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Improving plasma uniformity using superimposed multi-frequency of an inductively-coupled plasma source

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Die shrinks are essential for improving the productivity and performance of nanoscale semiconductor devices. Since the cost to manufacture a wafer is not proportional to the number of chips on the wafer, die shrinks reduce the manufacturing cost per chip by enabling the use of more chips on each wafer. As the chip size shrinks, it is possible to include many chips on the edge of the wafer. Thus, to achieve high profit margins, it is very important to increase the yield of the wafer edge. In current semiconductor manufacturing processes, it is very difficult to control plasma uniformity due to challenging nanoscale patterning. Recently, numerous theoretical and experimental studies have been conducted to improve plasma uniformity by investigating approaches, such as separate dual frequency excitation and very high frequency mixing.

In this study, superimposed multi-frequency operation on an inductively-coupled plasma (ICP) source was investigated as a method for controlling plasma uniformity. Toward that end, 13.56 MHz and 2 MHz radio frequency (RF) power was supplied to the same top electrode, and 12.56 MHz was applied to the bottom electrode. To examine how a low frequency source affects uniformity, single frequency and dual superimposing frequency were compared. The plasma parameters of a superimposed ICP with a biased substrate were measured under various conditions. A spatially resolved Langmuir probe with extensible bellows and linear drive was used to measure the plasma parameters across the 300 mm wafer to determine uniformity. The plasma characteristics of a superimposed dual frequency (13.56 MHz/2 MHz) ICP system were investigated and compared with a single frequency ICP system. Variations in multi-frequency source power changed the ion energy distribution profiles and plasma uniformity. It was observed that the plasma uniformity was better in the superimposed dual frequency ICP than the single source ICP.

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