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Increase of Lifetime of Thallium Zeolite Ion Source for Single-Ended Accelerator

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Increase of Lifetime of Thallium Zeolite Ion Source for Single-Ended Accelerator

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Utilizing multiple sintering, we have considerably increased the lifetime of a thallium (Tl) zeolite ion source used in single-ended electrostatic accelerators. The obtained lifetime of a small ion source (6.4 mm in diameter and 10 mm long) is about 4400 μAh (70 μAh/mm^3 for Tl material).

Key words

ion source, beam probing, plasma diagnostics, thallium, accelerator

Probing a plasma cross-section using a heavy ion beam (HIBP) permits us to measure important physical quantities such as the plasma potential and fluctuations in the potential and density.[1] Presently the 2 MeV HIBP on the TEXT tokamak and the 0.5 MeV HIBP on the JIPP T-IIU tokamak use a thallium zeolite ion source in a single-ended electrostatic accelerator. The source is used because of its simplicity, compactness, and low heater power (less than 100W) due to its low temperature operation (1000 °C).[2-5] Replacing an exhausted ion source with a new one requires considerable time and effort. The tasks include pump-down and opening of the accelerator tank which is filled with pressurized SF_6 gas for electrical insulation, opening of the accelerator tube and exchange of the ion source, re-pressurizing the tank with SF_6, the tuning up (gradual increase of the beam current) of the ion source and readjustment of controls to focus the beam. In addition, a larger beam current (10 to 100 μA) which leads to the shorter lifetime of the ion source, is required to study the micro-turbulence of the tokamak plasmas and this reduces the source lifetime. As a result, the lifetime of this ion source is one of the most crucial factors for the operation of a heavy ion beam probe in the MeV range.

The lifetime of the ion sources generally depends on the quantity of the beam material. Since the electric power, space, and cooling method are limited in the high voltage terminal of a pressurized single-ended electrostatic accelerator, a compact ion source is required. We have considerably increased the lifetime of a compact Tl ion source with a new treatment (multiple sintering of Tl zeolite) which increases the quantity of source material in a rather limited circumstance. In

addition, this paper is the first one which discusses the lifetime of a Tl zeolite ion source.

Four types of ion sources are discussed in this paper. In all cases, a housing of alkali-metal ion source[6-8] purchased from Spectra-Mat Instrument has been modified. We drilled a hole of 4.4 mm in diameter and 1.5 mm in depth at the top of the housing as shown in Fig. 1. The hole is filled with a mortar of Tl zeolite dissolved in ethyl alcohol. Tl zeolite is produced by stirring a mixture of sodium zeolite (Linde A) and thallium chloride in the pure water. Thallium ions exchange positions with sodium ions and thallium zeolite is then obtained by filtering the mixture. In all the tests, the ion sources is mounted in a Pierce-type ion extraction electrodes as shown in Fig. 2. The electrode geometry is the same as the ion gun of the heavy ion beam probe on the JIPP T-IIU.[4,5] Thallium ions are emitted from the ion source when the source material is heated and the extraction voltage of 5 kV is applied to the extraction electrode of the ion gun.

The beam current is measured by a Farady cup shown in Fig. 2. The target plate of the Farady cup is made of copper. At an early phase of the lifetime measurement, the current to the extraction electrode (I_{ex}) is observed, but it soon disappears. The target current (I_{ta}) at zero repeller voltage contains the secondary electron current of about 20 % and is nearly equal to the current of the high voltage power supplies at zero extraction current. We use this target current at zero repeller voltage as the target current, since in HIBP measurement, the current measurement including the secondary electron effect is usually performed. The measured lifetime of the first ion source ((1) in Fig.1) was 240 μAh and high current operation (50 μA) is not feasible. The

sintered Tl zeolite looks like ceramic after the initial baking at 900 °C and the volume shrinks to about 40% of the original volume (shaded area). After this observation, we investigated whether the effective volume of the source material could be increased by multiple sintering.

