OPTICAL DIAGNOSTICS OF LOW PRESSURE PLASMAS

R.W. Dreyfus, J.M. Jasinski and R.E. Walkup, IBM, T.J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York, USA, 10598

G.S. Selwyn, IBM, EAsst Fishkill Dev. Laboratory, Hopewell Junction, New York, USA, 12533

Understanding a plasma process requires information on a large number of chemical and physical processes involving gas phase and gas-surface interactions. These include knowledge of the concentration of species in the plasma as well as the spatial distributions and energy distributions of these species. Optical measurements are well suited to providing such information since they are both species and quantum level specific. In addition, optical measurements can provide excellent spatial and temporal resolution, and they are non-intrusive to a good approximation. A survey of optical diagnostics of microelectronics processing plasmas will be presented, with emphasis on laser techniques. The techniques to be discussed include optical emission spectroscopy with actinometry, laser induced fluorescence spectroscopy (LIF), laser optogalvanic spectroscopy (LOG), and modulated laser absorption spectroscopy.

Optical emission spectroscopy is in wide use because it is straightforward to implement, and it provides a great deal of qualitative information about the identity of reactive species, provided they emit. The concentration of ground state species can be inferred from optical emission measurements with the use of actinometry. The assumptions inherent in the use of actinometry in a plasma have been critically tested for the case of oxygen atoms. In-situ measurements of ground state oxygen atom concentrations, obtained via two-photon laser induced fluorescence, have been directly compared with optical emission measurements using argon actinometry. The results define the conditions under which actinometry can provide a reasonable measurement of ground state oxygen atom concentrations, and they provide a specific example of how actinometry can yield misleading results.

Laser techniques have the advantage that they directly probe species in the ground electronic state and provide higher spatial, temporal and spectral resolution than typical optical emission studies. In contrast to optical emission spectroscopy, which provides a broad qualitative picture, laser techniques are primarily useful for providing detailed information about a selected atom, molecule or ion. Laser induced fluorescence has thus far been the most commonly used laser technique for plasma diagnostic work. It has high sensitivity and spatial resolution and is applicable to many atomic species and to a number of small molecules and ions. Inherent limitations are that the species to be detected must have a reasonable fluorescence quantum yield, and that background plasma emission must be discriminated against. Techniques which circumvent these difficulties include optogalvanic spectroscopy.
and absorption spectroscopy. Optogalvanic spectroscopy is capable of very high sensitivity, but at present the optogalvanic effect is not as generally useful or as easily quantified as LIF. Absorption spectroscopy is inherently insensitive compared to LIF or LOG techniques. This situation can be improved by a variety of modulation schemes. With the use of these modulation techniques, laser absorption spectroscopy provides a sensitive plasma diagnostic technique. Specific examples of the use of each of these techniques in glow discharge diagnostics will be given.

In addition to species concentrations and spatial distributions, laser techniques can also provide non-intrusive methods for the measurement of electric fields in discharges. Electric field distributions have been measured by LIF and LOG spectroscopy by probing optical transitions between levels that are sensitive to Stark mixing. Such measurements can provide a detailed picture of the spatially and temporally varying fields in glow discharges.