Micromachined Surface-Flashover Ion Source Based on MEMS Technology

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Outline

- Introduction
- Micromachined process
- The Ion source test
- Summary

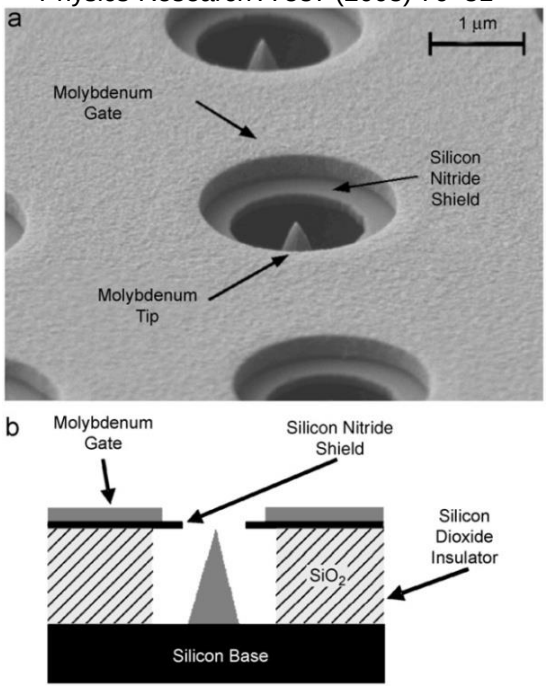
Introduction

- Typical neutron generators are based on the D-D (2.4 MeV n) or D-T (14.2 MeV n) fusion. Ion sources are the most important part of neutron generators.
- Some types of ion sources：

- Radio-frequency (RF) ion source
- Electron cyclotron resonance (ECR) ion source
- Cold-cathode Penning ion source
- Vacuum arc ion source
- …

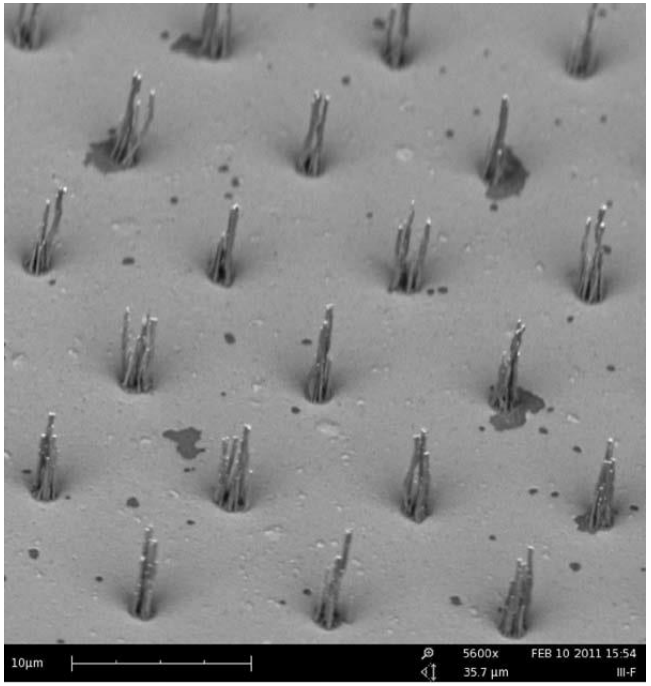
- MEMS technology + accelerator technology
- New ion sources and new configuration for neutron generators

