APPLICATION NOTE [BD01]

Impedans PLASMA MEASUREMENT

B-Dot probe measurements in an ICP discharge

THE STUDY

This study focuses on alternating magnetic field measurements in an RF ICP discharge using a B-Dot probe. B-Dot probes can be used to determine the plasma current, electric field and the complex conductivity for the alternating magnetic field measurements. B-dot probes have been used in inductive plasmas since the early days and their application and development continues.

THE EXPERIMENT

A new development in the B-Dot technology is the use of bare double loop probes to simultaneously measure dBz/dt and dBr/dt. The spatial coordinates refer to the cylindrical experimental system shown in figure 1 which has an internal coil that extends along the z axis.

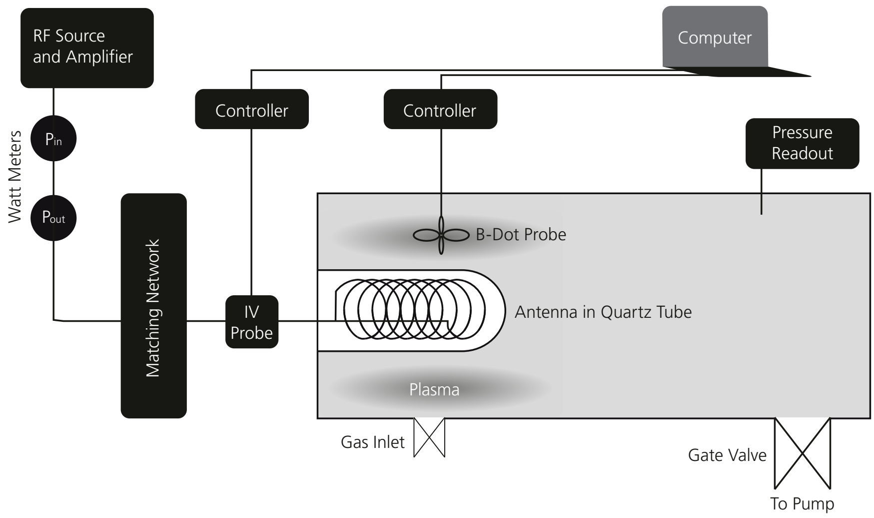

Figure 1: Experimental setup

The radio frequency coil current produces an oscillating B field in the z direction. The oscillating B field induces an E field which drives the plasma current in the azimuthal direction. The B-dot probe has one circular loop which measures Bz(r) while the other loop is a figure of 8 which provides the spatial derivative of Br with respect to z. The probe is scanned in the radial direction, from quartz tube to the reactor wall, and the resultant B field strength is calculated.

The rejection of the RF common mode (capacitive pickup) signal on the loops is critical for accurate measurement to B-Dot signal. The common mode signal is rejected using a Faraday shielded balun transformer i.e.

the primary and secondary windings are separated with a grounded electrostatic shield. A simple schematic of the single loop measuring circuit is shown in figure 2.

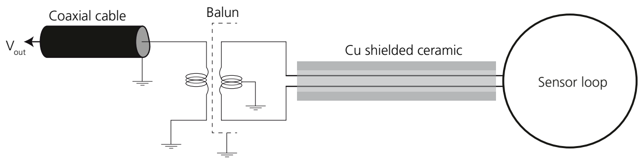

Figure 2: Schematic of the single loop B-Dot probe element

The single loop is calibrated by immersing it in a known magnetic field generated at 13.56MHz using a solenoid. For the geometry of the experimental system shown in figure 1 the following expression is true; ∇×B=0=dBz/dr-dBr/dzB. Therefore the figure of 8 loop can be calibrated against the single loop by performing a vacuum measurement in the plasma chamber.

As the probe is scanned from the quartz tube to the reactor wall the radial profiles of Bz and dBr/dz. Differentiating Bz with respect to r allows the azimuthal electric field Eθ(r) and the current density Jθ (r) to be calculated from the appropriate Maxwell's equations:

$$E_\theta(r)=10^{-8}\,\frac{i\omega}{r}\int_0^r r'B_z(r')dr'$$

$$J_\theta(r)=\frac{10}{4\pi}\left(\frac{dB_r}{dz}-\frac{dB_z}{dr}\right)$$

where r and z are in cm, B is in Gauss, E in V.cm-1 and J in A.cm-2. The integral in equation (1) is performed by assuming that E = 0 at the outer metallic wall of the vacuum chamber.

RESULTS AND FINDINGS:

Typical results are illustrated in this section. The single loop is scanned in the radial direction to measure Bz versus r in an Argon plasma at 100mTorr with 100W of RF power supplied. The result is shown in figure 3. There is a radial drop in magnetic field strength moving away from the coil location due to the cylindrical geometry as expected.

