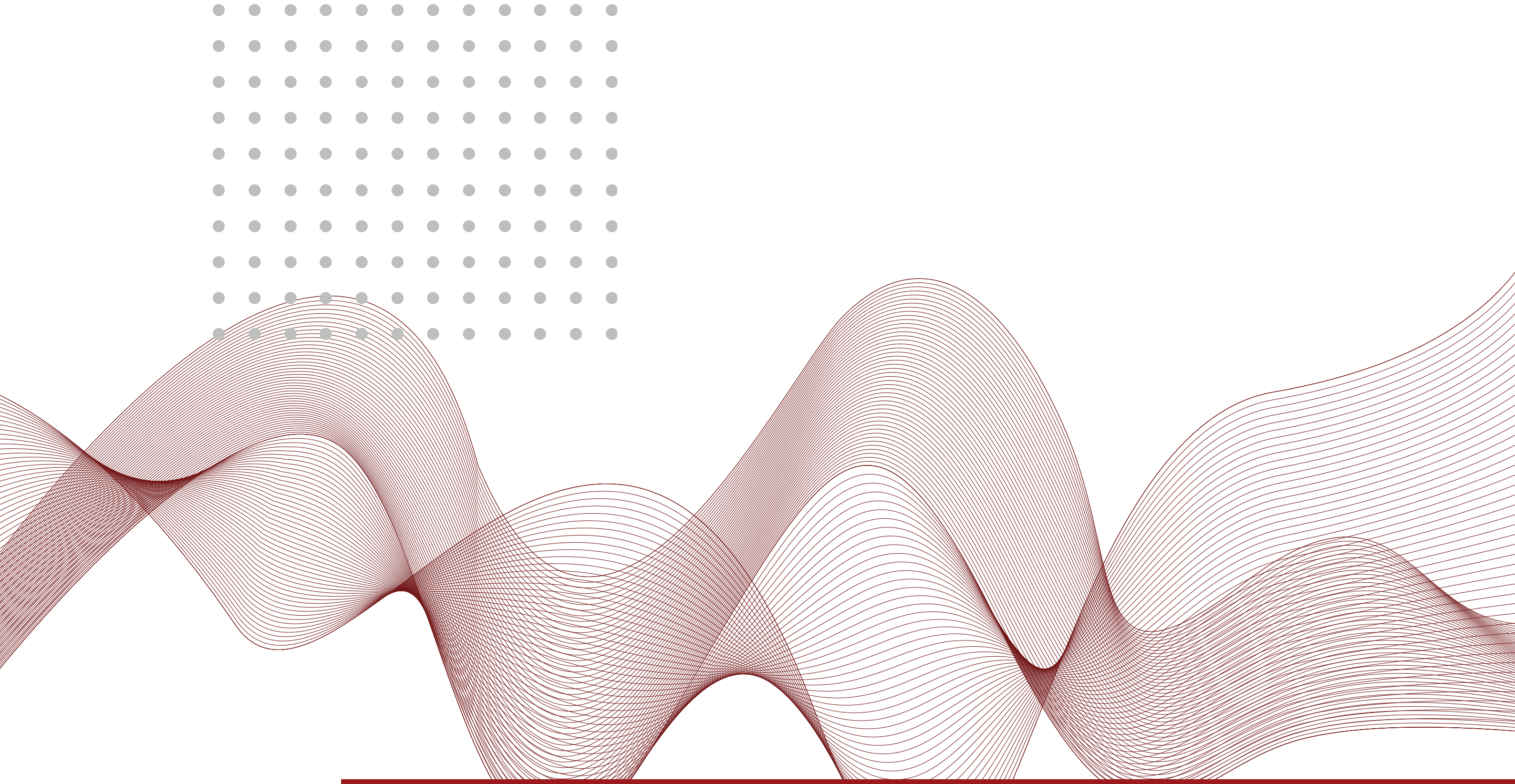

Impedans Octiv VI Probe used for Etch Rate Uniformity Measurements for a Photoresist Etch

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Introduction

Achieving uniformity in plasma etching is challenging due to the influence of etchant radical and ion flux distribution to the wafer surface in the plasma, especially at wafer edges. Real-time plasma diagnostics alone cannot predict etch rate uniformity without a theoretical model.

Impedans Octiv VI probes offer real-time, cost-effective RF measurements—such as current, voltage, phase impedance, and power—in CW and pulsed RF/DC environments for thin film deposition and etching. These insights are essential for correlating electrical variables with process parameters like ion flux and etching rates.

