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ENERGY SPREAD MEASUREMENT IN FIELD ELECTRON MICROSCOPY

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Résumé - La dispersion énergétique des cathodes à émission de champ d'orientation <100> et <111> a été mesurée dans les conditions de fonctionnement de la microscopie conventionnelle. Les différents paramètres qui l'influencent sont mis en évidence.

Abstract - The energy spread of field emission oriented <100> and <111> tips has been measured in the working conditions of CTEM. The different parameters that influence it are pointed out.

One of the interests of the field emission cathodes is their low energy spread at the emission. We have already shown by an indirect method {1} that in the microscope the beam emitted by a <100> field emission cathode can suffer of a very large energy broadening. We intended to verify very precisely with an energy filter what is, in the microscope, the energy broadening of a field emission illuminating system for specimen illuminating conditions of conventionnal transmission microscopy. For this purpose a very simple retarding energy filter {2} was set in the microscope camera chamber (Figure 1). This way, all the broadening effects occuring from the cathode to the specimen are taken into account and so our measurements give energy spread value at specimen level. We have verified on a resistor net and by computing trajectories inside the filter that its resolution is about 0.05 eV at 15 kV with an input aperture of 200 µm. The curve I = f(E) is obtained with a microcomputer that commands the retarding electrode potential. The curve acquisition is done in several times so as to get rid of beam noise inherent to field emission. Then the microcomputer derives the curve I = f(E) to get the curve N(E) = f(E), N(E) representing the number of electrons of total energy E. The width of this curve at half height gives the energy spread ΔE.

For an oxygen processed <100> tip there is a strong dependance of total beam current I_T, chiefly for tips of small radius. The extracting potential V_0 and factor $\beta = E/V$ gives an indication of radius size. Low V_0 and large β correspond to small radius. For example (Fig. 2), with a cathode heated at 1420 °C having $\beta = 4.8 \times 10^4$ cm^{-1} (V_0 = 1950 v at I_T = 10 µA), ΔE varies from 1.15 eV at I_T = 10 µA to 2.6 eV at I_T = 100 µA. The same filament at T = 850 °C has ΔE = 1 eV for I_T = 10 µA. With tips of larger radius the values of ΔE are much smaller : for example with a tip having $\beta = 1.2 \times 10^4$ cm^{-1} (V_0 = 3600 v at I_T = 10 µA), at 1420 °C ΔE varies from 0.95 eV at I_T = 10 µA to 1.6 eV at I_T = 100 µA. The same tip at smaller temperature (T = 850 °C) has ΔE = 0.85 eV at I_T = 10 µA.

We have also measured energy spread of a <111> oriented tip. At 850 °C, ΔE varies from 0.6 eV at 10 µA to 0.8 eV at 100 µA. This kind of filament is much less sensible to I_T variation. We suppose that the reason is the current per unit solid angle is lower with this kind of tip (at same total current the <111> oriented tip gives a probe current 3 to 5 times smaller than the <100> tip). This is due to the fact that the <111> tip gives a less angularly confined beam : that means an emission aperture angle α larger.

If we refer to Knauer {3} who gives for the broadening effect the following expression :

$$\Delta E \simeq 5{,}8\pi \frac{e}{4\pi\varepsilon_0} \left(\frac{m}{V_0}\right)^{1/3} \frac{1}{R^{1/3}} \left(\frac{1}{\pi\alpha^2}\right)^{2/3} I_T^{2/3}$$

where R is the tip radius, the others parameters being already defined above, we can see that energy broadening is not only dependent on total current and tip radius but also on emission aperture angle. This α effect is may be the reason explaining that energy spread of <111> tip is smaller than <100> tip at same total current but at lower probe current.

{1} TROYON M., Optik 52 (1979) 401
{2} BUNTING G.D., Manchester Fifth Eur. Cong. Electron Microsc., (1972) 150.
{3} KNAUER W., Optik 59 (1981) 335.

