# Radiation Resistant and Disposable ECRs

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R&D for ISOL Systems

ECRs are considered the best choice as ISOL ion sources for noble gases and other gaseous elements or molecules. To minimize losses, the ECR needs to be as close to the target as possible. This exposes the magnets that produce the plasma confining fields to very high radiation doses. Therefore, the ECRs need to be either radiation resistant or cheap and easily replaced. ISAC [1,2] and GANIL [3] have solved the problem by different methods. ISAC uses a source with coils and GANIL with disposable, small sources that confine the plasma with permanent magnets.

The best permanent magnetic materials (NdFeB) are fairly radiation sensitive. On the order of $10^{16}$ n/cm$^2$ of neutrons will severely affect their integrity [4]. The rare-earth cobalts, SmCo, for example are perhaps ten to 10000 times more radiation resistant, but have lower residual inductions. This would require more material to generate the same magnetic field configuration. Additionally, SmCo is significantly more expensive. The only practical approach is to make them very small, so the volume of expensive material is minimized. This is the GANIL approach.

The ECR at ISAC uses potted coils and encases them in a tight container so as the insulation is gradually destroyed it is trapped and the lifetime of the coil extended. It's unclear just how far this approach can be used because epoxies are converted to gas [5] at some level. Depending on the epoxy system, gas is evolved at rates of 0.3 to 1 cm$^3$ per gram per MGy. The ISAC expected dose rate is $10^5$ Gy/hr for a 50 kW target. Given a similar position, and hence exposure, the rate will be almost 1 MGy/hr. At an assumed average gas evolution rate of 0.5 cm$^3$/g-MGy, the epoxy will lose about 10% of its mass per year. This approach does not appear practical for RIA. There are some newer epoxies, being developed by Composite Technology Development under various SBIRs that show promise, but they would require testing. Even then, gains would probably be factors or 2 or maybe 5 – not sufficient to give confidence to this approach. Going to an all-inorganic coil system is a possibility that is being addressed in other R&D proposals.

The alternative is to use ECRs that are compact, cheap and easy to replace [1,2]. Somewhat larger systems are also used primarily as charge breeders in the $1+n^+$ systems [6], but would be too large and costly to be replaced frequently. Since we only required them to produce singly charged ions from a gas feed, they do not need to be very large or complicated. Ion sources used for ion implantation routinely produce milliamps of one plus ions and are very compact [7]. Sources produced at MSU have outside diameters of

58 mm and only 150 mm in length [8]. Other small sources have been produced and characterized [9]. Some of them are presented in Figure 1. A very small non-ECR plasma discharge source is seen in Figure 2.

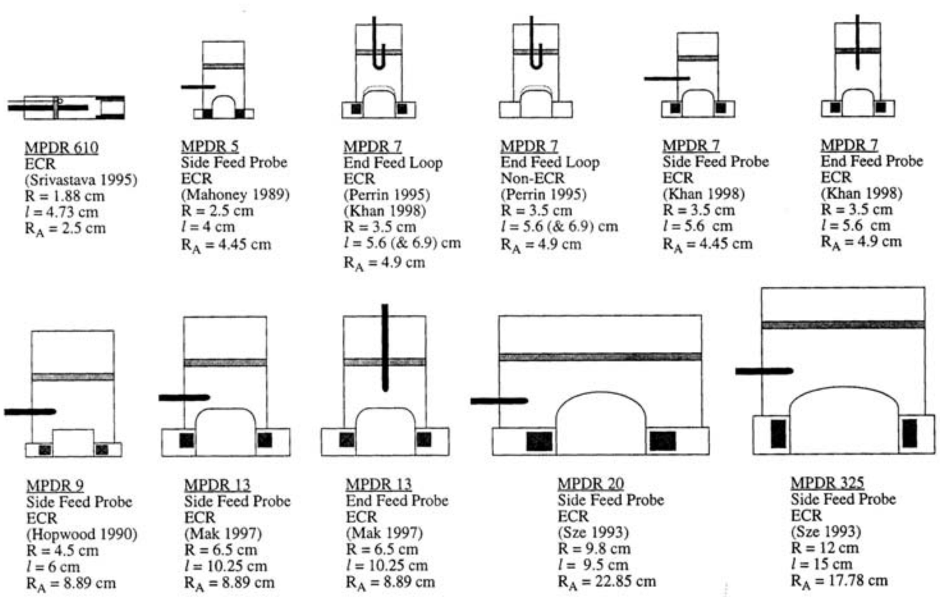


Figure 1. Some of the microwave plasma sources produced by the MSU Electrical Engineering Department in the last 30 years.

