ELECTRON EMISSION FROM NIOBIUM SAMPLES FOR HIGH APPLIED ELECTRIC FIELDS

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ABSTRACT

High field emission DC currents are measured by means of tungsten tips used as local probes in a scanning electron microscope (S.E.M.). The experiments give evidence for two distinct types of electron emission : strictly localized on few emitting sites or regularly distributed on the surface. The influence of an argon etching processing on electron field emission is also presented.

INTRODUCTION

The authors report evidence for two distinct types of electron emission from niobium samples subjected to high electric fields ($E > 20$ MV.m^{-1}) :

- a localized emission at a few emitting sites,

- a weak uniform emission from the whole samples area.

Some of these samples had been processed by argon etching at low energies (a few hundreds eV). This treatment caused a decrease of the emission current of both types of electron emission.

I) OBSERVATION OF TWO DISTINCT TYPES OF ELECTRON EMISSION

1 - 1 : Experimental setup [1]

The experiments are carried out in a scanning electron microscope (S.E.M.) (Figure 1).

Two tungsten anodes, used as local probes, are mounted in the microscope chamber in order to collect the emission current from the samples surface :

- a plane rectangular one (100*300 µm) (Figure 3) for DC current measurements,

- an hemispherical tip 30 µm in diameter for localizing more precisely the emitting sites.

The samples are niobium disks (14 mm in diameter, 2 mm thick) cut in the material employed for the RF-cavities and prepared in the same way : mechanical polishing followed by the SACLAY standard chemical polishing.

The pressure in the chamber is in the order of 10^{-5} Pa (10^{-7} mbar).

1 - 2 : Measuring procedure

The hatched area in figure 2 (7*7 mm) is firstly scanned with the rectangular probe in order to localize the emitting sites. The gap is then at 50 µm, the applied field is fixed at 30 MV.m^{-1}, the corresponding measured currents are in the range of 10^{-12} to 10^{-6} A. When an emitting site is detected ($i > 10$ nA) the smaller tip is used to localize it more precisely.

At this stage of the experiment, the site can be imaged by S.E.M.. The current field characteristics can also be recorded.

Apart from the sites, a weak regularly distributed current density ($i << 1$ nA) is found. This current is plotted as a function of the applied field at each one of the X_k points on the surface (Figure. 2).

1-3 -1 : The emitting sites [2][3][4][5]

A very small number of emitting sites, per sample, is detected on the scanned area. They are essentially of two types :

- some of them have an extrinsic origin (exemple: the Ag contamination particle in figure 4a),

- the others are originating from the surface oxyde layers, as shown in figure 4c and 4d

The feature in figure 4c is an oxide particle pulled out from the surface. That in figure 4d is a scratch, parts of which are erected by the field strength. They both can induce high local field magnification (β).

1-3 -2 : The weak regularly distributed emission

Apart the above mentioned sites, a weak emission is detected on the whole electrode surface. Figure 5a shows the aspect of the specimen surface at one of the X_k points (see

figure 2) where the current field characteristics are plotted. There is no particular feature in that region. The E.D.S. spectrum exhibits only niobium and oxygen for surface composition.

2. EFFECT OF ARGON ETCHING ON FIELD EMISSION OF NIOBIUM SAMPLES

2.1 : Experimental setup and procedure

A vacuum system is used to process the sample by argon etching. The working pressure in the vessel is about 0.1 mbar (10 Pa), the argon ions energy in the order of 350 eV, the exposure time : 5 min.

The samples are studied first in the S.E.M. by the procedure I-2, then introduced into the etching system; after etching they are transfered into the S.E.M. for new investigations. The samples transfer is performed under room atmosphere.

2.2 : RESULTS

2.2 - 1 : Effect of the argon etching on the regularly distributed emission

The regularly distributed emission is consideratly lowered by the argon etching, as it can be seen on figure 5.

2.2 - 2 : Effect of argon etching on the emitting sites

For all the studied niobium samples, the field emitting sites almost disappeared after the argon etching processing.

2.3 : Suggested interpretation

Niobium neutral atoms can be ejected by argon ions hitting the surface. Some of these atoms are ionized in the vicinity of the samples and return to the surface where they build up an oxide layer covering all the surface (Figure 7) . Considering the low energy of the argon ions (350 eV), only the first atomic layers are concerned by such a mechanism. We suggest the emitting particles remain on the surface but their activity would be suppressed by the last covering layer.

CAPTION OF FIGURES

Figure 1 : S.E.M. chamber with the anode probes

Figure 2 : Scheme of the specimen surface . The hatched area is scanned for emitting sites detection. The regularly distributed emission is checked at the X_k points.

Figure 3 : The rectangular probe.

Figure 4 : Localized emitting sites (a) an emitting site of extrinsic origin (b) corresponding Fowler-Nordheim plot (c) a pulled out Nb_2O_5 emitting site (d) Nb geometrical field emitting sites

figure 5 : An aspect of the region where the weak regularly distributed emission is observed, apart from localized emitting sites. (a) local picture (b) I = f(E) typical plot of X_k points.

