LOW-ENERGY ELECTRON PROJECTION MICROSCOPY

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Résumé - *Une pointe ultra-fine, préparée par des techniques de microscopie ionique de champ est placée très près d'une feuille de carbone ajournée. La courte distance entre le film de carbone perforé et la pointe est obtenue à l'aide d'un mécanisme d'approche similaire à celui utilisé en microscopie tunnel à balayage. Avec un détecteur à une distance macroscopique de la feuille de carbone, côté opposé à l'émetteur, on observe une image en projection des trous et de leurs structures internes. Les plus petits détails ainsi détectés ont des diamètres d'environ 30 nm. Le contraste est produit par des électrons d'énergie aussi basse que 30 volts.*

Abstract - An ultrasharp tip, prepared by field ion microscopy techniques, has been placed in close proximity to a partly transparent carbon foil. The short distance between the perforated carbon film and the tip is achieved by an STM-like approach mechanism. With a detector at a macroscopic distance opposite the emitter side, a projection image of the holes and structures therein can be observed. The smallest features detected in this way have diameters of about 30 nm. The contrast is generated by electrons with energies as low as 30 eV.

1 - INTRODUCTION

The basic idea underlying the technique briefly described here is well known from daily experience with light sources. An object is placed in the path of a divergent beam that originates from a source which generates an ensemble of free particles. A magnified projection image of the object can be observed on a distant screen. If the object absorbs the particles, a shadow picture showing the boundaries of the object will be apparent. The smaller the source the better the resolution of the projection image will be, at least until a regime comparable to the wavelength of the particle is reached. In a first approximation the magnification is given by geometry only; determined by the ratio of the object to detector and source object distance.

Here we briefly describe such a concept where the source is an ultrasharp tip generating low-energy electrons by field emission. The sample is a planar, partly transparent carbon film. For a more detailed description and for related earlier work of this kind see [1] and references therein.

2 - EXPERIMENTAL SETUP AND FINDINGS

The essential parts of the instrument are illustrated in figure 1. It is basically a field ion / field electron microscope combined with an approach mechanism adopted from STM technology [1]. The tip is mounted onto a loop in order that it be heated by passing a current through the loop. It can be positioned to face a channel plate detector so that the preparation and characterization necessary to form a point source for ions and electrons can be performed. A tripart tube scanner executes the fine movement of the tip in three orthogonal directions.

The sample, a partly transparent film, is mounted onto a louse, well known from STM technology, which serves as a rougher approach between the sample and the tip. A micro-channel plate and phosphor screen assembly is placed about 6 cm from the sample to observe the magnified projection image and for field ion microscopy with the source tip. The entire system can be cooled down close to the temperature of liquid nitrogen and is operated in an ultrahigh vacuum environment.

After treating the [111] oriented tungsten tip by sputtering and annealing techniques, the partly transparent film is approached by the tip. Initially, with the sample and the source 3 mm apart,

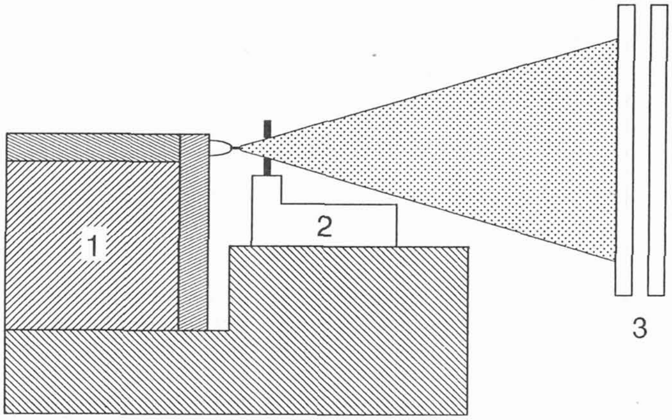

Fig. 1: Schematic side view of the low-energy electron projection microscope. (1) stainless steel cube with *x,y,z*-tube scanners for tip movement. (2) sample holder mounted onto a louse for rough movement toward and perpendicular to the tip (3) micro-channel plate screen assembly for electron or ion detection.