Nuclear Instruments and Methods in Physics Research A 587 (2008) 76–81



Field desorption ion source

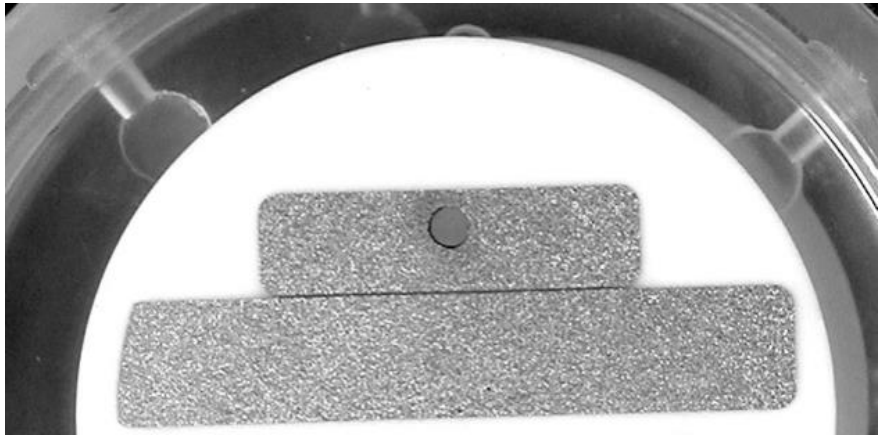
Review of Scientific Instruments 83, 02B312 (2012)



Field ionization ion source

Surface-Flashover Ion Source(or vacuum arc ion source)

20th International Conference on the Application of Accelerators in Research and Industry August 11-15, 2008



Close-up of surface flashover electrodes on the alumina substrate

J. Elizondo-Decanini at Sandia National Laboratories in the U.S. has been developing a compact neutron source using MEMS technology.

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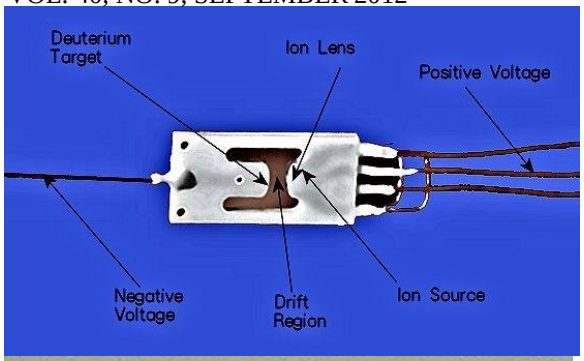
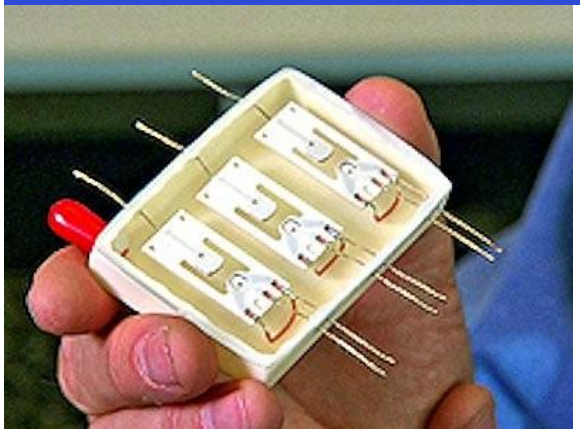


