Radiation Resistant and Disposable ECRs

Al Zeller and Peter Zavodszky
NSCL/MSU
J. Asmussen and T. Grotjohn
Dept. of Electrical Engineering
MSU

ISOL target to accelerator chain:

1. Effusion out of the target
2. Transport to ion source
3. Ionization and extraction from source
4. Transport to post-accelerator

Opportunities for losses in all the above.

Try to minimize loss in the source. Requires:

- **Efficient ionization**
- **Rapid release**
- **Minimize contamination with unwanted species and carrier gas**

Must operate in a very high radiation environment

Produce 1^+ charge state for every nuclide

Present models:
ISAC – 50 kW
GANIL

Different solutions to the problem:

ISAC – ECR with electromagnets encased in copper container
GANIL – small ECR with permanent magnets replaced every two weeks

Permanent magnets:

- No power supply to float on high-voltage platform
- No tuning needed
- Expensive material (NdFeB or SmCo)
- Susceptible to radiation and thermal damage
- No tuning possible

Active coils:

- Tuning possible
- Inexpensive materials
- Can be made radiation resistant to some degree
- Can operate at elevated temperatures
- Need power supplies
- Require connections that need to be changed when source is changed

GANIL has made ECRs as small as 3.5 kg, with small volumes to minimize ionization times and be cheaper to replace.

Ionization efficiencies range from 14-95%

Retention times in ECR source are ~100 ms, so short half-life nuclides have high losses. (ISAC)

ISAC radiation estimate on ECR is 10^5 Gy/hr. RIA would be 8 times more. Going to a more radiation resistant epoxy might give a factor or 2-4 increase in lifetime.

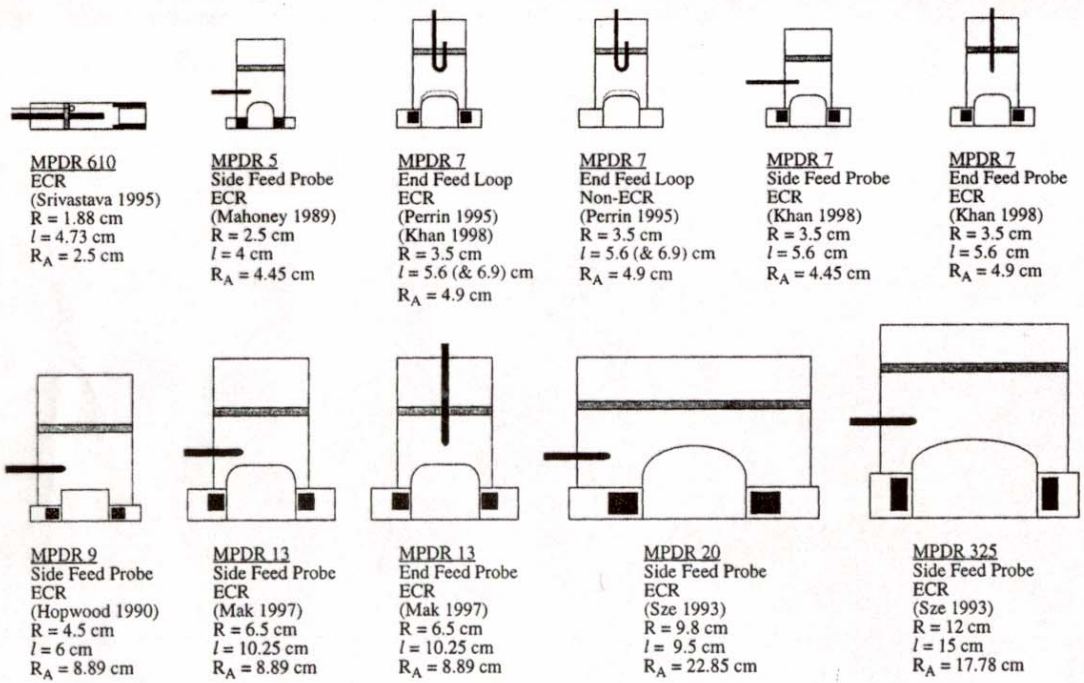
Problems, exist, however in the evolution of gas from the epoxy at 1 MGy/hr. At an average evolution rate of 0.5 cm^3/g-hr, 1% of the epoxy will be converted to gas in a month. (8 liters per kg)

MSU Engineering Department has 35 years of experience in producing microwave discharge/plasma technology, including small ECRs capable of producing milliamps of 1^+ beams.