−300 volts are typically required at the tip to draw an electron current of 0.1 nA. The approach is then continued by stepping the foil towards the tip in discrete steps between 0.1 and 1 micron with a repetition rate of up to 50 Hz. For the fine approach, the *z*-piezo of the three tube scanners on which the tip is mounted is used. The *x*- and *y*-scanners serve to select a particular feature of interest on the foil. In Fig. 2, two images from a sequence of an approach between tip and the carbon foil are shown.

During the approach, the magnification given by the ratio between the sample-detector and tip-sample distance is increased and easily reaches values of a couple of 10000 in our preliminary studies. As the magnification increases, the emission voltage decreases down to values around −30 V with the same emission current. This, incidently, provides a source of low-energy particles that should also be of general interest for standard microscopy in the low energy regime. In the projection microscope, this 30 eV electron beam allows us to image structures that are between 30 and 80 nm wide; they are shown in Fig. 2b.

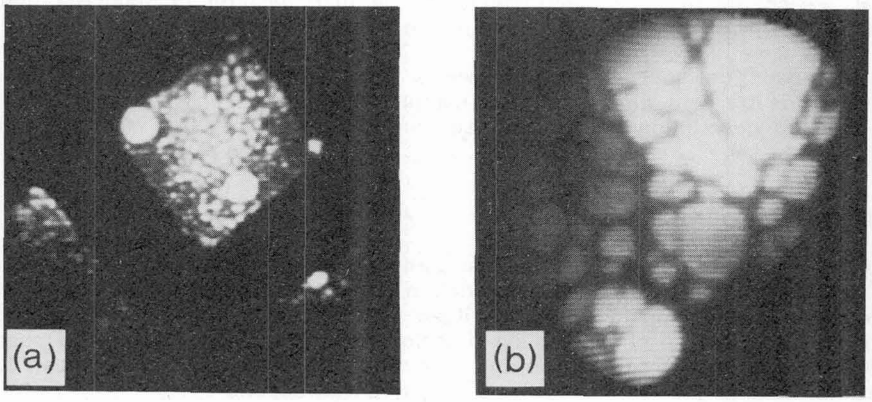

Fig. 2: Electron projection images of a perforated carbon film with low (a) and high (b) magnification. (a) One full section of the 40-micron grid supporting the carbon film is shown. With the source about 120 micron away from the sample, a magnification of $M=500$ is attained. The emission voltage is about 300 V providing a 0.1 nA current. (b) Subsequent steps decrease the emission voltage to only 30 V and the sample source separation to about one micron. This leads to a magnification of 60000, which allows fibers exhibiting widths between 30 and 80 nm to be imaged. Calibration of distances is done in two independent ways: by scaling down from the known grid size and by using the piezo calibration for lateral tip displacement. The two methods are in good agreement.

3 - OUTLOOK

With the setup described above we are also able to perform field ion microscopy through one of the holes in the carbon foil [1]. This enables us to adopt techniques to prepare single atom or trimer tips with atomic emission areas. The ultimate resolving power of the projection microscope will be determined by the size of the source at least until a regime comparable to the wavelength of the particles is reached. Using helium ions instead of electrons might not only complement the information gained by the low energy electron images but should also further improve the resolution since diffraction of the sub-angstrom wavelength ions will not be a severe limitation.

4 - CONCLUSION

By using precise mechanical manipulation, it has been possible to position a sharp tip in close proximity to a partly transparent film. Highly magnified, high-contrast and distortion-free pictures of the film holes and of filaments crossing holes have been produced in this way with low-energy electrons. In short, for objects that can be placed on a partly transparent conducting film as sample holder, the technique described here should be applicable and useful.

REFERENCES

1. Werner Stocker, Hans-Werner Fink and Roger Morin, submitted to Ultramicroscopy.