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Analysis of Triple-Frequency Capacitive Systems for Plasma Processing

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Dual- and triple-frequency capacitive systems are becoming more common among dielectric plasma etch systems in the industry today. Frequencies range from <1 MHz to ~ 200 MHz. The choice of frequencies is governed primarily by the relative effects desired with respect to density creation, average ion energy, and ion energy spread. At frequencies below 15 MHz, the dominant effect of mixing capacitive systems is seen in changes in ion energy and spread, with density affected to a lesser degree. At frequencies between 15 and 100 MHz, a trade-off exists between density creation and energy spread, particularly when these frequencies are combined with one or more frequencies below 15 MHz. When frequencies exceed 100 MHz, density formation dominates, with changes in ion energy getting progressively smaller at higher frequencies. In this paper, we explore practical density, energy, and spreads achievable for various combinations of frequencies using a physics DOE based on RF measurements of a triple-frequency system, and transform the results into process parameters proportional to density, energy, and spread.