C-4-4 B, Sb and Si Liquid Metal Alloy Ion Sources for Submicron Fabrication

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There is a growing interest in liquid metal ion sources to obtain fine beams with a high brightness and to apply for ion beam lithography, direct doping and ion milling, and microprobe analysis. Ga ion sources are stable and may be important for ion beam lithography. B and Sb ion sources are important not only for ion beam lithography but also for direct doping and other applications.

We have first succeeded in fabricating B, As and Si ion sources using liquid metal alloys, and the present work is the extension of our previous works. We achieved a significant improvement in the B sources and succeed in fabricating a stable n-type dopant (Sb) ion source.

The emitter tip was made of tungsten wire for B and Si sources or nickel wire for Sb sources with a diameter of 300 μm and spot-welded to tungsten heater. The emitter temperature was set slightly above the melting point (~800°C for the B alloys and ~300°C for Sb alloys). Alloys used were B-Pt-Ni for B source, Sb-Pb-Au for Sb sources and Au-Si for Si sources.

Typical current-voltage characteristics for the Sb alloy ion sources is shown in Fig.1. The angular current intensity was ~80 μA/sr at the extraction voltage of ~5.2 kV.

Fig. 2 shows mass spectra for the Sb alloy sources measured after 3.5 (a) and 7 hours (b) of a continuous operation. It is clear that the Sb sources can be operated for more than 7 hours without significant change in mass spectra.

The observed fraction of various ion flux intensity for the B and the Sb sources is summarized in Tab. 1. The ion flux intensity in the table is reduced to the singly-charged ion, i.e., the fractions of a doubly-charged ion flux and a di-atomic molecular ion flux are half and twice of the observed ion current intensity, respectively. For the B sources, singly-charged ^{11}B ion was dominant and 33 % of the total ion flux. This is a significant improvement over our previous ion source. The B sources were stable for more than 10 hours.

Total energy distribution of the ion beams for B alloy and Sb alloy sources were also measured. It was observed that the energy width varied with a ~ almost square root of the total ion current (I_s). The angular current intensity of singly charged ^{11}B and Sb was 33 μA/sr and 1.4 μA/sr, respectively, at a total energy spread (FWHM) of 20 eV. For B, these values are comparable with a Ga liquid metal ion source. We can expect that for singly-charged B and Sb, the energy spread is smaller than the total energy spread because of the smaller e/m ratio among other ion species.

In summary, we fabricated stable B and Sb liquid metal ion sources which is important for submicron fabrication. The ion intensity of B is significant. The Sb source is very promising for a n-type dopant ion. We expect to increase the Sb ion current by optimizing the alloy composition.

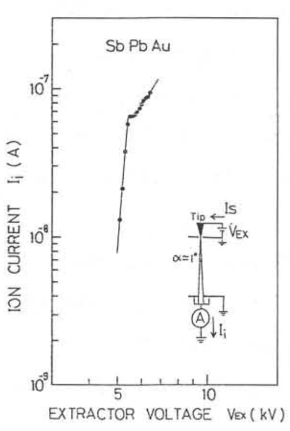
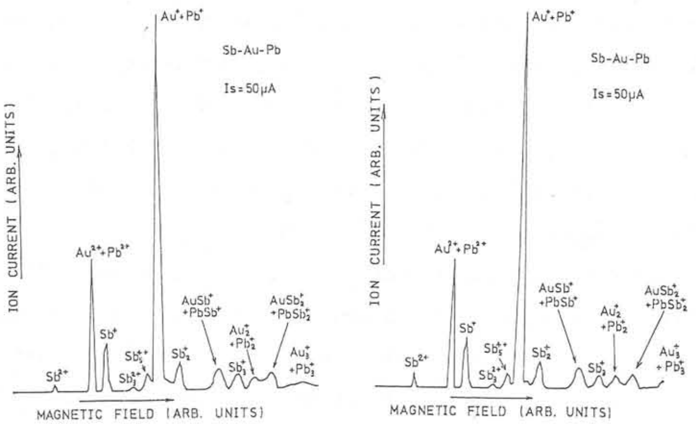


Fig. 1 Typical current-voltage characteristics of a Sb alloy source.



(a) (b)

Fig. 2 Typical mass spectra of ion beams for a Sb alloy source. (a) after 3.5 and (b) 7 hours.

Source material composition (at. %)	in flux fraction (%)
Sb Pb Au 50 42 8	Sb^+ 6.8, Sb^{2+} 0.9, Sb_2^+ 7.3, Sb_3^+ 5.5, Sb_3^{2+} 0.7, Sb_5^{4+} 2.4, Au^++Pb^+ 49.7, $Au^{2+}+Pb^{2+}$ 8.4 $Au_2^++Pb_2^+$ 3.7, $Au_3^++Pb_3^+$ 3.1, $AuSb^++PbSb^+$ 5.7, $AuSb_2^++PbSb_2^+$ 5.8
B Ni Pt 60 13 27	$^{10}B^+$ 8.1, $^{11}B^+$ 33.0, B^{2+} 0.5, Ni^+ 10.6, Ni^{2+} 4.8, Ni_2^+ 3.7, Pt^+ 24.2, Pt^{2+} 12.3, Pt_2^+ 2.9

Tab.1 Alloy and ion current compositions for Sb and B alloy sources.