Impedans PLASMA MEASUREMENT

Helping to address the issue of plasma uniformity in 450mm wafer processes

In the recent decade large area plasma source have become extremely important in a wide range of applications. In flat panel displays, glass panels 2200mm x 2500mm need to be processed. Similarly, efficient manufacture of Si microcrystalline layers for solar applications are using similar larger area plasma sources. In semiconductor applications the most demanding uniformity requirements are in the area of plasma etch. Here dual, or multi frequency capacitively coupled (CCP) plasmas are needed with very high uniformity and process areas of 450mm.

The key issues for 450mm etch system development are likely to be driven by:

1. Plasma uniformity, driven by ion flux and energy
2. Radical distributions driven by gas mixtures and electron energy distributions
3. Plasma stability
4. Plasma induced damage
5. Process performance (etch rate, selectivity, etc.)

The need for dual frequency systems is driven by the need to separate ion flux control from ion energy control and the need to improve process performance at low pressures. Higher frequencies allow lower pressure operation or higher flux at moderate pressures. The flexibility required to produce good process performance is greatly helped by generating the plasma at the higher frequencies (>13.56MHz). The downside is that the wavelength of the higher frequencies start to approach the 450mm wafer size and plasma uniformity suffers. Ion energy control is best achieved at frequencies below the ion resonance time (~2MH). The plasma sheath is an excellent high frequency modulator and the mixing of two frequencies in a plasma sheath and can add to the uniformity issues.

The design of plasma sources at 450mm and the development of a good process performance will require experimentation with the plasma power delivery and gas delivery. The Semion™ Multi Sensor supports the development engineer in quickly measuring plasma profiles in terms of ion flux and ion energy. These profiles are key in establishing a reliable system to begin meeting the needed uniformity for 450mm Wafer Process and Tool Developers.

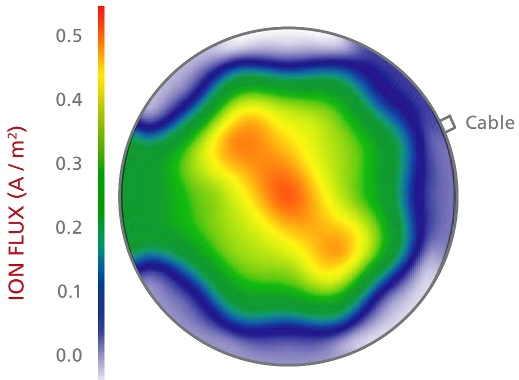

Figure 1: Spatial distribution of the ion flux to an RF biased substrate measured with the Semion™ Multi Sensor

Figure 1, shows the ion flux measured in-situ using the Semion™ Multi Sensor. The Semion™ system is unique in that it can measure simultaneously ion energy distribution functions and ion flux at 17 different location on a RF biased or grounded substrate. In Figure 1, a heat map is generated from a linear interpolation of measurements of retarding field energy analysers situated at the 17 spatial points. More advanced interpolation schemes are available within the software. The data shows that the ion flux is most intense in the centre of the plasma. This is likely due to the wave nature of RF and is typically of a non-optimised chamber design. Installing confinement rings and adjusting gas flow can help reduce the flux non-uniformity and the Semion™ Multi Sensor system allows real-time adjustment of the plasma input parameters (power, pressure, frequencies and chemistry) to find the optimum ion energy, ion flux and temperature with a spatial uniformity that meets the specific application requirements. Figure 1, also shows a hot spot (higher ion flux) near one edge. This may be due to the chamber design, cabling or other non-uniformity in the geometrical structure of the process tool.

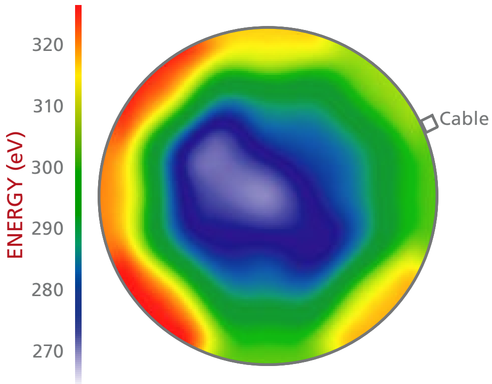

Figure 2: Spatial distribution of the average ion energy to an RF biased substrate measured with the Semion™ Multi Sensor

In Figure 2, a second heat map shows the mean energy of the ions. This is a low pressure plasma and has high energies in the range of 470-500 eV. In this case the energy is highest at the edge with a high energy hot spot (high energy) near the right hand edge. This feature is probably due to fringing electric fields near the edge of the plasma. Again the design needs to be modified to reduce the heating due to edge fields as these will alter the etch rate or process uniformity.

The ion energy at any location is a result of the local plasma potential. Higher ion energies indicate higher plasma potentials in that region and can result in axial fields across the wafer surface which can lead to charging of the wafer surface and local arcing or dielectric breakthrough. So again careful measurement of the ion energies is a valuable tool in initial testing of new chamber designs and in diagnosing issues with complex process development.

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