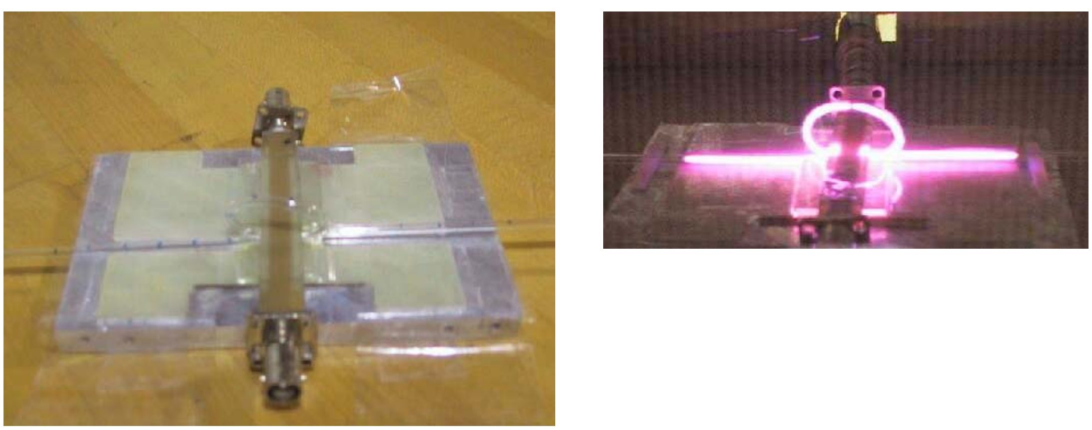

Figure 2. Miniature plasma discharge source. The glowing tube on the right is 2 mm in diameter.

The ISOL sources would not be required to produce large currents, but would need to be very efficient and have short holdup times to limit losses in the source-to-target chain. The small ones, such as the one in use at GANIL have ionization efficiencies of 14-95% [3]. Release time is typically 100 ms [10]. Improvements in release times would obviously improve the numbers of short-lived species and improved ionization efficiencies for things like neon would also increase the ion sent on. All of these ECRs do require high voltages for extraction and RF for ion production. All of these components would need to be radiation resistant, of reasonable cost, reliable and preferably not be activated with long half-life nuclides.

We propose to develop, design and test a compact, radiation resistant, and disposable microwave ion source that efficiently produces a singly charged ion beam. The source will be adaptable to efficiently produce ions from a variety of feed gas mixtures. The design approach will include (1) optimized source size with over all compactness a goal, (2) efficient and adaptable/tunable microwave coupling and ion beam extraction technologies, (3) use of cheap, radiation resistant materials and (4) employment of low cost microwave and vacuum technologies. Toward the goals of compactness, radiation resistant and low cost we will investigate methods of efficiently producing the appropriate microwave plasma with simple and low cost ECR magnetic configurations, and also will investigate the utility of employing lower magnetic field strengths, i.e. non-ECR magnetic fields, or even entirely removing the static magnetic fields. Certainly an efficient microwave plasma source operating without magnets considerably reduces the cost, complexity, and improves the radiation resistant properties of the ion source. Recently in our MSU laboratories we have demonstrated the ability of efficiently creating low-pressure microwave discharges without an applied static magnetic field. We will apply this microwave coupling technology and engineering know how to the source design and prototype construction. Modeling, production and testing would be undertaken.

The investigation, development, and application and commercialization of microwave discharge/plasma technology have been active research topics in the MSU Department of Electrical and Computer Engineering for over thirty-five years. The MSU electrical engineering research team has made important contributions to the fields of microwave plasma, free radical, and ion source technology and to microwave plasma assisted materials processing. Both very small and very large ECR and non-ECR plasma sources have been developed and have been applied to a variety of applications. These applications include large area ECR plasma submicron plasma etching for semiconductor processing, compact ECR plasma sources for molecular beam epitaxy, microwave plasma sources for ion and electrothermal spacecraft propulsion, microwave plasma assisted chemical vapor deposition (CVD) thin film deposition--- especially microwave plasma assisted CVD synthesis of diamond. Research efforts have focused on the invention, the engineering development, the experimental diagnosis, the numerical modeling, and the practical application microwave plasma technology, and have resulted in many useful microwave plasma and material processing devices from space engines to material processing machines. Much of this past work has been summarized in several publications [11- 15]. The NSCL, likewise, has expertise in ECRs, radiation resistant magnets and accelerators. The combination would provide a good base for examining the production of cheap and efficient ECRs or non-ECR plasma sources for ISOL beam production.

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