MICROSCOPIC ANALYSIS OF NIOBIUM FIELD ELECTRON EMITTERS

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ABSTRACT

An experimental set-up has been developed in a scanning electron microscope to give pictures and X-ray local analysis of the field electron emission sites detected by scanning a pointed anode. The very first results on niobium samples are reported.

INTRODUCTION

It is well established that ultimate performances of niobium superconducting RF cavities are limited by the field electron emission. Furthermore, it is also known [1, 2] that the electrical breakdown in vacuum for broad area high voltage electrodes is often generated by the electrons emitted by microscopic sites. So, we developed an experimental set-up situated in a scanning electron microscope (SEM) in order to :

a) localise at room temperature the emitting sites on niobium samples ;

b) investigate the elemental composition of the sites by means of an energy dispersive X-ray spectrometer.

EXPERIMENTAL SET-UP

Following Athwal and Latham [3] we have developed an experimental set-up in a SEM (Fig. 1) allowing the localisation and analysis of field electron emission sites on broad area electrodes. For localising the sites we successively used three tungsten probes with the following caracteristics :

a) a flat rectangular probe (300 X 100 µm) (Fig. 2) ;

b) a flat circular probe (Ø = 40 µm) (Fig. 3) ;

c) a standard electrolytically etched microtip 100 µm in diameter (Fig. 4).

These probes were mounted on an insulated electrical feedthrough and could be positioned precisely on the axis of the SEM with a XYZ manipulator. The niobium sample mounted on a goniometer was oriented normal to the probe and tilted at 55° to the SEM axis. We used the rectangular probe for scanning the sample line by line and roughly search the emitting sites. Then we used the two other probes to study precisely the sites. The working pressure in the SEM was approximately 10^{-5} Pa. In order to avoid the residual vacuum ionization and the related phenomena we set the electrode gap between 25 and 50 µm. The gap was adjusted by lightly touching-on the cathode with the probe outside the area in study and then setting the separation. The cathode roughness was less than 5 µm. The probe voltage was 5 kV thus allowing the field to raise up to 200 MV/m. The cathodes were cleaned using standard cavity techniques. In order to analyse the sites we used an energy dispersive X-ray spectrometer (LINK) without entrance window that allowed the detection of light elements (C, N, O).

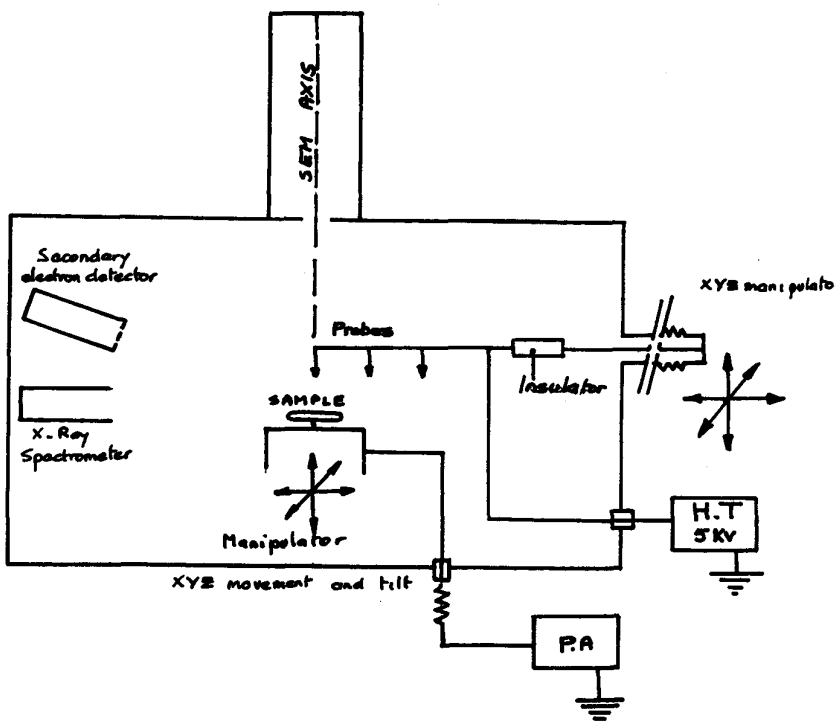

Fig. 1 - Experimental set up.