Three more types of modified ion sources (shown in Fig. 1) were made in order to elucidate the volume effect on the lifetime. The second one ((2) in Fig. 1) has the same shape as the first source, but after the initial baking, the hole is filled up again with a mortar. The third source ((3)) has an extension cup made of tantalum (50 μm thick). The cup is filled with zeolite mortar. The fourth source ((4)) has the same shape as the third source, but the cup is filled and baked 3 times to compensate the shrinkage of the sintered zeolite. In this case, the first baking is performed without the extension cup in order to optimally position the sintered zeolite at the bottom of the initial hole of the housing. In the second heating, the extension cup is mounted and filled up with a Tl zeolite mortar.

The first baking (sintering) is performed in vacuum although the zeolite is not activated in air.[7,8] The heater power is increased by 3 W in 5 minutes until an ion current of 50 μA is extracted. The extraction electric field during this procedure is 1 kV/mm. A milky zeolite powder dissolved in alcohol is used when refilling the cup so that it can penetrate into the narrow crevices or cracks produced by baking. The milky zeolite becomes dense mortar after the alcohol evaporates. Figure 3 shows the dependence of the required heater power on the thickness of the sintered ceramic at various extraction currents. The required heater power of the fourth ion source at the last sintering is about 30 W and more than one hour is necessary for the last

sintering. To prepare the fourth ion source, three days are necessary for all of the processes mentioned above.

A typical lifetime measurement of the fourth type of ion source is shown in Fig. 4. The heater voltage is adjusted to keep the beam current roughly at 50 μA. An integrated current is obtained by summing the current until it falls below 5 or 10 μA. The time history has 3 phases. In the first phase, an extraction electrode current is observed. At the second phase, the current is proportional to the heater voltage and the third phase has a decaying ion current.

Table 1 shows the measured lifetime of the 4 ion sources. We first compare the ion sources with equal cup volumes. The difference in lifetime between the first and second ion sources and the difference between the third and fourth ion sources are very large and show the effectiveness of the multiple sintering. It seems that the first ion sources is unstable to gravity during sintering and the shrinkage in the hole, since the beam is extracted horizontally to simulate the extraction of the beam at the accelerator. The second ion source is found to be stable to the gravity at the second baking because of the adhesion to the initial sintered ceramics in the hole. The third ion source is found to be stable to the gravity. After multiple sintering, the lifetime is proportional to the volume as can be seen by comparing the case of the second and fourth ion sources.

The time integrated current of the fourth source is 4400 μAh and 18 times larger than that of the first ion source. The weight analysis of the fourth source after the lifetime measurement, shows that most of thallium atoms contained in the sintered ceramic are emitted as beam ions. The lifetime per unit volume of a Tl zeolite mortar is 70

$\mu Ah/mm^3$. Multiple sintering increases the lifetime by a factor of 2.5. The volume decrease due to baking is much more apparent in Tl zeolite, than in Cs or K zeolite. Multiple sintering is only effective in enhancing the lifetime in Tl zeolite. This may be related to changes in the crystal structure during sintering.

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Reference

1)F. C. Jobes,and R. L. Hickok, Nuclear Fusion **10** (1970) 195.

2)P. M. Schoch, J.C.Forster, W. C. Jennings, and R. L. Hickok, Rev. Sci. Instrum. **57** 1825 (1986).

3)A. Ouroua, T. P .Crowley, R. L. Hickok, P .M. Schoch, K .A. Connor, J. F. Lewis, P.E. McLaren, J. G. Schatz, J. Schwelberger, B.Hoffman, Rev. Sci. Instrum. **63** 4582 (1992).

4)Y. Hamada, Y. Kawasumi, M. Masai, H.Iguchi, A. Fujisawa and JIPP T-IIU.. Group, Annual Review of NIFS, p.118 (1990).

5)Y. Hamada et al., Plasma Phys. Control. Fusion **36** 1050 (1994).

6)O. Heinz and R. T. Reaves,Rev. Sci. Instrum. **39** 1229 (1968).

7)R. K. Feeney, W. E. Sayle II, and J. W. Hooper, Rev. Sci. Instrum. **47** 964 (1976).

