Characteristics study of Field Emission Probes prepared at VECC for the Cryogenic Penning Ion Trap project

R. Menon[1]*, P. Y. Nabhiraj[1], Jaya Maithil[2] P. Das[1] and A. Ray[1]
[1]*Variable Energy Cyclotron centre, Kolkata 700064, INDIA*
[2]*Deptartment of Physics, National Institute of Science Education and Research, Bhubaneswar,INDIA.*
** email:ranjini@vecc.gov.in*

Introduction

One of the major challenges of VECC Cryogenic Penning Ion Trap project [1,2] is the ion source. It has been planned that the radioactive species will be produced in an accelerator facility and would be implanted in a suitable catcher medium. The catcher material hosting the radioactive species would carry them inside the trap for regeneration within the ion trap. The electrons generated by field emission process would impinge this catcher at a grazing angle and radioactive ions weakly bound to the catcher would be liberated free. It is expected that the ions generated would have at least 1+ charge state and they can be trapped with our designed electrode arrangement according to our simulation studies.

The Field Emission Probes (FEP) thus becomes an essential part of the VECC Penning Ion Trap project. These are being fabricated at VECC and test results are reported here.

Field Emission Process

The emission of electrons from a metal or semiconductor into vacuum or dielectric under the influence of a strong electric field is called field emission. Compared to thermionic and photoemission processes where electrons gain energy and overcome the barrier, in field emission process, the electrons tunnel through a potential barrier rather that escaping over the barrier. It is pure quantum mechanical process and it occurs because the wave function of an electron does not vanish at the classical turning point but decays exponentially into the barrier. As a result the electrons having total energy less that the potential energy of the barrier have a finite probability of crossing the barrier.

FEP probe preparation method

Electrochemical etching is a simple and well established technique for etching good field emission tips from metal wires [3]. For etching the tungsten field emitter, KOH was used as the etchant and stainless steel as counter electrode. The process of etching starts when voltage is applied across the electrodes. The current flowing through the circuit will give an indication of the rate of etching. On the cathode, at the air – electrolyte interface a neck is formed and the etch rate is enhanced at this junction. This neck narrows down with time and thus the current through the circuit also reduces. Current drops sharply when the immersed portion of cathode breaks off, leaving a sharp tip on the remaining portion. At this time the circuit needs to open quickly to avoid further etching of the tip and destroying the shape of tip. An automated system is developed to control the etch process using Labview GUI. Cleaning process before and after the etch are also very important and it is seen that the result varies drastically with change in cleaning process. Figure1 Shows the current flowing through the system while etching the tungsten wire.

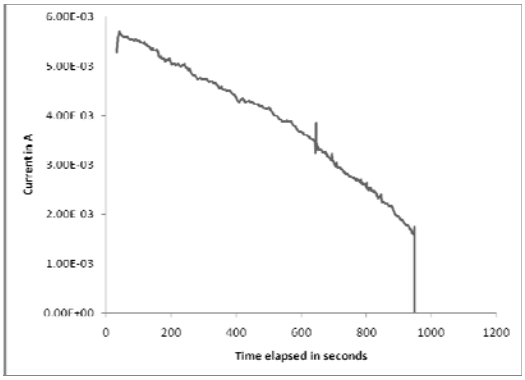

Fig. 1 Current flown through etching system

Characteristics study of FEP probes

A setup, as shown in Fig 2 was fabricated for studying the characteristics of the field emission probes prepared. The FEP probe tip was fixed a distance of ~1 mm from the collector plate. The setup shown was placed inside a chamber and evacuated to 1×10^{-6} mbar before applying bias. The distance of the FEP tip was varied and V-I characteristics were studied. Characteristic V-I curve of one of the FEP probes is shown in Fig 3. We obtained ~2nA electron beam from the FEP tips studied at 1200V to 1600V depending on the tip to collector distance.

However, in the trap assembly, the collector should have a hole for extraction of electrons. So the collector design is being changed and the electronic current would be measured after extraction through the hole. The expected electronic current in the trap would be estimated from these measurements.

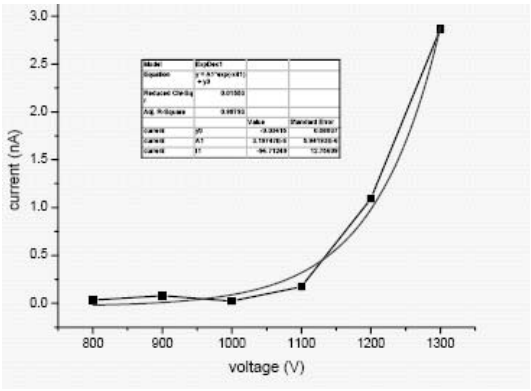

Fig. 3 V-I characteristic of a FEP probe

References

[1] P. Das et al. Proc. Of the National Symp. On Nucl. Inst-2010, **33** (2010)
[2] DAE Symp. On Nucl.Phys. (2010)
[3] Sophie Kerfriden et al. Electrochemica Acta, Vol. 43, Nos 12-13, pp. 1939-1944, 1998.

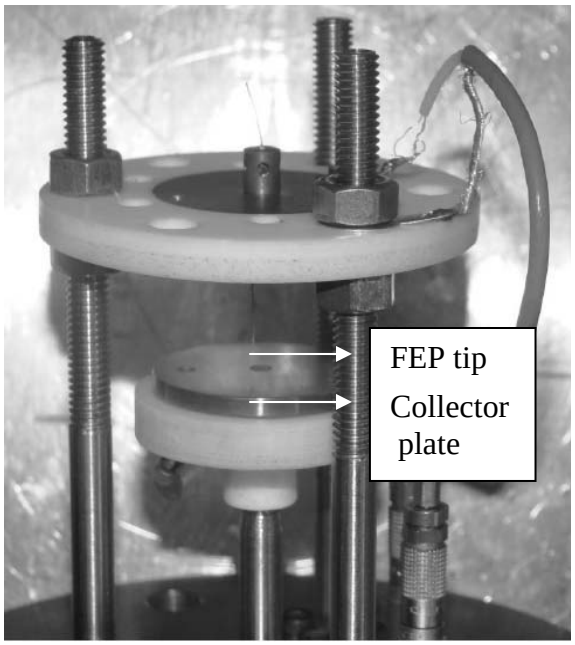

Fig. 2 Setup for FEP probe study