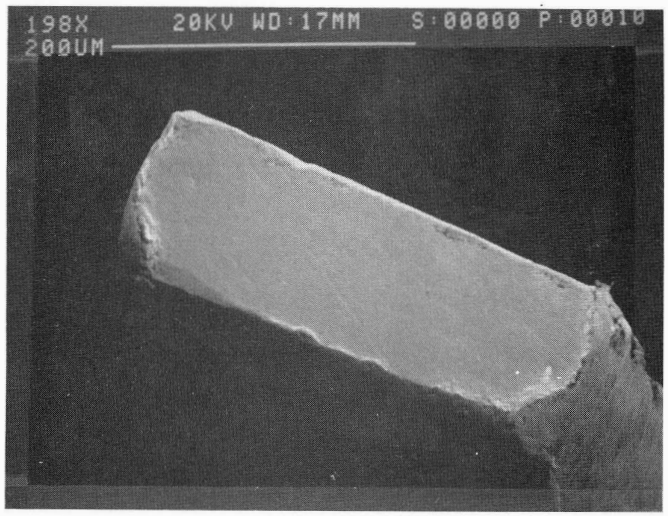

Fig. 2 - Flat rectangular probe 300 x 100 µm

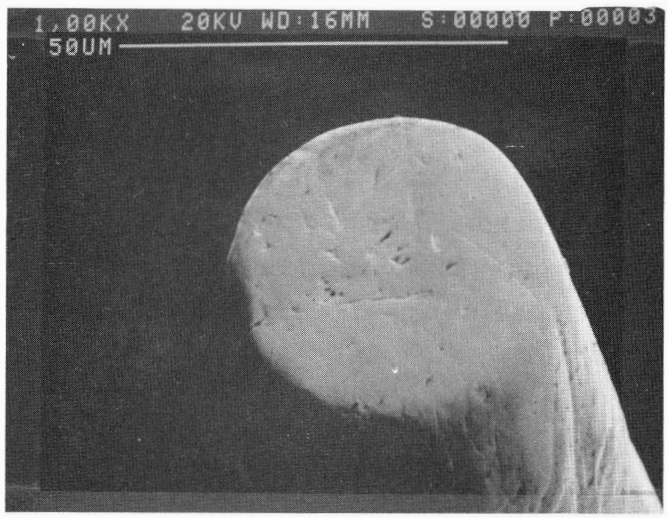

Fig. 3 - Flat circular probe Ø = 40 µm.

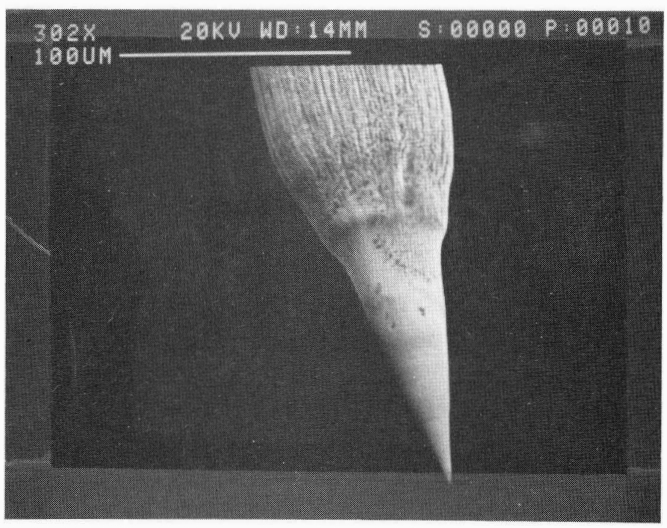

Fig. 4 - Microtip probe.

RESULTS

Two different kinds of sites were observed in dependence on the applied field :

1) First kind : sites for low electric field.

The area of cathodes was systematicaly studied with elecric field from 10 to 40 MV/m. We have localized and studied different sites of various nature. They all have a strong secondary electron emission and are certainly of insulating or semiconductor type [1, 2]. The X-ray analysis of sites revealed some light and heavy elements (Ni, Si, Ag, N, C, O) (Figs 5, 6, 7, 8).

2) Second kind : sites for high electric field.

We have have selected a flat microscopic region of the sample where no field emission occured for $E < 40$ MV/m and without foreign particles (Fig. 9). With the flat circular probe we have raised the electric field up to 160 MV/m without noticeable emission. Then an electronic current appeared and raised very quickly with the electric field (Fig. 12). The field was raised up to 180 MV/m and then lowered to zero. The surface of the sample, observed afterwise, exhibited craters (Figs 10 and 11) obviously created during the process. The X-ray analysis did not show any tungsten in this craters, so the emission area was certainly caused by Joule heating from the emission current. The I/V characteristic of the site probably represents a switching phenomenon with a memory effect (Fig. 12).

CONCLUSION

These preliminary tests have shown the possibilities of this experimental set-up for the investigation of emitting sites. The origin of the different elements in the emission sites is no clear : dusty particle, segregation in the bulk material revealed by the chemical processing, chemical components not eliminated by water rinsing. We plan to improve the set-up by measuring the work fonction of the emission sites by photo-emission.

REFERENCES

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[2] - R.V. LATHAM - IEEE on Electrical Insulation, (1988) **23**, n°5.