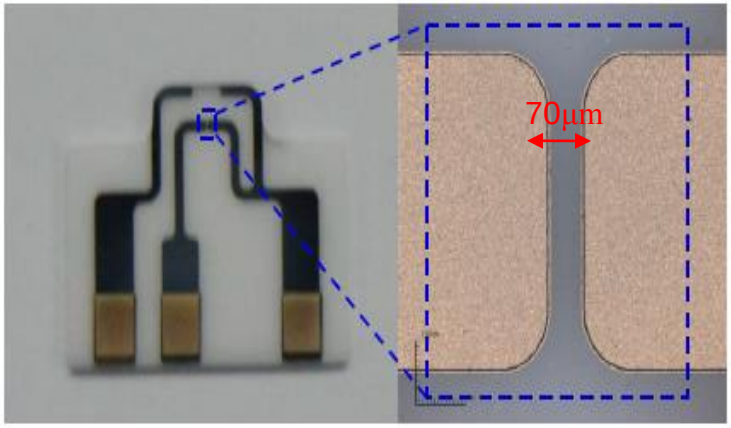


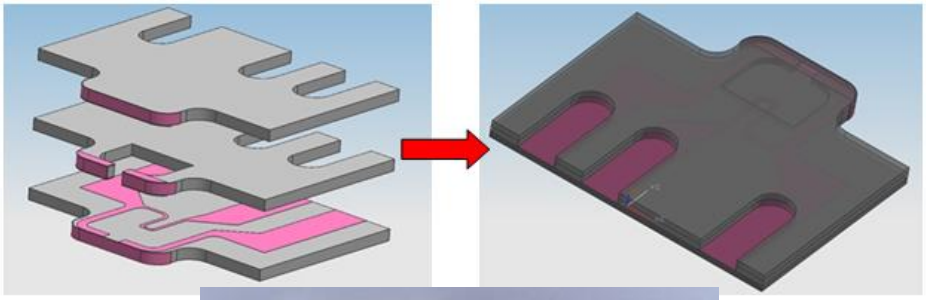
World's smallest neutron generator-“NEUTRISTOR”

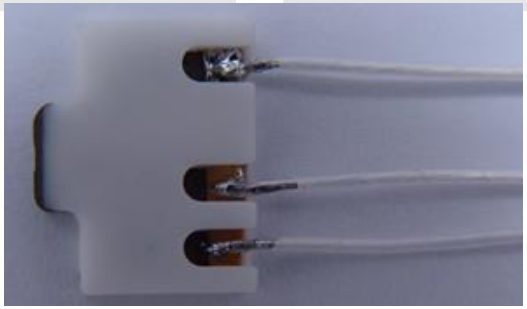
- Our research team’s goals:
- Developing an micromachined surface-flashover ion source for millimeter-sized neutron generator.
- Advantages:
- miniaturization, low cost, mass produced, and integrated feature

Micromachined Process

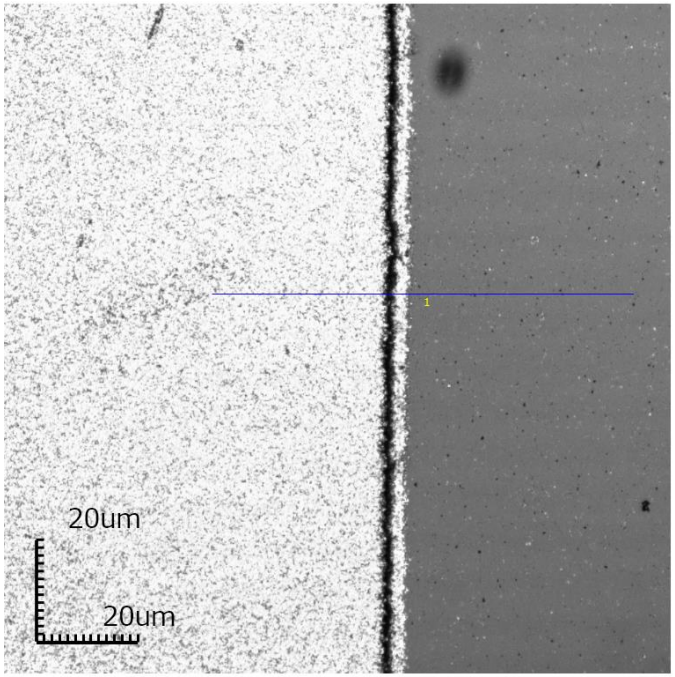
- The ion source is consist of two titanium electrodes fabricated by available lithography and metal deposition techniques.
- Firstly, the ~2.5μm thickness of titanium layer was deposited on a 0.5mm thick polished alumina substrate using magnetron sputtering.
- The photoresist layer was spun, exposed and developed to define the ion source geometry, and the exposed titanium layer was etched by H_3PO_4 solution.
- In order to convenient for jointing, the 5000Å Au layer was deposited on titanium film.

