RF Plasma Ion Source Developments

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The aim of this project is to develop low-density, plasma-sputter negative ion sources as well as high-efficiency, high-density positive ion sources, based on RF-plasma excitation, for potential use for radioactive ion beam (RIB) generation. Besides the advantage of low cost and easy maintenance, RF source enclosures operate at low temperatures, allowing the efficient ionization of elements like C, N, O which are chemically reactive at high temperatures. Fig. 1 shows a proposed ion source for generation of radioactive ion beams.

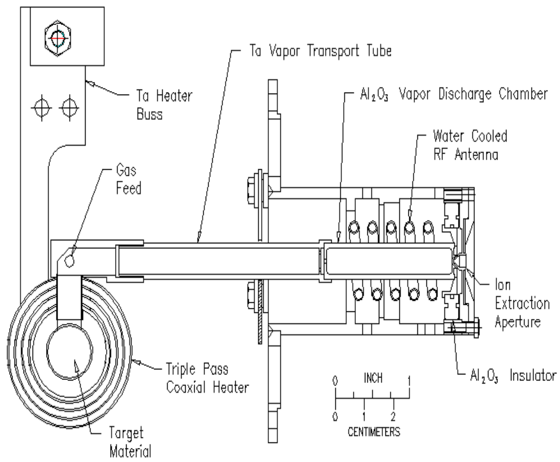

Fig. 1: Positive RIB Ion Source

A RF-plasma diagnostic test stand was constructed for use in designing and optimizing RF antennae, RF matching network systems and Langmuir probes; for determining RF power/plasma coupling efficiencies, antenna radiation patterns and for measuring the fundamental properties of RF generated plasmas. The test stand enables the rapid interchange of prototype RF antennas and Langmuir probes for their respective evaluation in igniting and measuring fundamental properties of plasmas.

The RF system consists of an 80 MHz amplifier, a matching network and the specific antenna for evaluation. A manual tuned matching network was designed for matching the impedance of the generator and antenna. RF diagnostic tools such as a grid dip meter, RF voltage meter, a field strength meter and an R-X meter were used to increase the tuning range and power handling capabilities of the network. Langmuir probes are routinely used to determine fundamental properties of plasmas including: electron densities, electron temperatures, plasma potentials and degrees of ionization. These parameters can be derived from the electron/ion signals measured with the probe submerged in the plasma. A Langmuir probe system, including a cylindrical RF blocking capacitor, a gas feed line and a pressure barrier was designed, constructed and used to measure the plasma parameters.

Up until the present time, the major thrust of the work has been directed toward optimally designing, developing and evaluating high-Q RF antennae that will efficiently couple RF power into plasmas. The key to successful use of this technique for high efficiency ion source applications depends on the degree to which this objective can be met. Thus far, we have designed and evaluated eight different RF antenna designs. Each antenna is evaluated on the basis of the power required to ignite the plasma, the minimum pressure required for ignition and the properties of the plasmas they produce. For example, the evaluative procedure includes measurement of plasma density as a function of magnetic field strength, operating pressure and applied RF power for each antenna design. A discharge can be maintained at a power level as low as 1 W and stable operation can be achieved at levels as low as 5 W.

In developing the antennae, a technique was discovered which greatly reduces the time required to reach an optimum design. The technique is to vary the coil spacing so that the coil, in combination with the RF feedthrough are resonant at the operating frequency of the RF power supply (in our case, 80 MHz). So far the highest plasma densities were achieved for a 4 turn, self resonant helical antenna (30.5 mm OD), at a magnet field strength of 560 Gauss, a RF power of 200 W and an Ar pressure of 1.8 mTorr. Under these conditions, the electron density reaches values of $5x10^{12}cm^{-3}$, corresponding to an ionization efficiency of about 10%. We have reached an optimum design for initial use in generating plasmas for plasma-sputter negative ion source applications. In the near future, we will apply the same principles and techniques in the optimum design of a small diameter antenna for potential use in generating positive radioactive ion beams.