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Modified miniature metal vapor vacuum arc source for the Shanghai electron beam ion trap

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A modified miniature metal vapor vacuum arc ion source has been developed for the Shanghai electron beam ion trap. Several kinds of elements have been tested to extract lowly charged ions, such as Fe, Au, Ge, Mo, Ti, Al, and Cu. Besides high enough ion beam current and a short pulse width, we focus on the operation reliability, long term operation, and convenience of use. © *2006 American Institute of Physics.* [DOI: 10.1063/1.2173967]

I. INTRODUCTION

In 1986, Brown *et al.*[1] developed a miniature metal vapor vacuum arc (MEVVA) ion source for operation at Livermore electron beam ion trap (EBIT). For their experiments,[2] the ion source was operated under the condition of about 0.5 mA beam intensity with 25 μs pulse width. The Tokyo EBIT is also equipped with a similar MEVVA ion source.[3] Experiments showed that this kind of miniature MEVVA can meet the need of EBIT operation. Normally the MEVVA needs maintenance frequently. Keep this in mind, a MEVVA source was developed for the Shanghai EBIT. We aim at reliability, convenience, and long operating time.

The Shanghai EBIT has been constructed.[4,5] After several months of conditioning, this EBIT can be operated stably with electron beam of 100 kV/110 mA. X-ray spectra of Ar, Kr, Xe, and so on have been measured using a high purity Ge detector. The ion source is located on top of the EBIT and is far away from the trap. In order to compensate the current loss due to the long flight path, the ion source should produce high intensities. Desktop experiment of the MEVVA source has been done. Now it is mounted on the EBIT and the injection test is planned for the near future.

II. SOURCE DESCRIPTION

A schematic diagram of the MEVVA is shown in Fig. 1. This ion source consists of several components, such as cathode, trigger, anode, extractor, and so on. All components of the source are mounted on a base flange which is insulated from the ground with a ceramic tube. The central cathode is 1.5 mm in diameter. The anode, the suppressor and the extractor constitute a three-electrode system, with concentric apertures, 1 mm in diameter. The source is designed to allow easy interchange of target materials. As a result, assembly and disassembly are very convenient. To replace the cathode, only the target head needs changing. The target head is connected to the cathode holder by a screw thread. First, the cathode holder is removed from the base flange. Because a rubber *O* ring is used for vacuum sealing between the cathode holder and base flange, it is very easy to remove the cathode holder. Then the target head is changed. The whole operation can be finished in less than half an hour. Because a rubber *O* ring is used for vacuum sealing, the cathode holder can move ahead and backward smoothly. If the target tip eroded by the arc, the target head can be moved toward the arc area without breaking vacuum.

In order to reduce vapor deposition, adequate pumping is provided. The entire system is fabricated from ultrahigh vacuum compatible materials. A turbo molecular pump maintains a pressure in the MEVVA of about 10^{-9} Torr. This level of vacuum is sufficient to prevent significant losses to the ion beam from charge-exchange collisions with residual gas.

The arc power supply is a *RC* discharge circuit and its

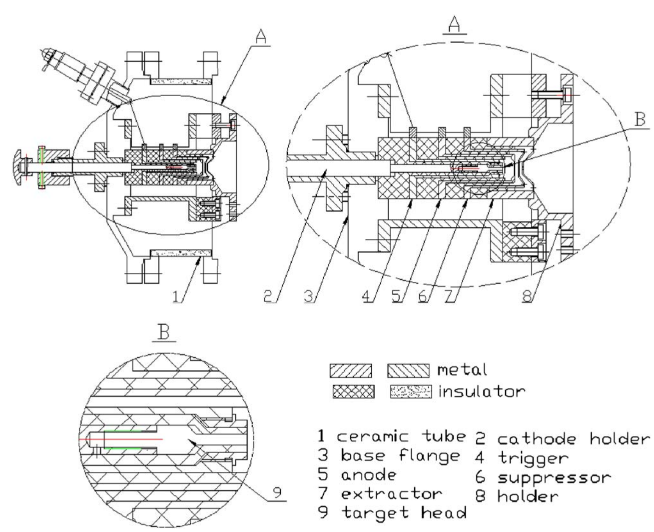

FIG. 1. A schematic diagram of the MEVVA.

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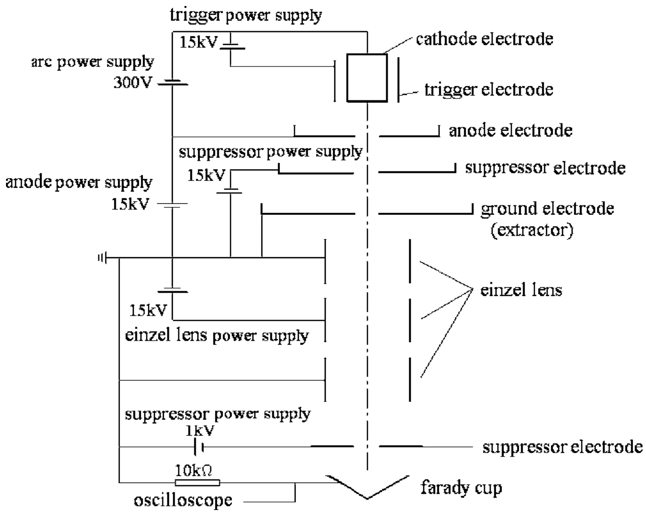

FIG. 2. Experimental setup.

current can reach over 200 A. The trigger power supply can provide a peak voltage of 15 kV with pulse width of 6–12 μs.

