Emission Characteristics of Liquid Metal Alloy Ion Sources of $Au_{60}Be_{40}$ and $Au_{61.6}Si_{22.8}Be_{15.6}$

by

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A number of studies of a liquid metal alloy ion source providing a source of Be ions for implantation, resist exposure and imaging have been carried out.[1,2] For the most part previous investigations have utilized a Au-Si-Be alloy for the source of Be. Typically, the total Be content observed in the beam at low total currents was < 3% for the $Au_{61.6}Si_{22.8}Be_{15.6}$ source and appeared mostly as Be^+ and Be^{2+}. In contrast, for the $Au_{40}Be_{60}$ the total Be content was 12 to 14 % depending on the total source current. For both alloys a minimum energy spread (full width at half maximum (FWHM)) of 5 to 6 eV/charge was observed for Be^{2+}. For focused ion beam (FIB) column analysis one needs values for the FWHM and the corresponding angular intensity (I') which was missing from previous studies. For FIB applications the contribution to the focused beam is primarily the chromatic aberration and de-magnified virtual source size. It can be shown[3] that the key source parameter for maximizing the beam current for a given focused beam size is given by: $I' / (FWHM/charge)^2$.

In this study we compare emission characteristics for the alloy sources $Au_{60}Be_{40}$ and $Au_{61.6}Si_{22.8}Be_{15.6}$. The binary Au-Be alloy forms a eutectic at the $Au_{60}Be_{40}$ composition which melts at 875 K. However, the beam composition was in the range of $Au_{85}Be_{15}$ thus causing an enrichment of Be in the liquid phase and forcing the source to operate ~ 990 K as expected from the phase diagram. Nevertheless the vapor pressure of Au (the more volatile of the two elements) is estimated to be < $1x10^{-8}$ torr which is still in an acceptable range for liquid metal ion sources. According to the phase diagram an alloy composition of $Au_{50}Be_{50}$ leads to compound formation of AuBe with a melting point of 1003 K.

This study was carried out with a high resolution mass spectrometer from which both beam composition and energy spread were obtained. The single and double charged species of Au and Be from the $Au_{60}Be_{40}$ source accounted for 92% of the beam composition with a variety of charged clusters of Be and Au and compounds of the form Au_mBe_n constituting the remainder of the beam composition. Fig. 1 gives the relative amounts of the principal species in the beam for the binary source. Figs. 2 and 3 show the total energy distribution (TED) for the Au and Be species at 5 µA total current. The singly charged species show significant tails on both the high and low energy sides of the TED. The FWHM values of the principal species vs. total current, shown in Fig. 4, increase with current and mass due to coulomb interactions in the high current density beam. The figure of merits at 5 uA for Be^{2+} are 223 and 28 nA/sr-V^2 for the binary and ternary alloy sources respectively thereby showing the superiority of the binary source for probe formation applications.

[1] H. Arimoto and T. Fujii , J. Va. Sci. Technol. **B9 (5)** , 2578 (1991)

[2] K. Gamo, T. Matsui and S. Namba, Japan J. Appl. Phys**. 22 (11),** L692 (1983)

[3] L. W. Swanson, Appl. Surface Sci. **76/77**, 80 (1994)

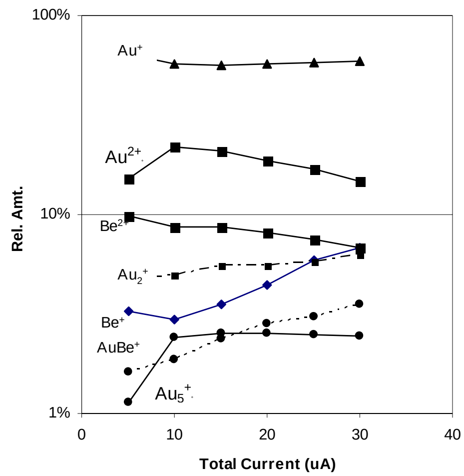

Figure 1. Graph shows the major species observed in the $Au_{60}Be_{40}$ alloy source versus total source current.

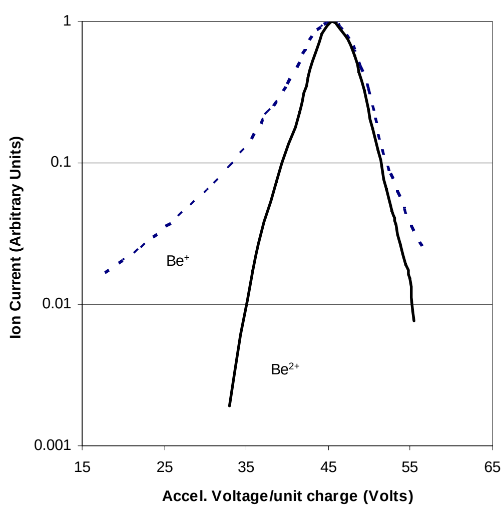

Figure 2. The energy distribution curves for Be^{+} and Be^{2+} are shown at 5 µA source current for the $Au_{60}Be_{40}$ alloy source. The I' values for Be^{+} and Be^{2+} are 1.1 and 6.4 µA/sr respectively.

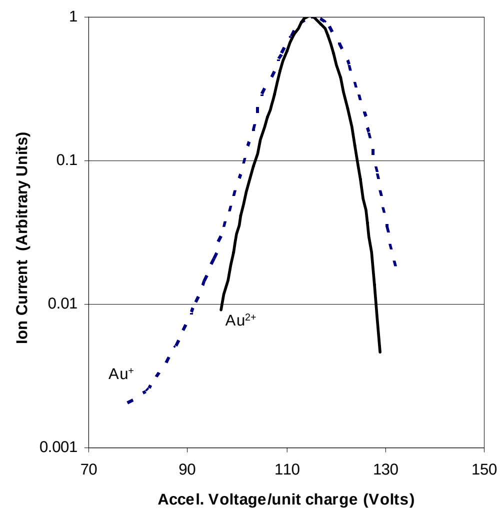

Figure 3. The energy distribution curves for Au^{+} and Au^{2+} are shown at 5 µA source current for the $Au_{60}Be_{40}$ alloy source. The I' values for Au^{+} and Au^{2+} are 21 and 9.9 µA/sr respectively.

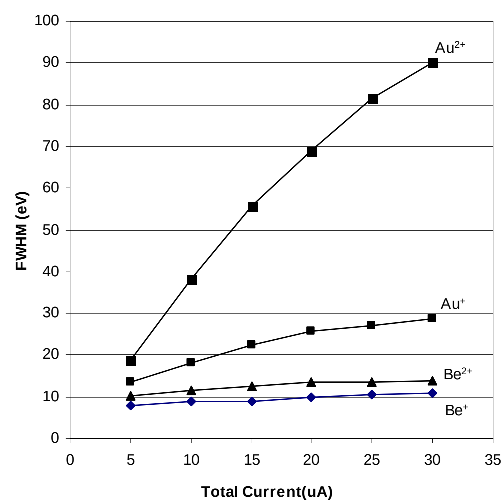

Figure 4. The FWHM values versus total source current are shown for the indicated species for the $Au_{60}Be_{40}$ alloy source.