will be explained due to the tilt of the FEG-emitter were observed.

References

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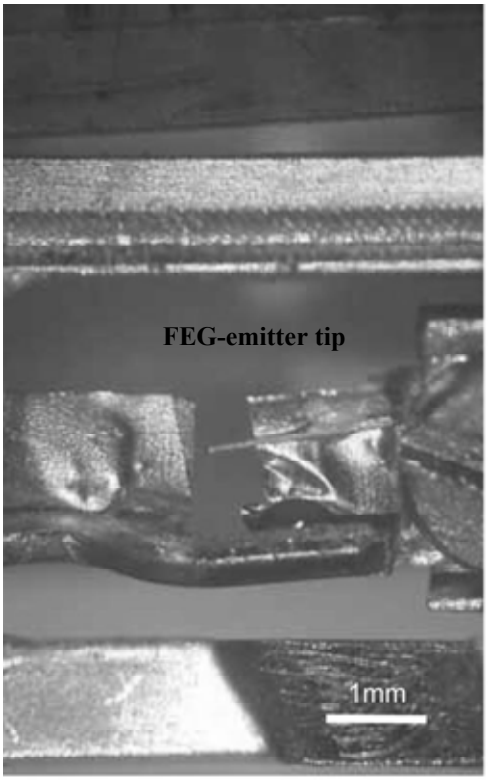

Fig.1 The developed specimen cassette and the fixed FEG-emitter tip.

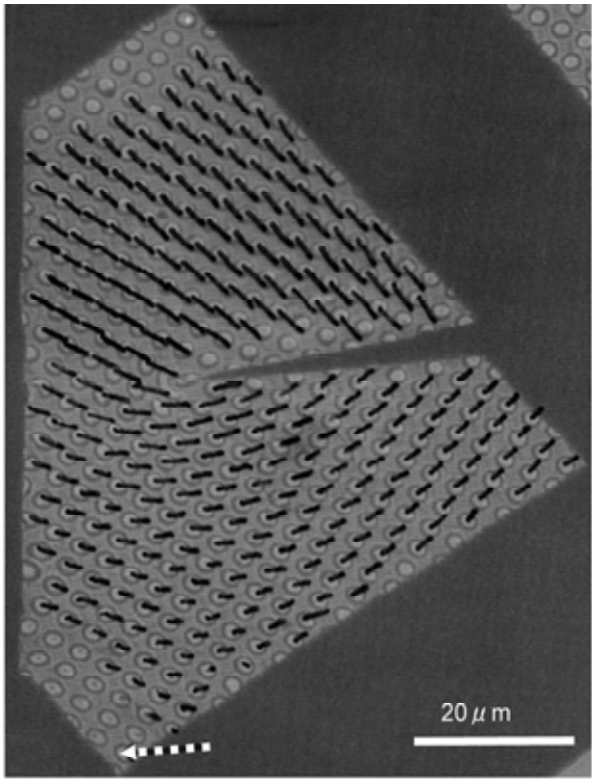

Fig.2 The shadow image distortion showing the field distribution.