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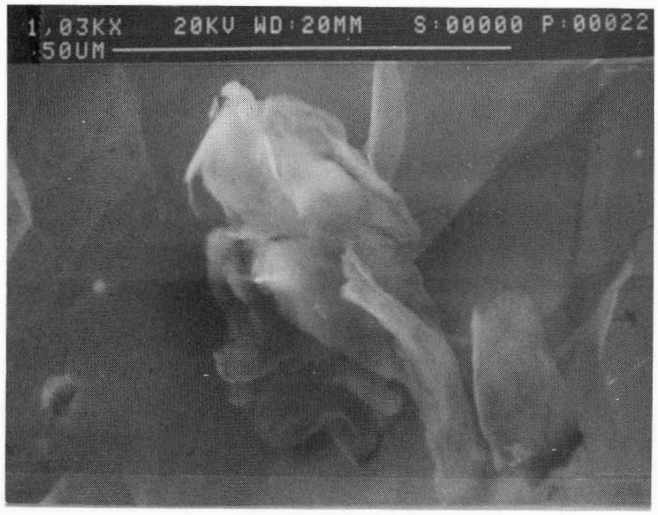

Fig. 5 - Site with C, N, O.

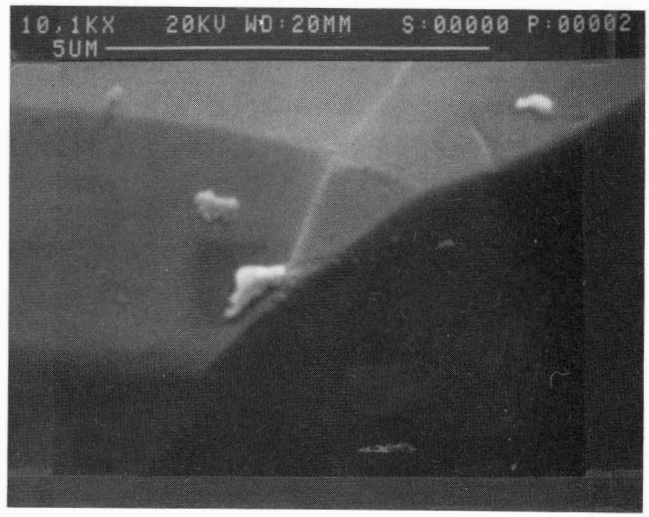

Fig. 6 - Site with Ag.

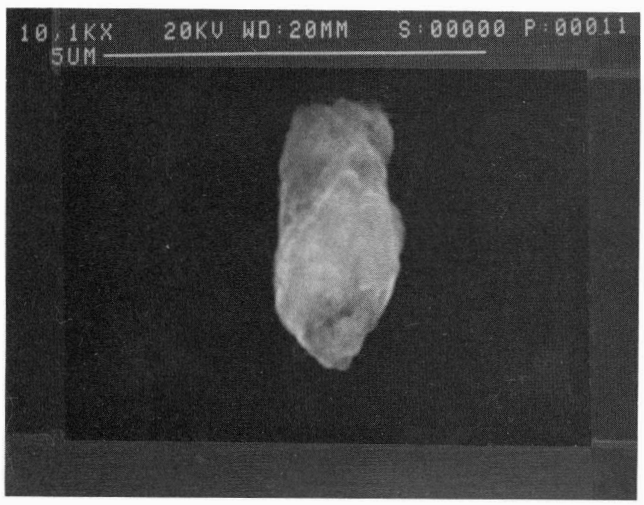

Fig. 7 - Site with Si, O.

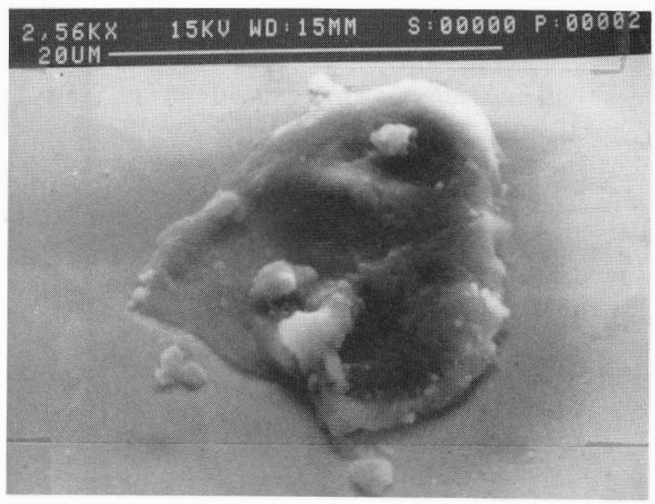

Fig. 8 - Site with Ni.