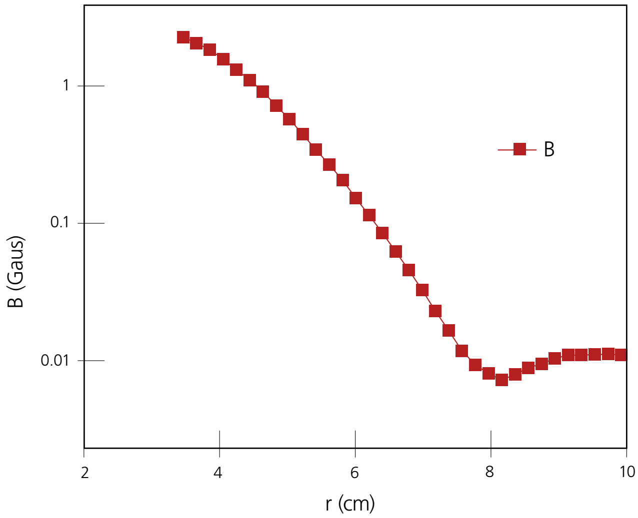

Figure 3: Radial profile of the Bz magnetic field strength measured with the single loop

In figure 4 a graph of dBr/dz from the figure of 8 loop is presented as a function of radial position across the reactor. In this figure a plot of the first derivative of Bz with respect to r (dBz/dr) is also shown. In this particular reactor geometry it is clear that the dBr/dz term is much smaller than dBz/dr term but it is not insignificant and should be taken into account when calculating Jθ (r).

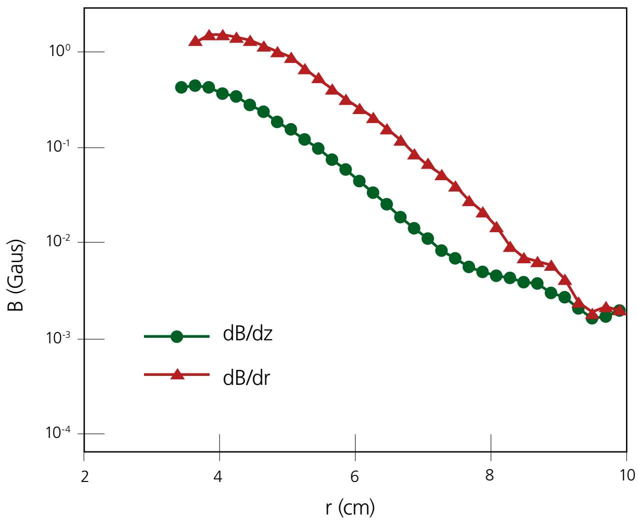

Figure 4: Radial profile of dBr/dz and dBz/dr

Figure 5 shows the result of the azimuthal electric field calculation using equation 1. Finally figure 6 shows the calculated azimuthal plasma current density using equation 2. These radial profiles are expected for this particular plasma geometry.

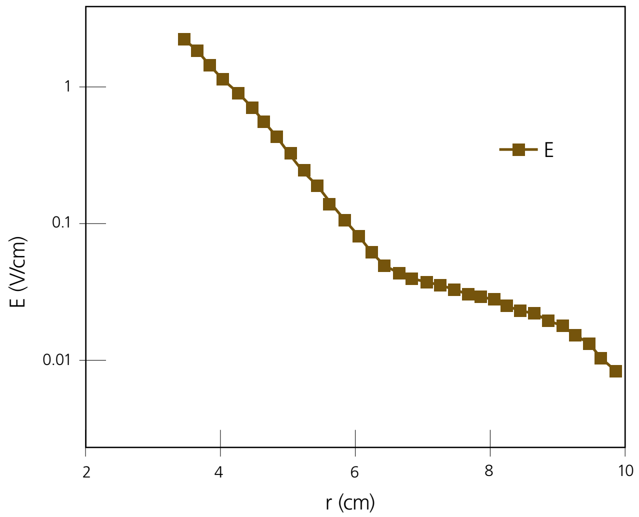

Figure 5: Radial profile of the calculated azimuthal electric field

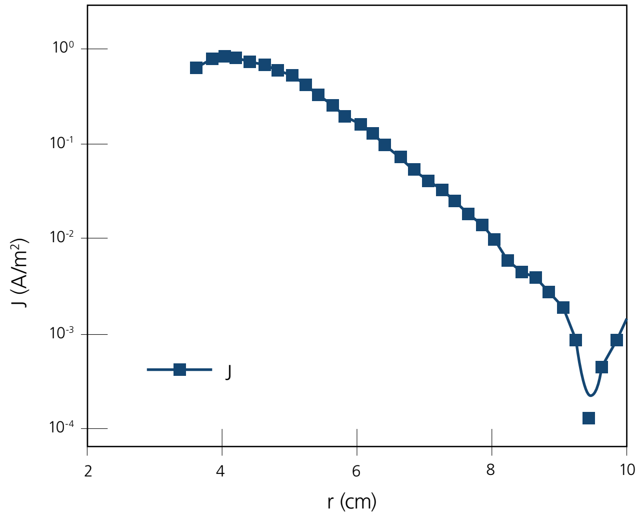

Figure 6: Radial profile of the calculated azimuthal current density

References

* *Measuring Current, Voltage and Impedance in RF Plasmas*
David Vender
Frontiers in Low Temperature Plasma Diagnostics
http://www.phys.tue.nl/FLTPD/invited/vender.pdf
Presented at Workshop on Frontiers in Low Temperature Plasma Diagnostics IV March 25-29, 2001 in Rolduc, The Netherlands