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Dual-frequency Capacitively Coupled Plasma-enhanced Chemical Vapor Deposition System for Solar Cell Manufacturing

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Dual-frequency (DF) capacitively coupled plasmas (CCP) are used to separately control the mean ion energy and flux at the electrodes [1]. This separate control in capacitively coupled radio frequency discharges is one of the most important issues for various applications of plasma processing. For instance, in the Plasma Enhanced Chemical Vapor Deposition processes such as used for solar cell manufacturing, this separate control is most relevant. It principally allows to increase the ion flux for high deposition rates, while the mean ion energy is kept constant at low values to prevent highly energetic ion bombardment of the substrate to avoid unwanted damage of the surface structure.

DF CCP can be analyzed in a fashion similar to single-frequency (SF) driven with effective parameters [2]. It means that DF CCP can be converted into SF CCP with effective parameters such as effective frequency and effective current density. In this study, comparison of DF CCP and its converted effective SF CCP is carried out through particle-in-cell/Monte Carlo (PIC-MCC) simulations. The PIC-MCC simulation shows that DF CCP and its converted effective SF CCP have almost the same plasma characteristics.

In DF CCP, the negative resistance arises from the competition of the effective current and the effective frequency [2]. As the high-frequency current increases, the square of the effective frequency increases more than the effective current does. As a result, the effective voltage decreases with the effective current and it leads to an increase of the ion flux and a decrease of the mean ion energy. Because of that, the negative resistance regime can be called the preferable regime for solar cell manufacturing. In this preferable regime, comparison of DF (13.56+100 or 200 MHz) CCP and SF (60 MHz) CCP with the same effective current density is carried out. At the lower effective current density (or at the lower plasma density), the mean ion energy of SF CCP is lower than that of DF CCP. At the higher effective current density (or at the higher plasma density), however, the mean ion energy is lower than that of SF CCP. In this case, using DF CCP is better

than SF CCP for solar cell manufacturing processes.

Keywords: DF-CCP, Plasma, solar cell manufacturing, PECVD