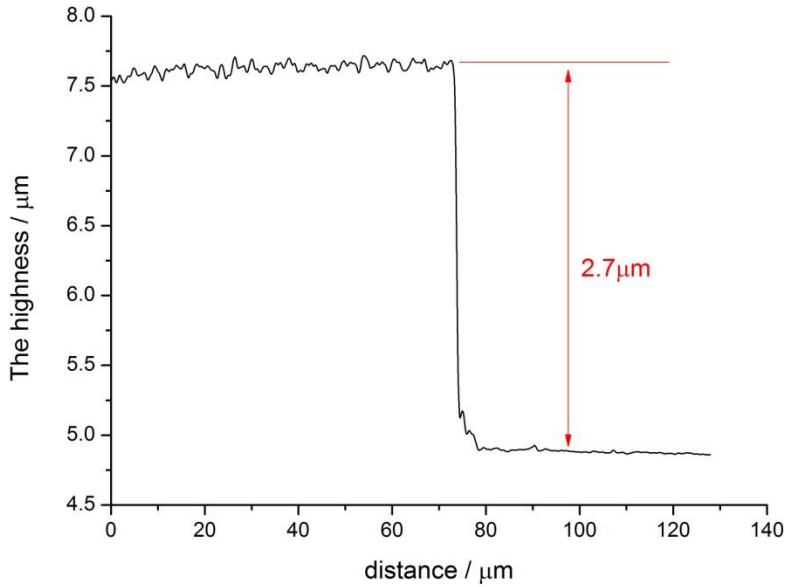






Micromachined Surface-Flashover Ion Source

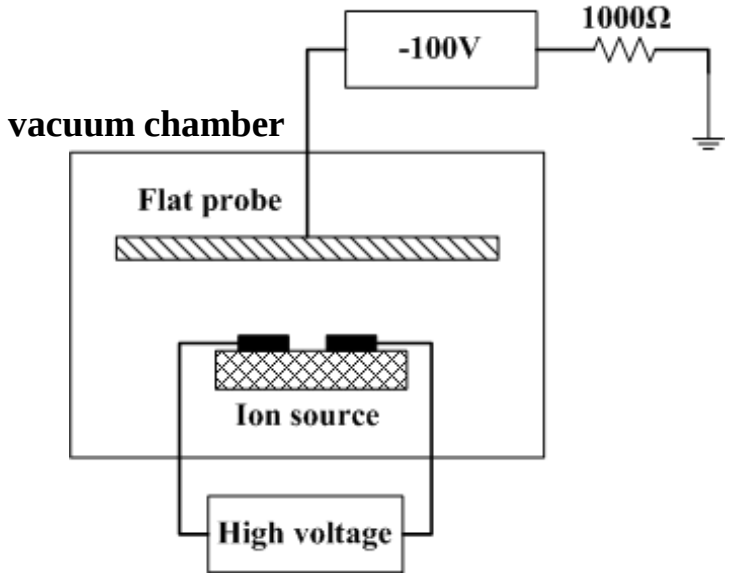


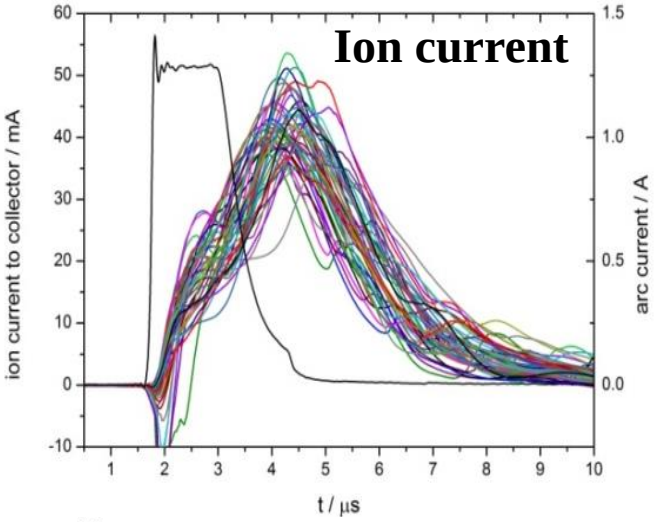


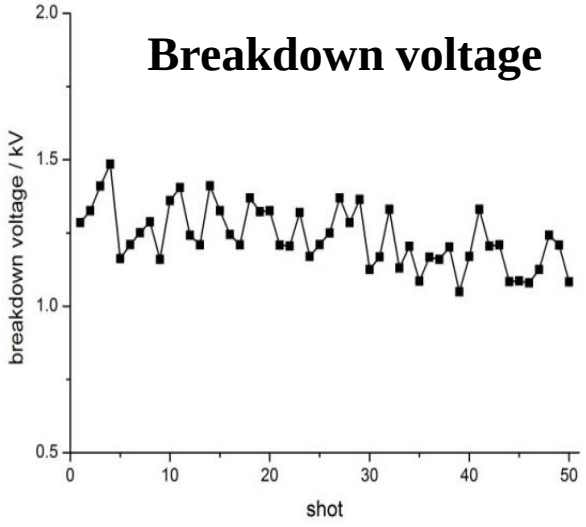
The thickness of titanium layer is 2.7μm, and the titanium electrodes have vertical sidewalls.