Sources have been made as small as 58 mm OD and 150 mm long.

ECR Microwave Plasma Sources

Work on microwave plasma sources and reactors has been underway at MSU for over 30 years. Several of the variations in reactor designs are shown in the figure below.



MPDR 610
ECR
(Srivastava 1995)
R = 1.88 cm
l = 4.73 cm
R_A = 2.5 cm

MPDR 5
Side Feed Probe
ECR
(Mahoney 1989)
R = 2.5 cm
l = 4 cm
R_A = 4.45 cm

MPDR 7
End Feed Loop
ECR
(Perrin 1995)
(Khan 1998)
R = 3.5 cm
l = 5.6 (& 6.9) cm
R_A = 4.9 cm

MPDR 7
End Feed Loop
Non-ECR
(Perrin 1995)
R = 3.5 cm
l = 5.6 (& 6.9) cm
R_A = 4.9 cm

MPDR 7
Side Feed Probe
ECR
(Khan 1998)
R = 3.5 cm
l = 5.6 cm
R_A = 4.45 cm

MPDR 7
End Feed Probe
ECR
(Khan 1998)
R = 3.5 cm
l = 5.6 cm
R_A = 4.9 cm

MPDR 9
Side Feed Probe
ECR
(Hopwood 1990)
R = 4.5 cm
l = 6 cm
R_A = 8.89 cm

MPDR 13
Side Feed Probe
ECR
(Mak 1997)
R = 6.5 cm
l = 10.25 cm
R_A = 8.89 cm

MPDR 13
End Feed Probe
ECR
(Mak 1997)
R = 6.5 cm
l = 10.25 cm
R_A = 8.89 cm

MPDR 20
Side Feed Probe
ECR
(Sze 1993)
R = 9.8 cm
l = 9.5 cm
R_A = 22.85 cm

MPDR 325
Side Feed Probe
ECR
(Sze 1993)
R = 12 cm
l = 15 cm
R_A = 17.78 cm

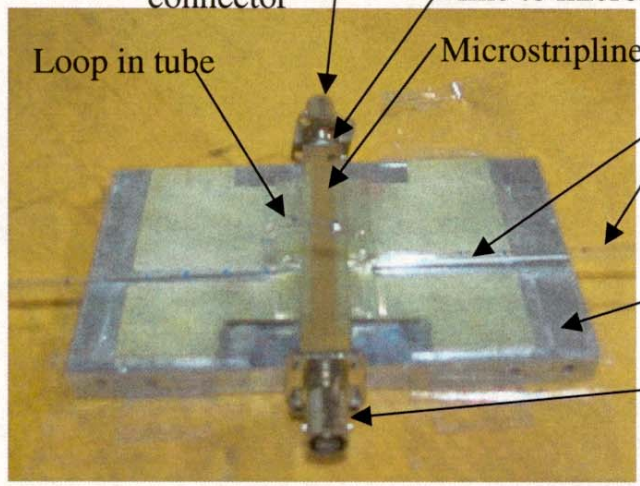
Miniature Plasma Sources

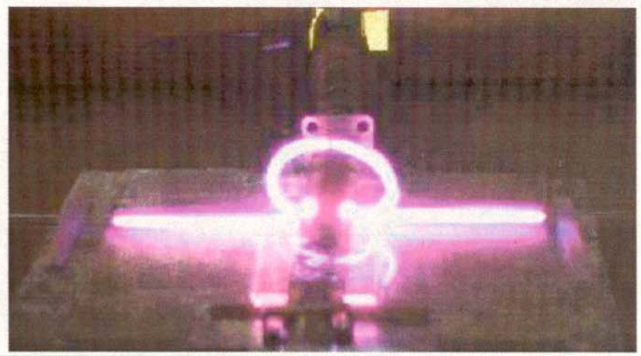
Explore experimental methods and applicator circuits for creating very small microwave discharges with dimensions from 200 microns to 2 mm.

Determine the experimental behavior of these discharges.

Possible Applications include:

- **Local area deposition of protective films- local area plasma torch**
- **Coating the inside of small tubes, parts etc.**
- **Plasmas-on-a-chip: spectroscopy or sterilization**





Proposed R&D

1. optimize source size
2. make efficient and adaptable microwave coupling and ion beam extraction
3. make use of cheap/radiation resistant materials
4. use low cost microwave and vacuum technology
5. investigate non-ECR magnetic configurations
6. modeling of sources

7. investigate rapid ionization to reduce retention times
8. investigate sources that don't use magnets for plasma confinement