Enhancement of radical uniformity in CCP using a Rogowski electrode and spatial analysis via OES

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Capacitive Coupled Plasma (CCP) sources driven by RF power are widely used in semiconductor processes. Among these, oxygen plasma-based Atomic Layer Deposition (ALD) is one of the most commonly employed methods for fabricating SiO_2 wafers.[1] In CCP systems using conventional flat electrodes, however, the non-uniform distribution of radicals deteriorates the uniformity of semiconductors. This nonuniformity is attributed to the stronger electric field at the edge of the electrode, a phenomenon that has been previously observed.[2]

In this study, the plasma uniformity was improved by applying a Rogowski profile—commonly used to prevent electrode damage in discharges[3]—to the RF plasma system, thereby promoting more uniform plasma generation. Furthermore, a new probe device was developed and implemented to measure the spatial distribution of the plasma through optical emission spectroscopy (OES).

An RF source with 13.56 MHz and 500 W was applied to a 20 cm diameter electrode to generate plasma in a controlled environment. High-purity oxygen gas (99.999%) was supplied with adjustable flow rates to maintain pressures of 0.5, 1, and 5 Torr. The developed probe was utilized to measure the line-integrated OES light intensity, which can give the spatial density distribution using the inverse Abel transform within the cylindrically symmetric CCP. In this presentation, Based on the measured OES data, the generation of oxygen radicals corresponding to the intense 777 nm emission was compared between the conventional flat electrode and the Rogowski-profiled electrode. The results revealed that while the flat electrode exhibited a higher radical density near the edge, the Rogowski electrode effectively suppressed the edge density increase. These findings demonstrate that the Rogowski profile reduces the electric field enhancement at the edge, thereby significantly improving the radical uniformity.

References
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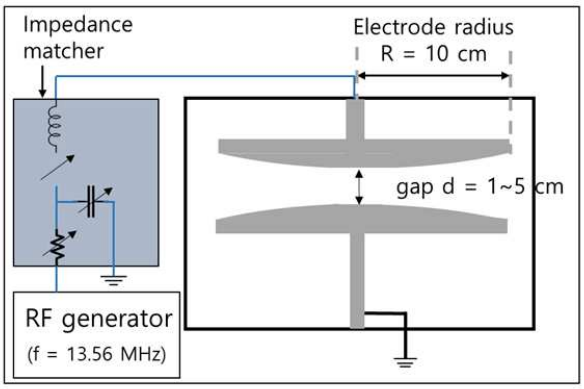

RF power P = 500 W
Frequency f = 13.56 MHz
Pressure p = 0.5 torr, 1 torr, 5 torr
Gas type : Oxygen 99.9% gas

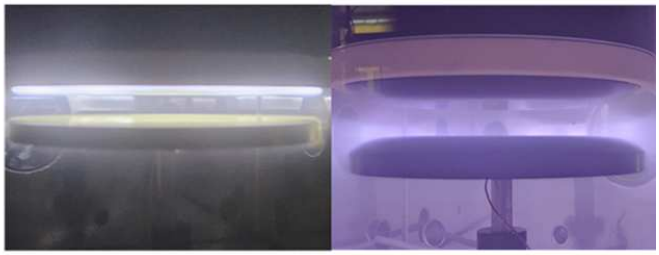

Figure 1. Experimental setup of the Capacitance-Coupled Plasma(CCP) system (left), CCP discharge with a flat electrode (center), and with a Rogowski profile electrode (right).