8)D. W. Hughes, R. K. Feeney and D. N. Hill, Rev. Sci. Instrum. **51** 1471

(1980).

Figure Captions

Figure 1. Schematics of 4 zeolite ion sources used for lifetime measurements. Length is in terms of mm.

Figure 2. Schematic diagram of the test stand used for lifetime measurement.

Figure 3. Heater power necessary for various beam extraction currents versus thickness of the sintered disk of Tl zeolite ceramics in the initial baking.

Figure 4. A typical time history of a long lifetime Tl ion source. V_{he}, I_{ex}, and I_{tar}, are the heater voltage, extraction current, and target current respectively.

Table captions

Table 1. Integrated current, lifetime, sintered volume, and cup volume of 4 types of Tl zeolite ion source shown in Figure 1.

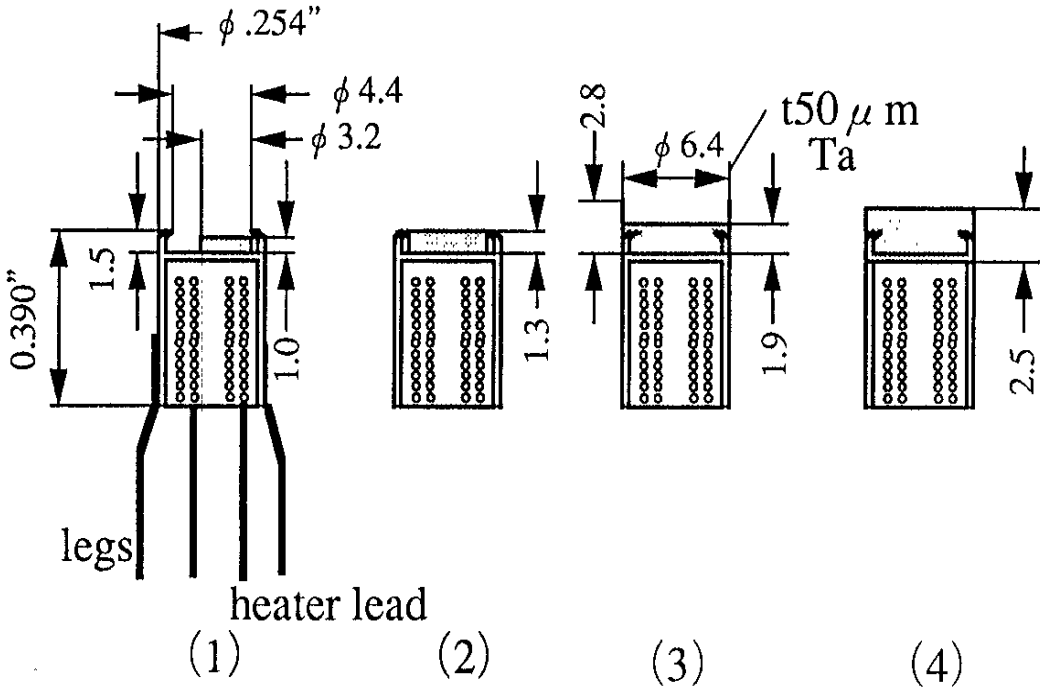
ϕ .254"
ϕ 4.4
ϕ 3.2
0.390"
1.5
1.0
legs
heater lead
1.3
2.8
ϕ 6.4
t50 μ m
Ta
1.9
2.5
(1)
(2)
(3)
(4)

