ECONOMICAL CHARGE PARTICLE SOURCE FOR INDUSTRIAL ACCELERATORS

E.O. Popov*, O.P. Korovin, S.S. Karatetskii, V.N. Shrednik,
A.F. Ioffe Physicotechnical Institute of Russian Academy of Sciences,
26, Polytechnicheskaja, St.Petersburg, 194021, Russia

Abstract

The distinguishing features of the new type of unheated liquid metal field emitter are reported. The emitter is based on track membrane technology and therefore its surface can be made as large as necessary. It is cheap in construction, fabrication and exploitation. The emitter can be operated indefinitely long time in field emission, explosive emission or ion emission mode by poor vacuum up to 10^{-4} Torr without noticeable change of emission characteristics.

1 INTRODUCTION

The working condition of industrial accelerators and consequently demands to electron and ion sources for these devices are much harder than for research ones. The question is about charged particles source lifetime, stability of emission under low vacuum (10^{-4} Torr) and after contact with atmosphere and so on. For sources with large emitting area heat expenditure can be decisive factor. Application of proposed emitter allows to satisfy many of these requirements.

2 LIQUID METAL EMITTER CREATION METHOD

The emitter is formed by the system of large number of liquid gallium tips formed by pulling gallium through holes in polymer film (track membrane). The track membranes widely used nowadays as filter elements are fabricated by irradiation of polymer film (polythelentherephtalate in our case) with heavy ions (Ar^{+7}, 40 MeV) and subsequent etching. The density of holes can be as high as 10^8 1/cm^2. Diameter of holes is usually 0.3-0.4 μm . According to membrane fabrication technology the track membrane has width about 1 meter and the length 50 m.

Fig. 1 represents the principal view of emitter. The process of emitter fabrication is very simple. Gallium layer of necessary thickness is deposited on conducting plate and is covered by track membrane. Emitting tips are being formed by pulling gallium through the orifices in membrane by application of electric field. In our case the height of tips determined by membrane thickness was 10 μm . Tips density was 6x10^7 1/cm^2. The voltage applied by pulling gallium through the orifices was 1.5-2 times higher than working one of emitter. Fig.2 represents small part of emitter surface taken by scanning electron microscope.

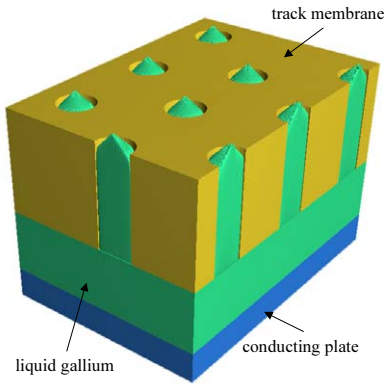

Figure 1: Liquid metal tips array

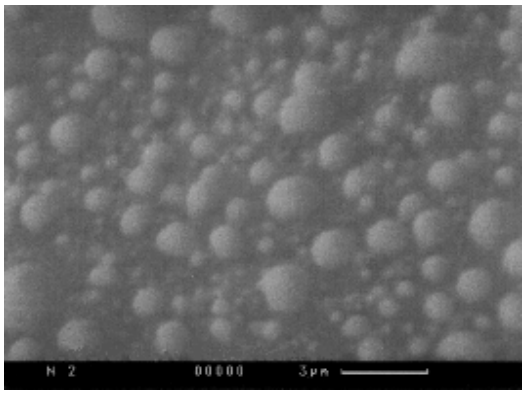

Figure 2: Track membrane with Ga underlayer after long time operation under applied voltage

3 CURRENT-VOLTAGE CHARACTERISTIC MEASUREMENTS

Current-voltage characteristic measurements have been made in diode construction. Special registration two channels system with analog digital converter have been designed, where the data were transferred to PC for processing. The registration system provides in 10 seconds measurements 500 current-voltage characteristics, each containing 1000 points.

