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Nonlinear standing wave effect and plasma uniformity in very-high-frequency capacitively coupled plasmas[1]

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Plasma non-uniformity caused by standing wave effect (SWE) has brought about great challenges for material processing. In previous studies of SWE, researchers emphasized the role of the fundamental driving frequency. Nevertheless, nonlinear SWE associated with the higher harmonics generated by plasma series resonance (PSR) have been recently attracting even more attention. In this talk, I will present the experimental observation of nonlinear standing waves excited by PSR-enhanced harmonics in very high frequency (VHF) CCPs. Special emphasis is placed on the role of higher harmonic excitations on plasma non-uniformities. In experiment, we employed a home-made magnetic probe to determine the radial profile of the harmonic magnetic field, in combination with a double Langmuir probe to measure the radial profile of the plasma density. The measured harmonic magnetic fields are well reproduced by an electromagnetics model, which allows us to analyze the underlying physics. The nonlinear SWE is observed to be prominent at a low pressure, in which regime higher harmonics are excited by PSR, which can induce spatial wave resonances, with current/voltage peaked on-axis, resulting in a center-high plasma. The effects of DC (direct current) and LF (low frequency) source parameters on the plasma uniformity have been systematically investigated in experiment. It was found that the plasma uniformity is significantly affected by changing the DC and the LF source, which can be well explained by the changes of measured harmonic magnetic fields with the DC voltage and LF source parameters. Particularly, this study was extended to the case of more complex driving waveforms (i.e., 30 MHz +60 MHz), the experimental results show that the harmonic magnetic fields and the plasma uniformity can be well controlled by adjusting their phase angle.

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