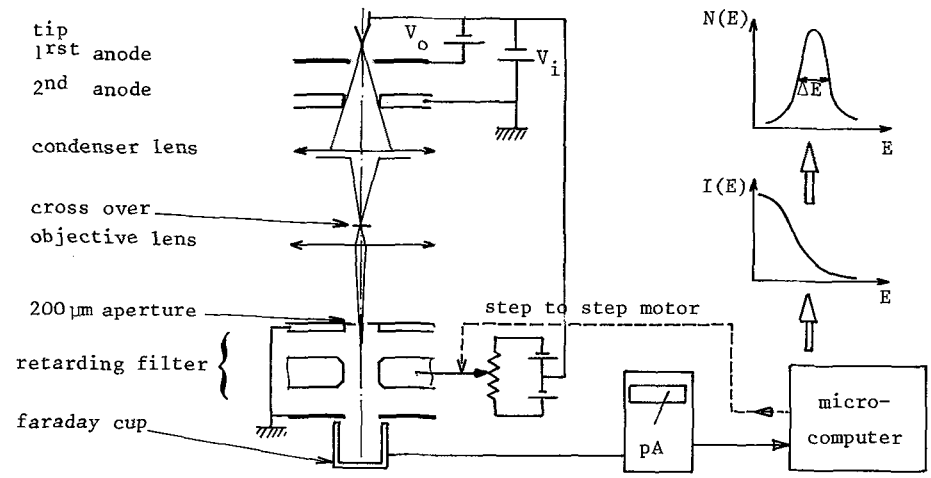

Fig. 1 : Experimental set-up for energy spread measurement

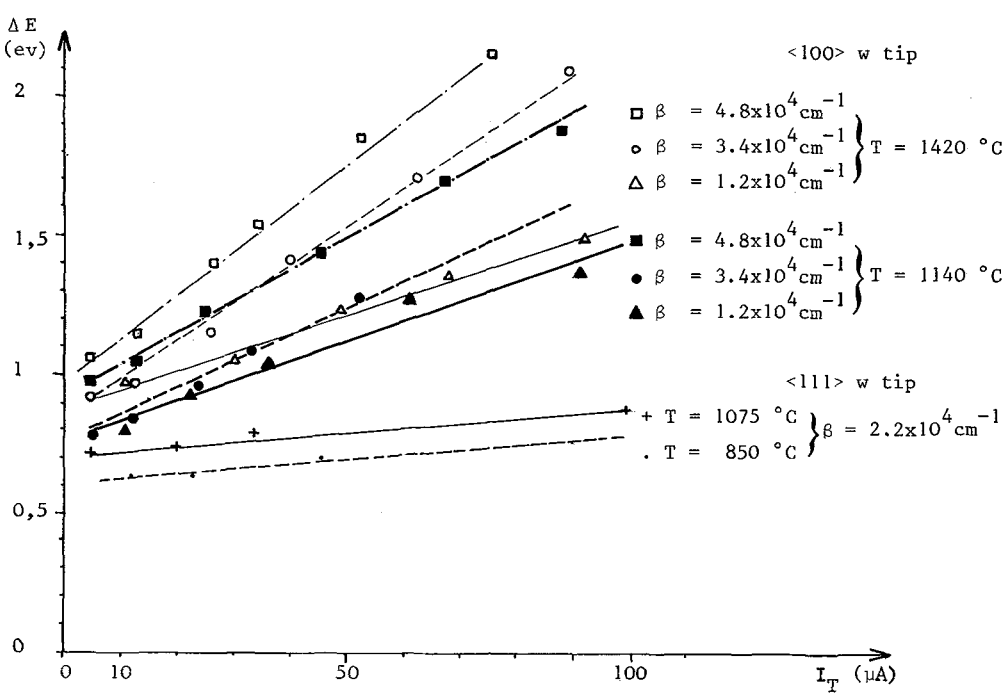

Fig. 2 : Energy spread versus total emitted current