In Fig.3 voltage and field electron current are plotted against time with alternation 440 Hz supply voltage. Measurements at 50 Hz, 55 kHz AC and DC also have been performed.

In these experiments maximum stable current density was 200 mA/cm^2. It is assumed that optimization of emitter design can give the maximum current density of the order 10 A/cm^2.

*phti@yandex.ru

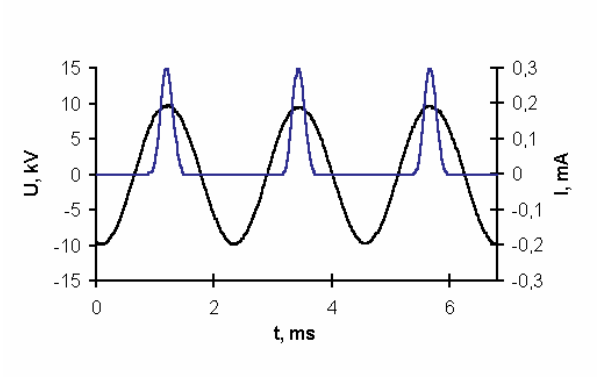

Figure 3: Oscillograms of voltage and electron current

By alternative voltage supply of emitter starting from certain threshold voltage explosive emission pulse appears, when current from a single tip exceeds the level of 10-30 μA. The width of voltage interval for this transition from field emission to explosive emission is about 0.02% from maximal field emission voltage. This process is easily controlled by the voltage change. During one alternate at 50 Hz one can get from one to 40 pulses of explosive emission.

The time interval between explosive emission pulses could be changed from 25 μs to 1 ms. The current amplitude was 50 A by pulse duration on half amplitude level 40 ns. In our experiments there was no visible change of emitting parameters after 10^7 such pulses.

In Fig.4 the integrated pulse from 500 single pulses of explosive emission is presented.

It was experimentally proved that the change of voltage sign give rise the gallium ion current. Thus the emitter can be also used as gallium ion source. The maximal ion current in our experiment was 10 mA from the emitter area of 1 cm^2. The tests of the emitter in field emission, explosive emission and ion emission modes allow to formulate the principal features of the device.

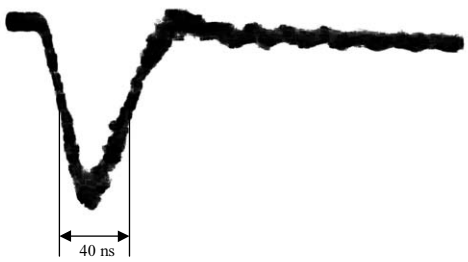

Figure 4: A typical integrated oscillogram of the explosive emission current pulse

4 CONCLUSION

The principal advantages of the discussed emitter can be formulated as follows:

1. Simple and cheap technology of fabrication of liquid gallium multiple tip emitter with high density of tips.
2. The possibility of designing the unheated emitters with complicated form and large emitting area.
3. The possibility of operation in different modes, such as field emission, explosive emission, ion emission.
4. Stable emission during long lifetime in any of the above-mentioned modes due to insensitivity to ion bombardment, lack of tip degradation and self-restoring of tips due to stock of gallium.

Proposed emitter can be applied for designing accelerators with large cathode area for laser pumping, industrial accelerators for material irradiation, powerful X-ray tube and so on.

5 REFENCES

[1] Popov E.O., Korovin O.P.,. Karatetskii S.S, Shrednik V.N. The problem of stable field electron emission of the multiple tip liquid metal cathode// 46th International Field Emission Symposium, IFES 2000, July 23-28 2000, University of Pittsburgh, Pittsburgh, USA, Poster P43

[2] Popov E.O., Korovin O.P.,. Karatetskii S.S, Shrednik V.N. Some peculiarities of field emission of multiple tip liquid metal emitter// 13th International Vacuum Microelectronics Conference, IVMC'2000, Guangzhou, China, 14th–17th August, 2000, Poster P64