ROLE OF ADSORBATES ON CURRENT FLUCTUATIONS IN DC FIELD EMISSION

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ABSTRACT

Field emission experiments in DC regime usually show important current fluctuations for a fixed electric field. These fluctuations are attributed to adsorbed layers (molecules or atoms), liable to affect the work function, height and shape of the potential barrier binding the electron in the metal.

In the following paper, we investigate the role of these adsorbed species by showing that the field emission from a well desorbed sample is stable and reproducible and by comparing the emission from the same sample before and after desorption.

INTRODUCTION

According to the Fowler-Nordheim theory [1], a fixed and stable electron field emission current is drawn at a given electric field. Nevertheless this prediction is only true under the assumption that the metallic surface is perfectly flat and clean. Practically, the latter condition is rarely satisfied ; gaseous species stick on the metal surface by adsorption phenomena (physisorption and chemisorption) [2]. The resulting modification of the work function has been well known ; as an example, a reduction of one eV has been measured on water-covered Cu(110) at 100 K [3]. Furthermore, adsorbates can affect significantly the shape of the potential barrier seen by the electron and thus its tunneling probability [4,5]. Experimentally, the effect of gases on the emission currents from metallic micropoints in ultra-high vacuum has been reported [6].

More recently, experiments in RF field emission showed that the mean current on a RF millisecond pulse was stable after a conditioning period [7]. This stability has been attributed to a desorbing process due to the RF surface loss heating of the emitting sample. These observations suggest a possible stabilization of the DC emission current by the mean of a thermal desorption. The present experiment gives both some understanding on current fluctuations and an effective method to cure them.

EXPERIMENTAL SET-UP

The experimental set-up essentially consists of an anode-cathode system placed in a ultra-high-vacuum vessel equipped with two viewports (Fig. 1). The spacing gap is measured by a cathetometer through the first viewport. The second viewport is used for the heating of the sample by a 200 W halogen lamp installed outside the vessel.

The high voltage application, the emission current measurement and the safety device are monitored by a LABVIEW program. More detailed descriptions are available in [8,9].

The field emission is studied on two copper samples ; emission sites are intentionally set by scratching the surface with a diamond tip.

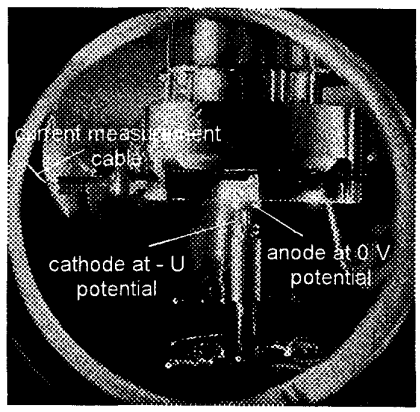

Fig. 1. The anode-cathode system

DESORBING PROCEDURE

1/ After the mounting of the sample inside of the UHV vessel, an intermediate vacuum of 10^{-6} Torr is set and a baking of the vessel by heating strings at 200 °C lasts 48 hours.

2/ The vessel is cooled down.

3/ Ultra High Vacuum better than 10^{-9} Torr is set by an ion pump.

4/ The sample heating is realized by an 200 W halogen lamp placed at the first focus of an ellipsoidal rear reflector. The luminous power converges at the second focus which corresponds to the sample location. The temperature at the thermal equilibrium is measured with a thermocouple in a similar configuration. It is about 700 K.

A voltage is applied to draw approximately a current of 1 µA during the heating that lasts 6 hours.

RESULTS

1/ Effective stabilization of the emission current is obtained. Fig. 2 shows a comparison of fluctuations before and after the desorbing procedure. The relative fluctuation on the desorbed sample is found to be 1.9 % around 100 nA and 0.9 % around 800 nA.

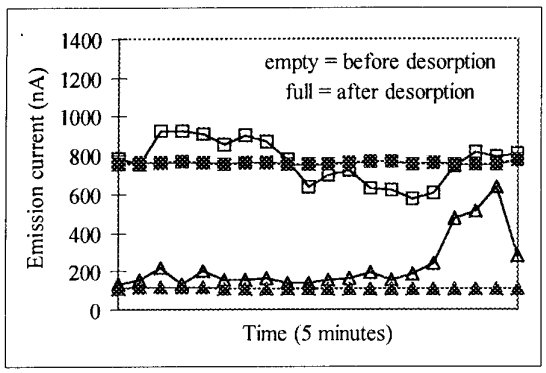

Fig. 2. Reduction of current fluctuations

2/ The stable emission is reproducible. The reproducibility is tested by two consecutive measurement cycles (increasing and decreasing field in one cycle) with identical parameters : gap = 0.97 mm, minimum voltage = 3 KV, maximum voltage = 5.5 KV, step increment/decrement = 0.25 KV, number of measure on one step = 20, time interval between two measures = 1 second. A total of 440 points are read on one cycle ; each point is reported by one cross in Fig. 3.