Figure 1

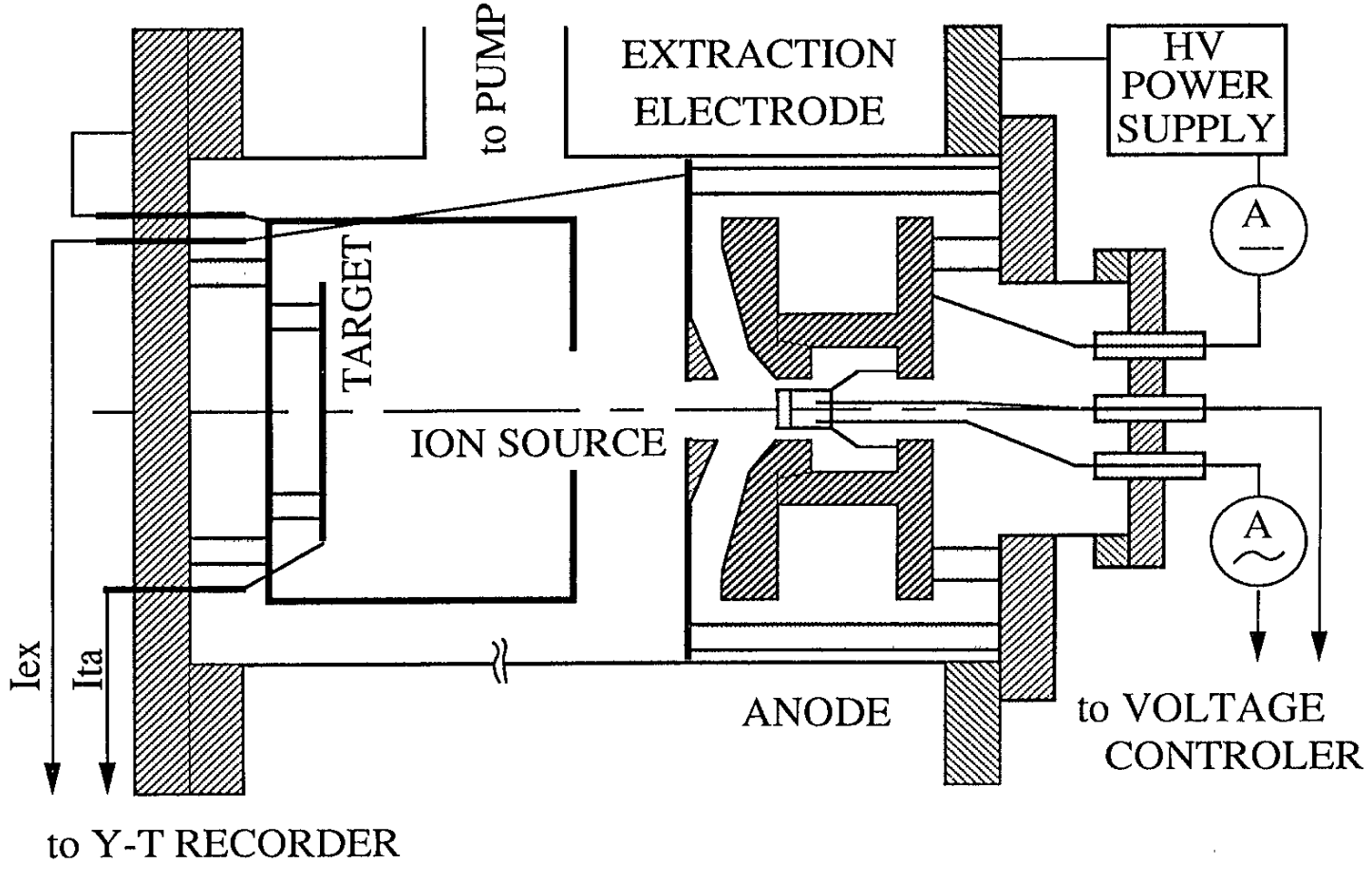
to PUMP
EXTRACTION ELECTRODE
HV POWER SUPPLY
A
TARGET
ION SOURCE
A
Iex
Ita
ANODE
to VOLTAGE CONTROLER
to Y-T RECORDER

