Knowledge based process control in technological high frequency plasmas by Voltage Waveform Tailoring

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As process requirements in plasma technology continue to increase, empirical methods of process development/ optimization fail and knowledge-based approaches become essential. Based on a fundamental understanding of the charged particle dynamics in capacitive RF discharges, Voltage Waveform Tailoring (VWT) has been introduced as a new method to realize ultimate control of energy distribution functions of different particle species in such plasmas to overcome a variety of process limitations.

Multi-frequency power generator and impedance matching technology to upgrade existing RF plasma sources to use VWT without modifying the reactor itself will be described [1,2]. VWT will be demonstrated to provide a better quality of separate control of the mean ion energy and flux at the wafer compared to classical dual-frequency discharges [3]. Moreover, options to customize the shape of the Ion Energy Distribution Function (IEDF) by using customized voltage waveforms and their potential advantages for plasma etching will be discussed. Recent results also show that VWT allows for controlling the Electron Energy Distribution Function (EEDF) in the plasma volume and at boundary surfaces [4-8]. Selected examples will be discussed to demonstrate the advantages of this technology for the selective generation of reactive neutral radicals and for accelerating energetic electrons into High Aspect Ratio (HAR) etch profiles to compensate in-feature wall charging and avoid feature/mask distortion. Finally, the effects of VWT on plasma uniformity across large electrodes will be presented for selected discharge conditions. By tuning the relative phases between multiple consecutive harmonics used to construct tailored voltage waveforms the plasma uniformity is found to be improved significantly [9,10].

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