Figure 6 : Current field characteristic (a) before (b) after the argon etching. The current plotted is $i = \Sigma i(X_k)$

Figure 7 : Illustration of the suggested effet induced by argon etching

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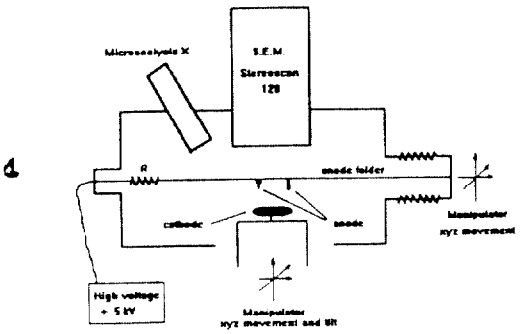

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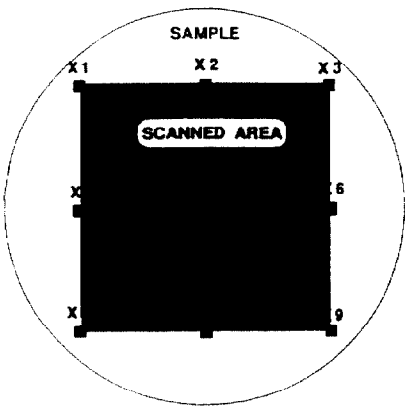

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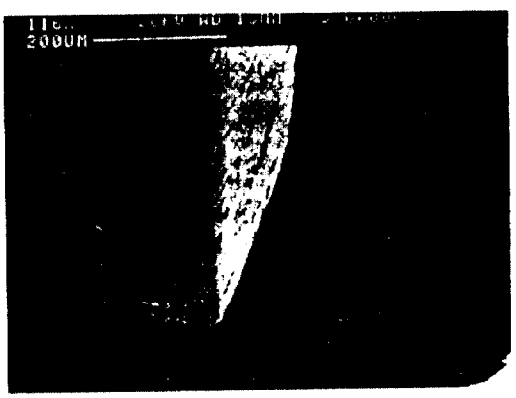

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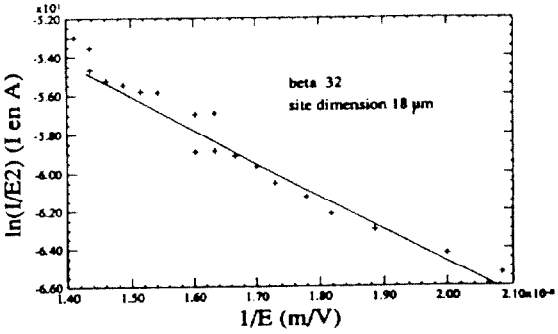
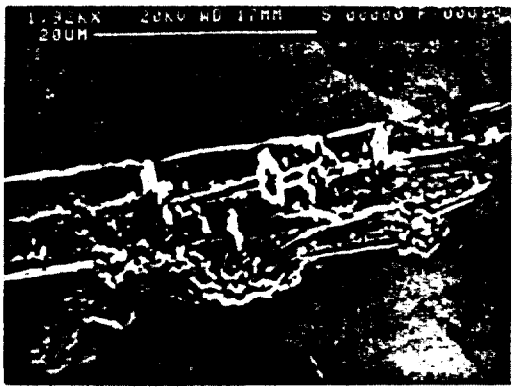
4a

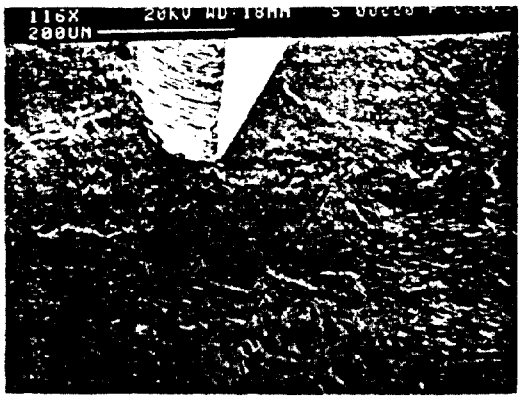
4b



4c

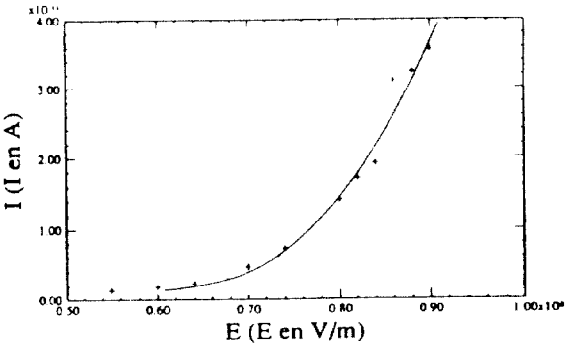
4d

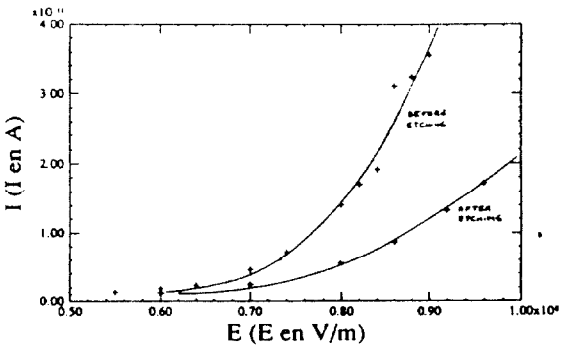




5a

5b





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