A recent publication in Journal of Plasma Chemistry and Plasma Processing highlights the application of Impedans Octiv Poly VI probe in the measurements of etching uniformity of photoresist on large size wafers. Octiv probes were used for bias power measurements, which played a key role in validating the theoretical etch model developed to quantify the role of radical and ion flux towards total etch rate.

Experimental setup

Plasma etching of a 300 mm photoresist (PR) coated wafer was carried out using a cylindrical remote inductively coupled plasma (ICP) reactor. The reactor was powered by a 13.56 MHz RF source, while a 12.56 MHz RF bias was applied to the electrostatic chuck, as illustrated in Figure 1. The bias power was measured using a VI probe (Impedans, Octiv Poly).

PR plasma etching was performed at a fixed pressure of 150 mTorr. The processing power varied from 1000 to 1600 W for the source power and from 50 to 400 W for the bias power. CF4, O2, and Ar gases were injected into the top plate of the chamber. The total process time was fixed at 60 s to calculate the etch rate and the etch rates were measured at eight locations on the wafer using a reflector (TFM-100-300, Vine), marked with red dots in Figure 1.

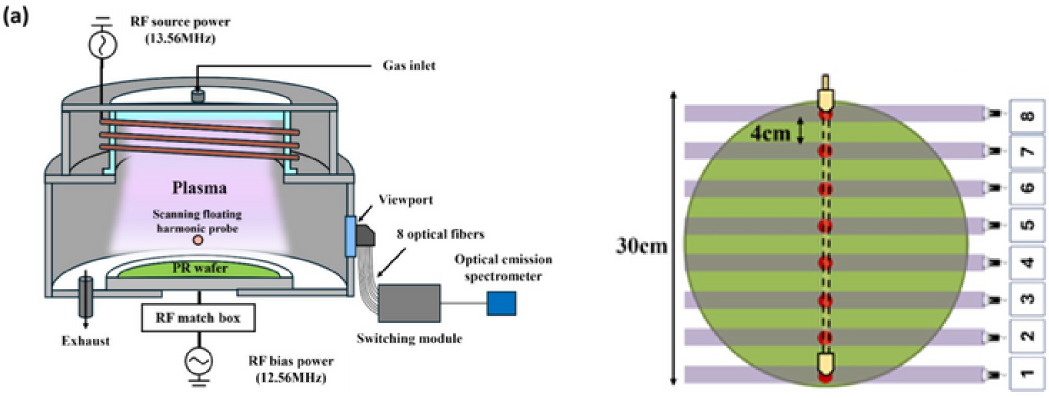

Figure 1 (Left) Schematic of a cylindrical-type remote ICP reactor equipped with Octiv VI Probe installed between RF bias power and the matching network. (Right) Locations of etch rate measurement.

Results

Etch rates at various locations on each channel were measured under different conditions, varying source and bias powers, as illustrated in Figure 2. The average etch rate across the eight channels increased by approximately 35% when the source power was raised from 1000 W to 1600 W. The etch rate in the central region was higher than at the edge by about 0.8% at 1000 W and 2.6% at 1600 W.

Additionally, as the bias power increased from 50 to 400 W at a fixed source power, the etch rates also rose, as shown in Figure 2b. At bias powers of 250 W and above, etch rates at the edge region surpassed those in the central region. The average etch rate across the eight channels increased by approximately 37% when the bias power was increased from 50 W to 400 W. Furthermore, the uniformity of etch rates across the eight channels improved with increasing bias power, achieving a uniformity of 1.4% at 250 W.