Total ion current measurement

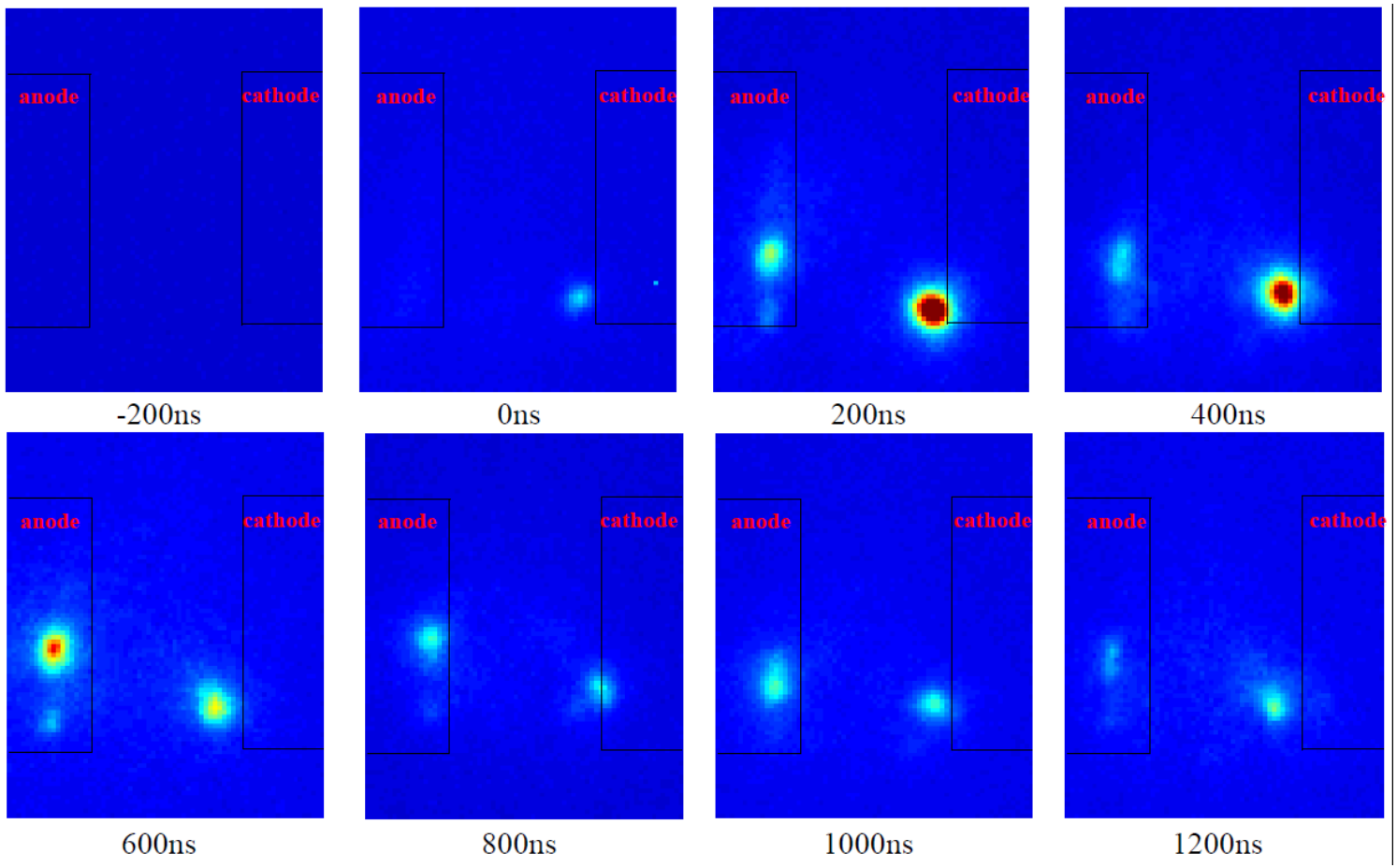
Experimental setup





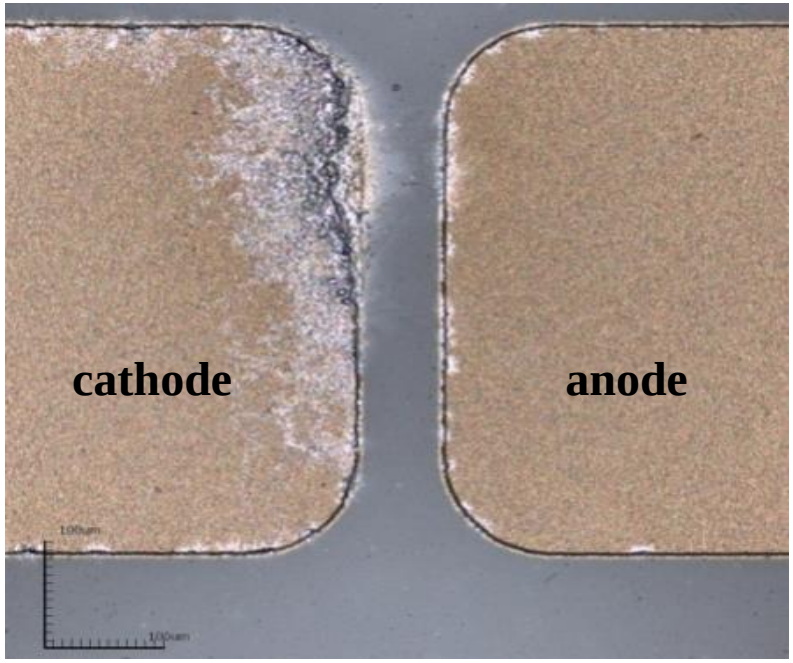


1. The average amplitude of ion current is 43mA, and the relative standard deviation is 10.0%.
2. An ion current pulse has a large duration and time delay relative to the arc current pulse. The results are associated