Figure 2

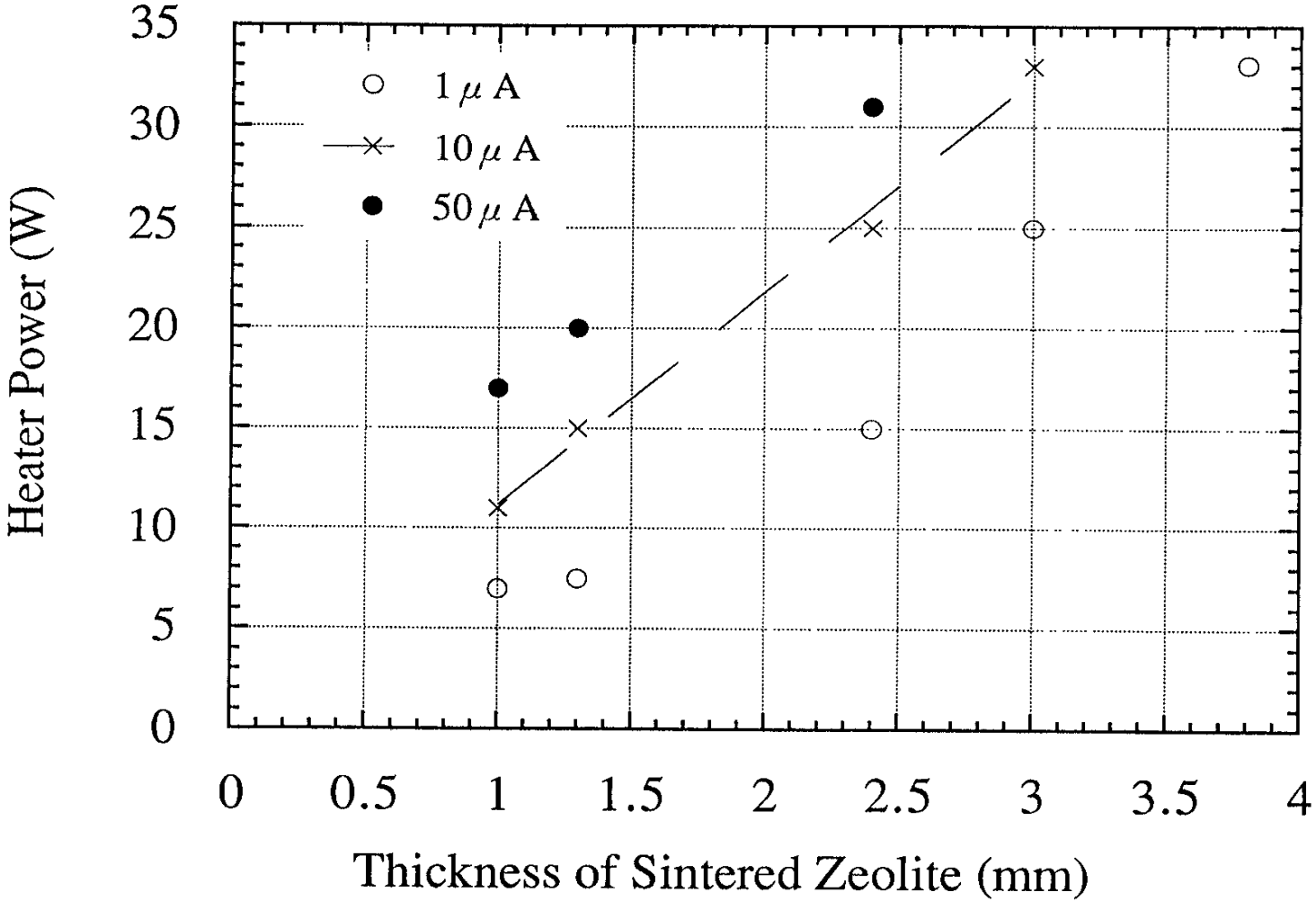
Heater Power (W)
35
30
25
20
15
10
5
0
1 μ A
10 μ A
50 μ A
0
0.5
1
1.5
2
2.5
3
3.5
4
Thickness of Sintered Zeolite (mm)

