Ion Plasma Sputtering Developments with the 14Gz AECR-U Ion Source

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The 14GHz Advanced Electron Cyclotron Resonance ion source, AECR-U[1], is one of two ion sources which provide ion beams for regular operation to the 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory. During fiscal year 2005, approximately 30% of cyclotron beam time was dedicated to the acceleration of cocktail beams provided by the AECR-U for the space radiation effects testing program[2]. Cocktail beams require several different ions at the same mass over charge ratio, many of which can only be produced from solid material. The ion sources at the 88-Inch cyclotron utilize high and low temperature ovens[3] for introducing solid material into the plasma. To increase the variety of cocktail ions available, an additional method of sputtering solid material into the plasma has been developed for routine cyclotron use.

To sputter material into the discharge plasma ions are accelerated towards a negatively biased target placed on the edge of the plasma region. If the kinetic energies of the bombarding ions exceed the binding energy of the target material, atoms are dislodged from the surface of the sputter probe[4]. These atoms can then diffuse into the plasma region to be ionized. On the present sputter probe up to three different target materials can be mounted at the end of a tantalum holder. The targets are positioned just outside the plasma region through one of the six radial ports available at the AECR-U. Negative voltages of up to –5 kV are applied to the probe for sputtering.

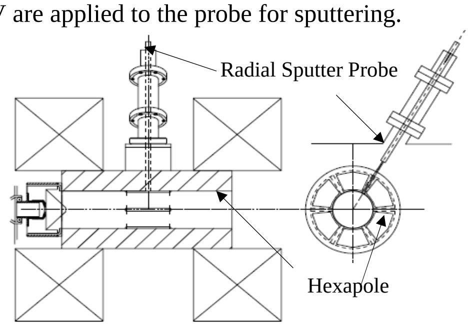

FIG 1. Schematic of the AECR-U with Radial Sputter Probe

During development a moveable, single material sputter probe was used to find the optimal radial distance of the probe to the plasma. The probe distance was varied with respect to the inner edge of the hexapole structure (at the chamber wall, 3.8 cm from the center of the plasma chamber) to about 1 cm inside the hexapole structure (4.8 cm from center of chamber).

Results for obtaining high charge state gold ions at different probe positions can be seen in fig.2. As the probe is moved further away from the plasma, higher bias voltages are required to sputter material into the plasma. When positioned at or near the wall of the chamber, closer to the plasma, the output of high charge states such as Au^{40+} drops significantly with increasing probe bias voltage. The charge state distribution shifts to lower charge states as a result of the increased flux of target material entering the plasma. This shift of the peak of the charge state distribution at 0.3cm from the wall is shown in fig.3. Since the applied program at the 88-Inch Cyclotron requires very high charge states, a position of 0.6cm from the plasma chamber wall was chosen for optimum high charge state production. A peak current of 2.3 eμA of Au^{38+} was produced by the LBNL AECR-U. In comparison the Texas AMU 6GHz source reached a peak intensity for Au^{38+} of 1.1 eμA.[5]

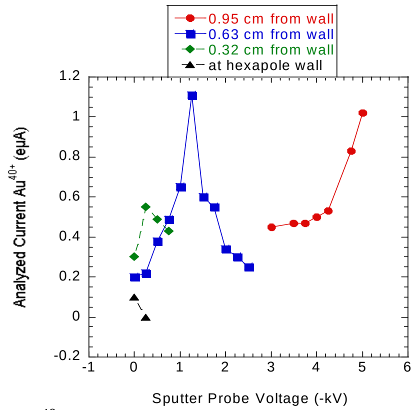

FIG. 2 Au^{40+} beam current extracted from the AECR-U ion source at varying distances from the wall of the hexapole magnet structure.

The Argonne PII-ECR ion source, a 14GHz source similar to the AECR-U, operates for production of medium to low charge states. With a sputter probe positioned at the wall of the chamber, the PII-ECR source obtained peak beam intensities for $^{238}U^{27+}$ of 38 eμA, and for Au^{22+} of 17 eμA.[6]

To optimize for production of medium to low charge states in the LBL AECR-U, the probe was positioned closer to the plasma, 0.3cm from the chamber wall. A peak beam intensity of 23.6 eμA Au^{27+} was produced by a sputter voltage of –500V.

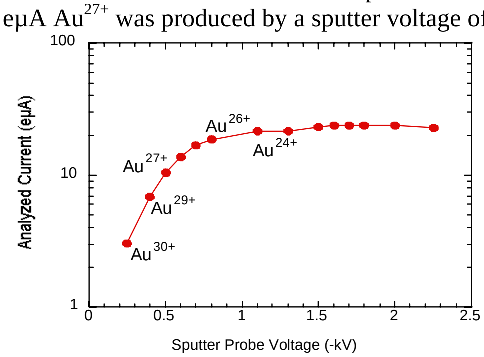

FIG.3 Beam intensities of sputtered gold at probe position .3cm from chamber wall. Peak charge states indicated on spectrum.

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