with different values of the directional velocity of ions in the plasma.
3. The breakdown voltage that the ceramic flashover electric field is higher to 180kV/cm, which is because of the alumina substrate is polished.



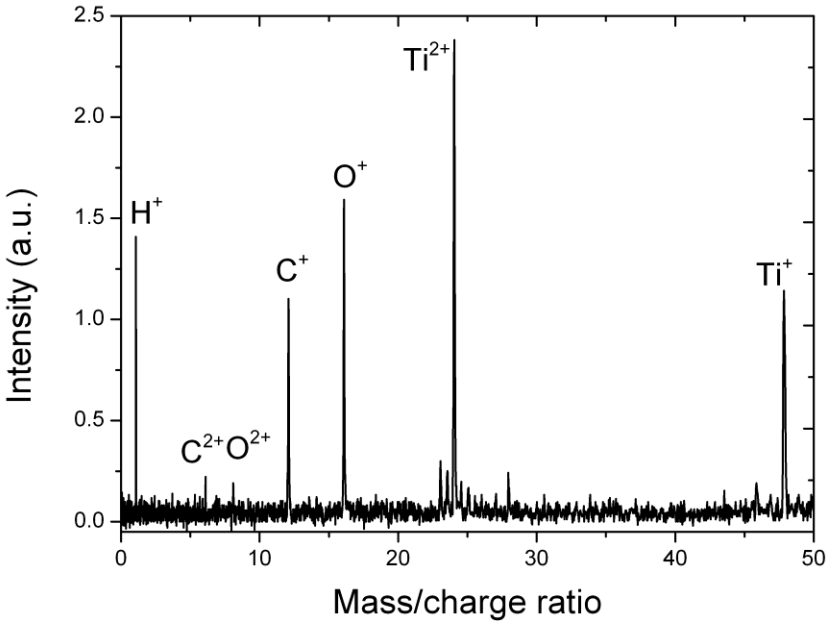
The discharge evolution image of the surface flashover ion source by the high-speed camera