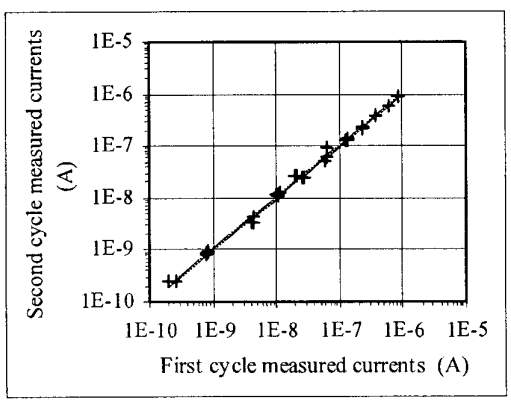

Fig. 3. Reproducibility of stable emission

3/ A desorbed sample kept in UHV vessel for one week conserves approximately its stable emission characteristics (Fig. 4). The relative fluctuation stays under 5 %.

4/ The stable emission obeys the modified Fowler-Nordheim theory (Fig. 5).

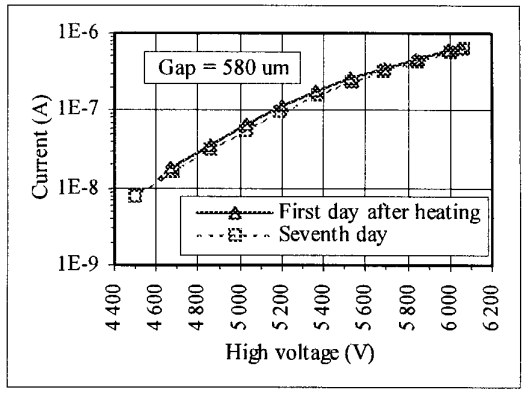

Fig. 4. Conservation of emission characteristics

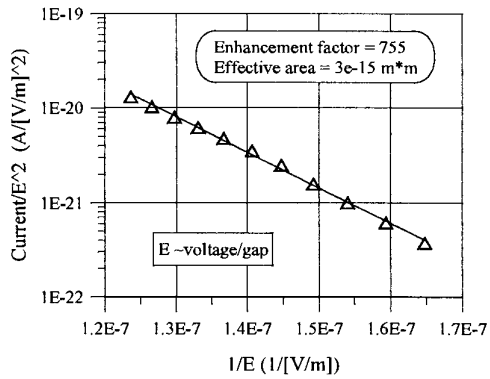

Fig. 5. Fowler-Nordheim plot

5/ Important fluctuations of the emission current reappear after a vacuum incident during which the pressure inside the vessel reached a value of 10^{-4} Torr.

A new pumping with a turbomolecular pump resets a vacuum of 10^{-6} Torr. Then a new measurement is made. The current behavior is presented in Fig. 6.

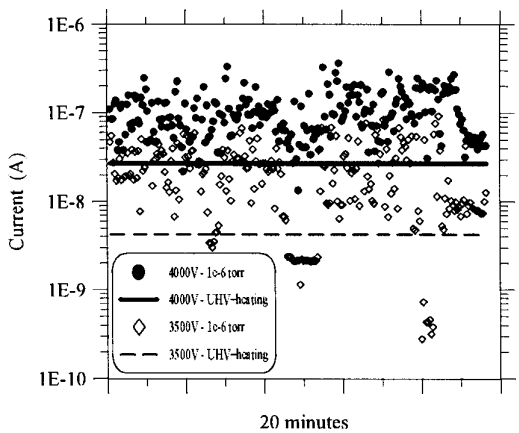

Fig. 6. Reappearance of fluctuations after vacuum incident

DISCUSSION

This study proves that field emission is not an intrinsically fluctuating process since an effective stabilization of the current has been obtained by the heating of the sample under ultra-high vacuum. The usually observed fluctuation could be due to adsorption of molecules or atoms on the metallic surface.

The experimental identification of the adsorbate responsible to the current fluctuation is not an easy task because of the small area of the sample compared to that of the walls of the vessel ; a very sensitive method is required. However a possible absorbate can be guessed thanks to the large data base concerning the adsorption of the main gases present in atmosphere, on copper surfaces (H_2, N_2, O_2, CO_2, CO, H_2O).

According to data found in [10], H_2, N_2, CO_2, and CO are not adsorbed on copper at 300 K. On the contrary, O_2 is strongly chemisorbed and a thermal desorption even at 1020 K can not leave a atomically clean surface. Consequently, water adsorption and desorption appear as the most likely processes that might affect the current stability in field emission.

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