III. EXPERIMENTS

A schematic drawing of the experimental setup is shown in Fig. 2. An einzel lens is employed to prevent the beam form diverging as it travels across the source area to the experimental region. A Faraday cup is added not only for source test but also for the temporal check during EBIT operation. The cup entrance is 15 mm in diameter.

The pulse width of the trigger signal can be adjusted from 6 to 12 μs. Experiments show that the width does not affect the arc. Therefore, the pulse width is fixed at 12 μs. The current output of the trigger power supply does not coincide with the peak voltage, and a delay about 1 μs is found. However, the pulse width of the current output of the arc power supply is the same as the triggering signal. In most cases, the peak voltage is about 7 kV.

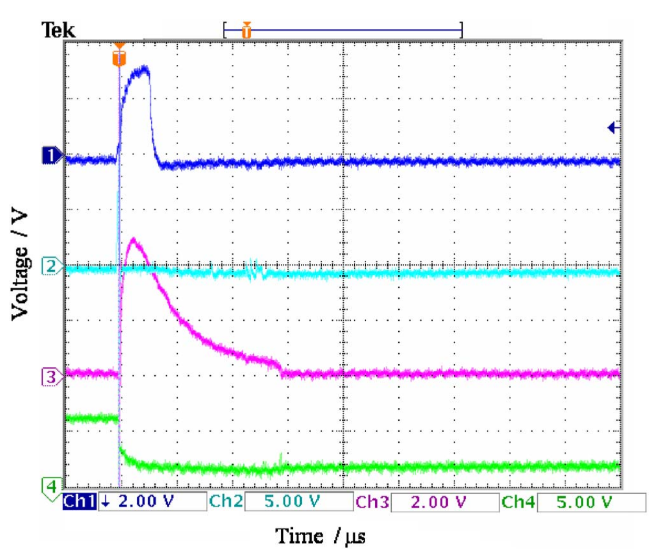

FIG. 3. Pulse shape of trigger and arc power supply outputs. (1) Current output of trigger power supply, (2) voltage output of trigger power supply, (3) current output of arc power supply, and (4) voltage output of arc power supply.

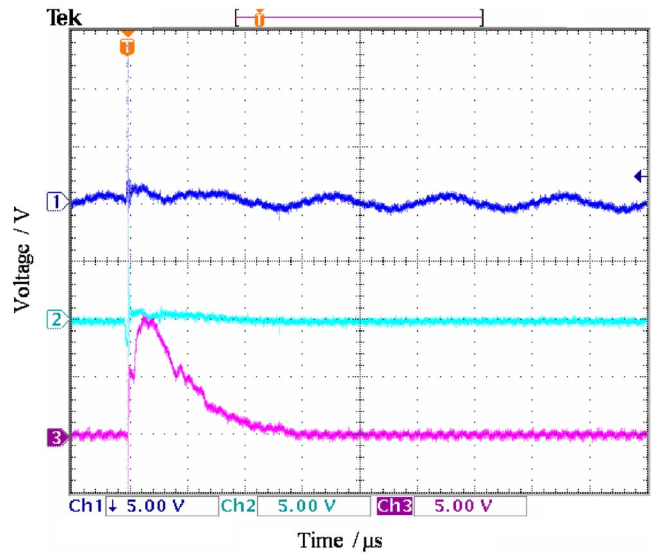

FIG. 4. Extraction current shape measured with oscilloscope. (1) Current output of anode power supply, (2) current on ground electrode, and (3) beam current of Fe target.

The arc power supply is a simple *RC* discharge circuit. The voltage and current outputs of trigger and arc power supplies are shown simultaneously in Fig. 3. These were measured from Mo target under a condition of trigger power supply of 7 kV and arc power supply of 60 V. When the arc current is established, the arc voltage falls to about 15 V. In order to shorten the beam pulse width, a 20 μf capacitor and a 0.5 Ω resistor have been adapted.

In Fig. 4, a typical example shows the pulse shape of the beam intensity measured from an Fe target. A peak beam current over 1 mA can be extracted. The current pulse was normally around 25 μs. It was found that the diverging beam put a small amount of current load on the anode and ground electrodes. Peak beam intensities for a number of targets are listed in Table I. Based on the parameters especially for EBIT operation, tests were made under the condition of about 0.6 mA beam intensity and 20–30 μs pulse width. It was estimated that the MEVVA lifetime can reach over 50 000 shots.

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TABLE I. Peak beam intensities of some elements.

Element	Fe	Au	Ge	Mo	Ti	Al	Cu
Current (mA)	3.3	1.7	3.0	1.7	2.3	4.0	2.5
Extraction voltage (kV)	10	10	12	10	10	10	10
Arc current (A)	90	150	70	72	62	100	120
Pulse width (μs)	80	90	50	50	50	90	60

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