Vacuum Arc evolution: initial injection of cathodic electrons and breakdown→anodic evaporation by cathodic jet → micro-gap arc maintained by plasmas occurred in two electrodes.

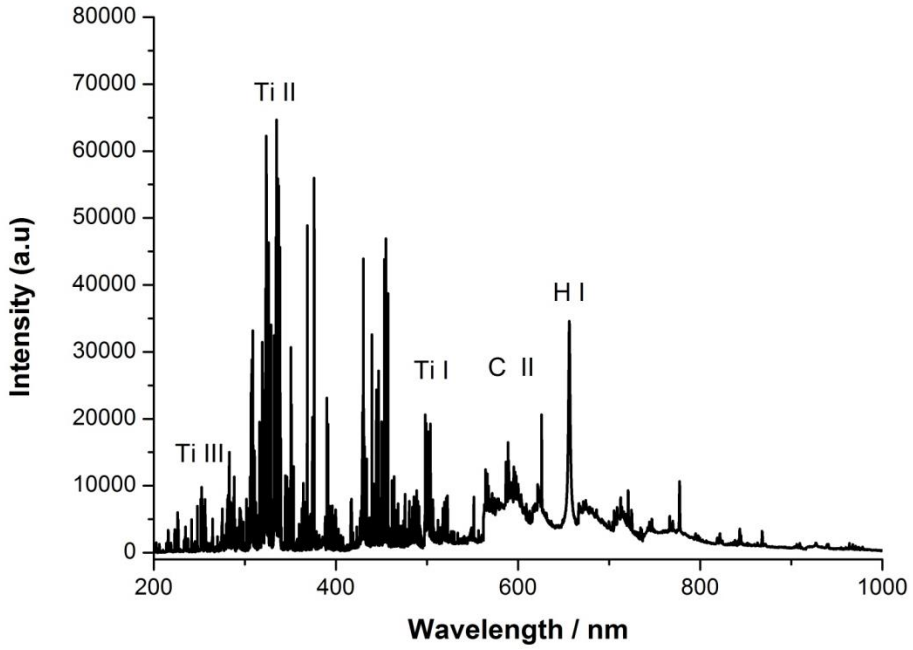


The electrode image after 80 shots with arc current 1.3A by laser confocal microscope

The electrodes are eroded by the arc (predominantly the cathode), which shows that the ion source has a finite lifetime.



Mass–charge spectrum of the ion beam by TOF



The emission spectroscopy by the spectrometer

It can be seen that Ti^{2+} ions prevail in the ion beam extracted from the plasma. Impurity ions were also present, the reason for the emergence of such impurities is that gases was desorbed from the surfaces of the electrode and the substrate. The results by TOF was agreement with the EOS.

Summary

- To study the ultra compact neutron source, the surface-flashover ion source is micromachined based on MEMS technology.
- The average amplitude of ion current is 43mA, The ratio of ion current to arc current is 3.6%.
- The breakdown voltage of surface flashover ion source is range from 1.0kV to 1.5kV. It shows that the ceramic flashover electric field is higher to 180kV/cm.
- The micro-gap arc was maintained by plasmas occurred in cathode and anode.
- The electrodes are eroded by the arc (predominantly the cathode), which shows that the ion source has a finite lifetime. With gas loaded the source can function for many thousands of pulses.

Thank you!