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# : Real-time plasma monitoring during plasma semiconductor processing

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Advanced process control (APC) refers to the fine-tuning of plasma processing based on real-time feedback signals from various plasma process monitoring devices. In fabrication fields, recent demands for sub-nanometer patterning and high aspect ratio- and atomic scale-etching and deposition have greatly increased process difficulty, leading to wide interest in APC and real-time plasma process monitoring. The latter has contributed to productivity improvements through providing feedback signals to process control units; the feedback signals are produced via the gathering and post-processing of myriad monitoring parameters such as plasma emission light, voltage and current of the electrode, antenna, and electrostatic chuck, chamber pressure, gas flow rate, and plasma parameters (electron density, electron temperature, etc.). Among these monitoring parameters, electron density is one of the crucial factors because it is directly related to processing time and quality.

Many diagnostic techniques including electrical, laser, optical, and microwave methods have been developed to measure electron density. Examples include the Langmuir probe, laser Thomson scattering diagnostics, optical emission and absorption spectroscopy, and microwave probes. Most of these approaches, though, are not suitable for plasma process monitoring; the Langmuir probe cannot operate under conditions with probe tip contamination (especially in the deposition process), laser Thomson scattering diagnostics is highly sensitive to the environment and requires quite a large space, and the optical emission and absorption method operates only within a narrow window.

On the other hand, the microwave method has attracted great attention for application to plasma process monitoring since microwave probes are not affected by probe tip contamination, afford high measurement accuracy, and further, the required microwave power is small enough to not disturb the plasma. One drawback though is that microwave probes provide few parameters, namely electron density and temperature. Nowadays, research is focused on the development of a planar and compact microwave probe for real-time plasma process monitoring, since a small and planar probe can be embedded into a wafer chuck or chamber wall, and is therefore non-invasive. Variations such as the curling probe (CP), the planar multipole resonance probe (pMRP), and the planar cutoff probe have been developed and are currently under improvement via commercial three-dimensional (3D) electromagnetic simulation (CST Microwave Studio [cst]) as well as experimental validation. Here, the computer simulation approach is quite simple and economical for the optimization and analysis of microwave probes.

Through this talk, I want to introduce a diagnostic method called "cutoff probe" and its modeling technique which has been performed for recent year. This talk focus on the whole progress for the cutoff probe including how to start to develop the cutoff probe in the initial period, what idea has been included during the development, how to evolve it by means of our physical modeling, especially what is going on for real-time plasma monitoring during the process.

The cutoff probe was made by simple intuition for the cutoff phenomenon of the plasma wave but without test of validation of probe itself. Later, by supposing the circuit modeling, the physics behind for the cut off probe spectrum (S21) was revealed and the accuracy and the application window of the probe were established. Recently, the TUSI (Tele-measurement of Plasma Uniformity using Surface-wave Information) which is installed below the wafer is developed for real time uniformity monitoring during the process. All other different versions of cutoff probe based on the different ideas and mathematical models would be presented through this talk

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