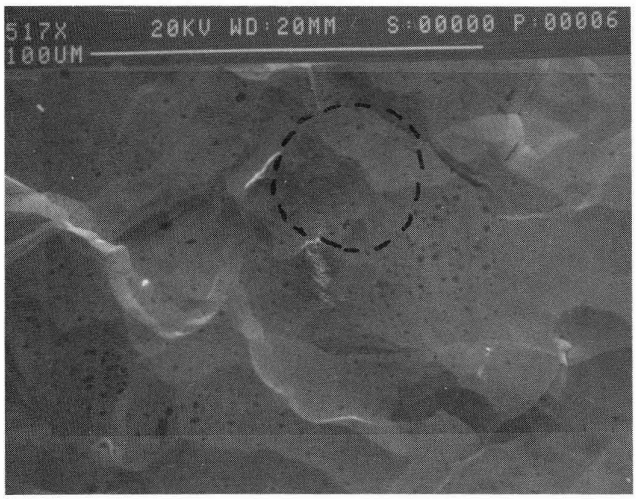

Fig. 9 - Selected region before creating sites
(the active region is inside the dot line)

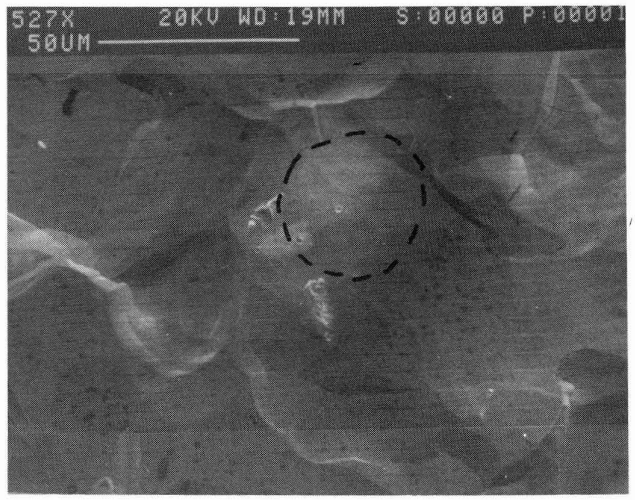

Fig. 10 - Selected region after creating site.

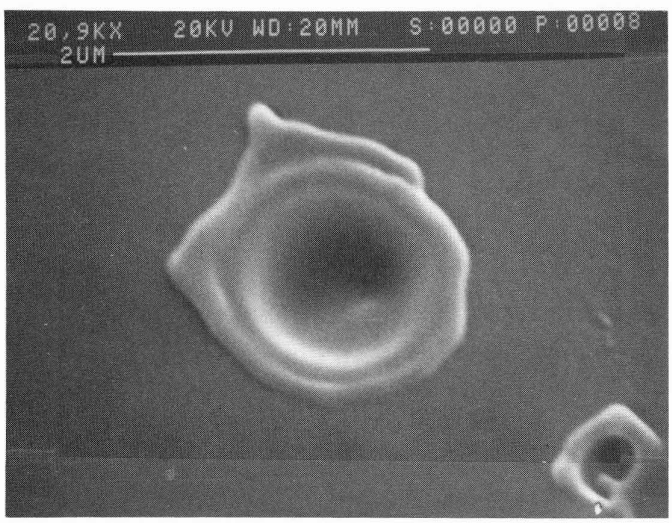

Fig. 11 - Emitting sites of figure 10

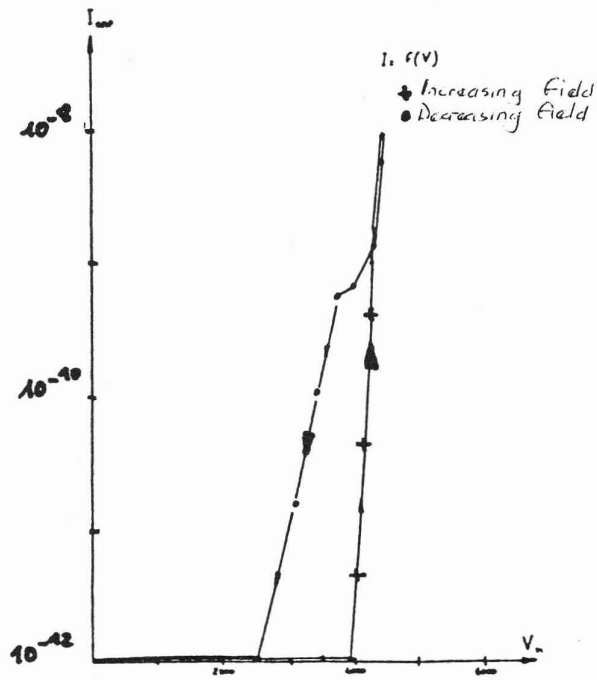

Fig. 12 - I = f(V) characteristic of emitting sites.