Figure 3

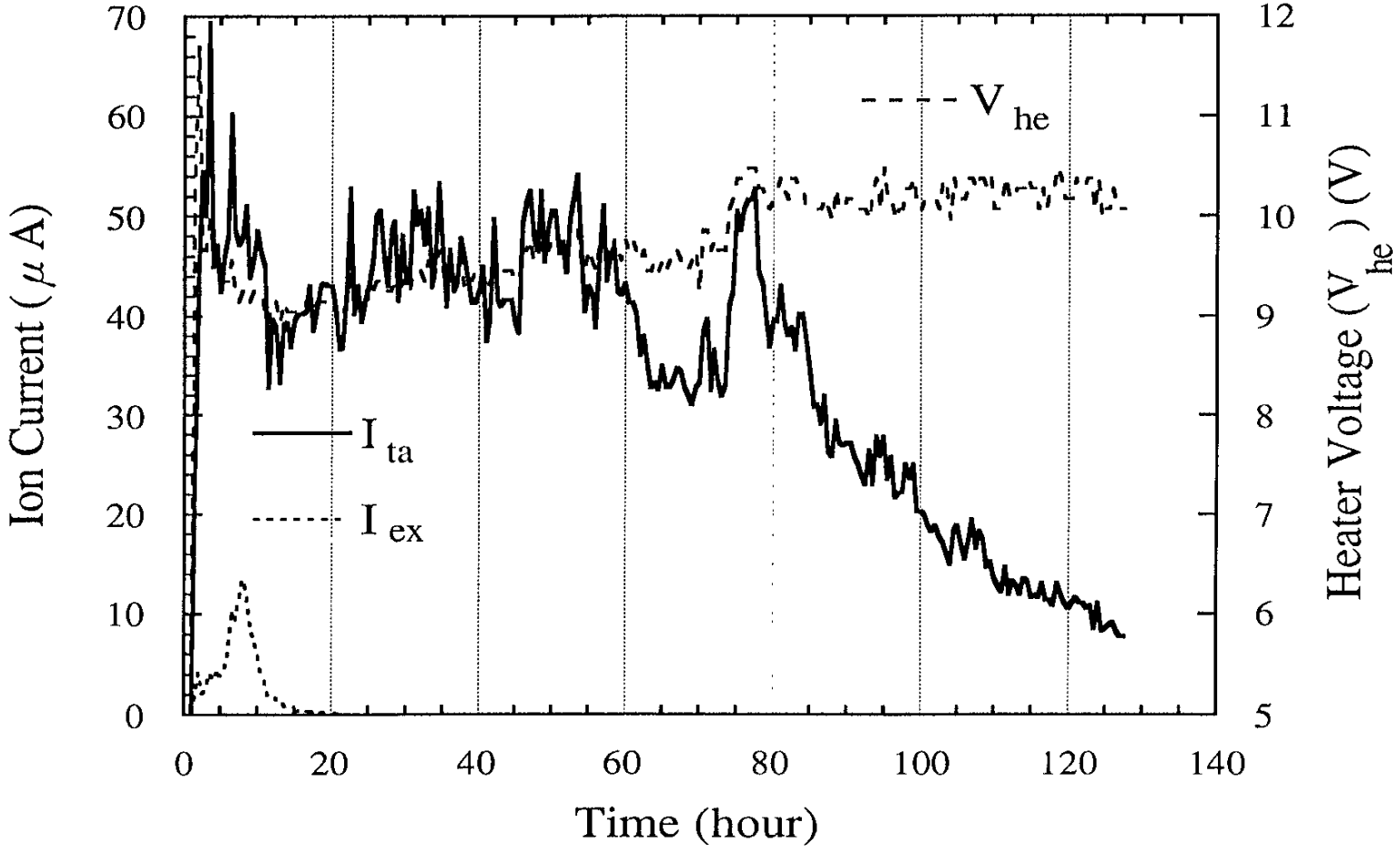
Ion Current (μ A)
Heater Voltage (V_{he}) (V)
Time (hour)
V_{he}
I_{ta}
I_{ex}
0
10
20
30
40
50
60
70
5
6
7
8
9
10
11
12
0
20
40
60
80
100
120
140

Figure 4

type	time integrated current (μ Ah)	lifetime (h)	zeolite volume (mm^3)	cup volume (mm^3)
1	243	35.5	8.04	22.8
2	1951	71	19.8	22.8
3	1213	61	22.6	64.6
4	4421	127.5	54.9	64.6

Table 1

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