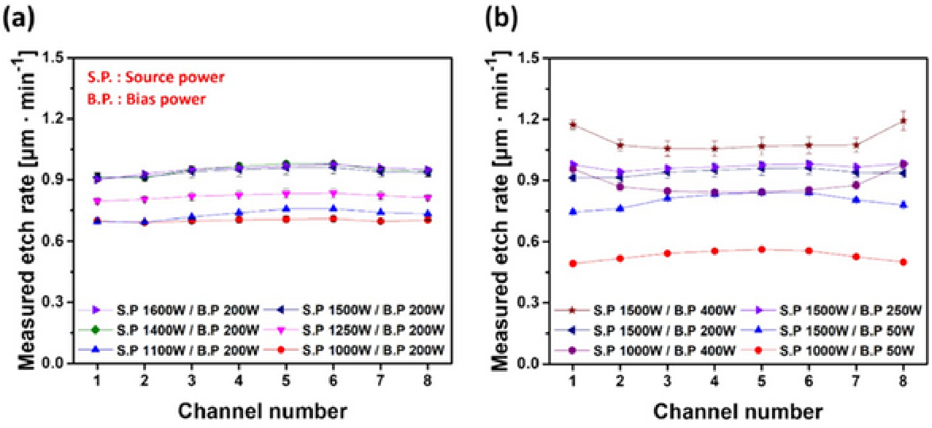

Figure 2 Measured etch rates at the eight channels at various (a) source powers and (b) bias powers

The F radical densities were monitored using OES at various bias powers while keeping the source power constant, as shown in Figure 3. Across all process conditions, the F radical densities in the central region were, on average, 12.0% higher than those in the edge region. Additionally, ion fluxes at eight locations on each channel were measured using a scanning floating harmonic probe to analyze the ion etching characteristics, as depicted in Figure 3 (right).

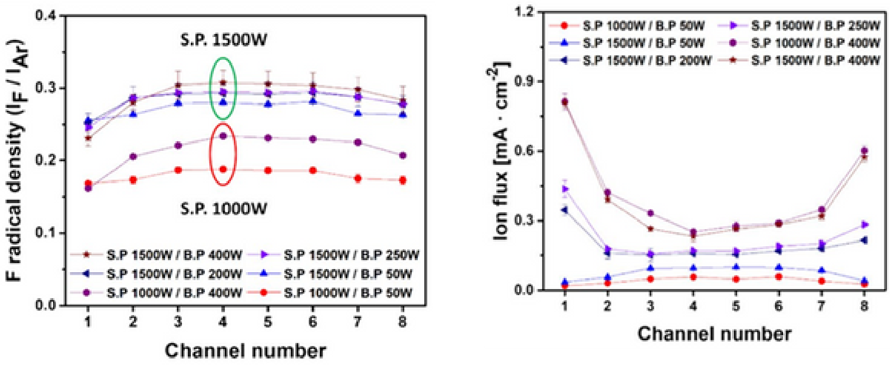

Figure 3 (Left) F radical densities estimated by 8-channel OES as a function of various bias powers. (Right) Ion fluxes at the eight channels at various bias powers

The relationship between the F radical density and ion flux contributions to the measured etch rate was further explored using a theoretical model at each channel. By incorporating these factors, the combined etch rate model was able to predict the spatial distribution of etch rates across all eight channels. This model demonstrated high accuracy, with an R^2 value of 0.99 and a mean absolute percentage error (MAPE) of 1.3%, aligning well with the measured etch rate uniformities, as illustrated in Figure 4.

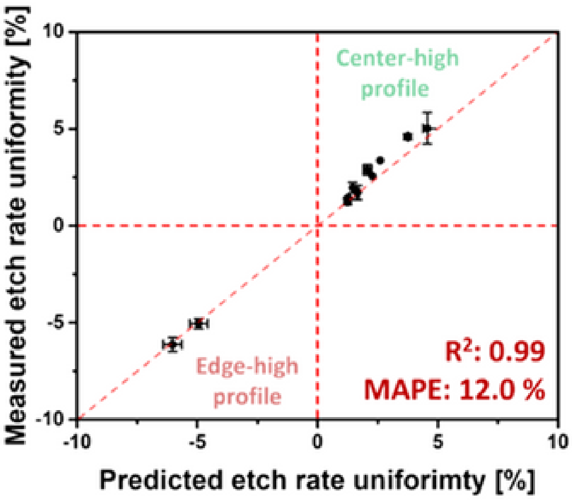

Figure 4 Comparison of measured and predicted etch rate uniformities using combined etch rate model in all process conditions.

Summary

A spatially resolved etch rate model was developed to monitor etch rate uniformity during PR etching using CF4/O2/Ar plasmas under various source and bias power conditions. This model integrates both radical-spontaneous and ion-enhanced etch rates. The combined etch rate model demonstrated strong consistency with the measured etch rate uniformities.

By using Impedans' Octiv VI probe to measure etch rates, as well as the radical and ion flux reaching the electrode, direct insights into the PR etching process were obtained, allowing for the verification of the theoretically developed etch rate model. This model can thus be applied to various plasma etching processes.

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