Investigating the effects of electron bounce-cyclotron resonance on plasma dynamics in capacitive discharges operated in the presence of a weak transverse magnetic field

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The two critical parameters which can control the processing rates and the quality of the wafer in plasma reactors used for silicon wafer etching and material deposition in semiconductor industries are ion flux and impact energy of ions on the substrate. Single frequency capacitively coupled plasma (SF-CCP) discharges cannot control ion flux and ion energy independently. To overcome this limitation, several ideas had been proposed like dual-frequency capacitive discharges, electrical asymmetric effects, non-sinusoidal or tailored voltage/ current waveform excitations, very high frequency (VHF) driven CCP discharges, CCP discharges in presence of external magnetic field (**B**) etc.
An external transverse magnetic field in SF-CCP discharges enhances the ion flux and also provides a mechanism to control the ion flux and ion energy[1]. However presence of large magnetic fields causes undesirable non-uniformity due to ExB drift in the bulk plasma[2,3].
A different regime where a significant enhancement in the performance of low-pressure CCP discharge at much lower transverse magnetic field has been reported[4-7] . Recently, we[7] have reported the existence of an enhanced operating regime when a low-pressure (5 mTorr) capacitively coupled discharge (CCP) is driven by a very high radio frequency (60 MHz) source in the presence of a weak external magnetic field applied parallel to its electrodes. Our particle-in-cell simulations show that a significantly higher bulk plasma density and ion flux can be achieved at the electrode when the electron cyclotron frequency equals half of the applied radio-frequency for a given fixed voltage. In the present work[8], we take a detailed look at this phenomenon and further delineate the effect of this "electron bounce-cyclotron resonance (EBCR)" on the electron and ion dynamics of the system. We find that the ionization collision rate and stochastic heating are maximum under resonance condition. The electron energy distribution function also indicates that the population of tail-end electrons is highest for the case where EBCR is maximum. Formation of electric field transients in the bulk plasma region is also seen at lower values of applied magnetic field. Finally, we demonstrate that the EBCR-induced effect is a low-pressure phenomenon and weakens as the neutral gas pressure increases. The potential utility of this effect to advance the operational performance of CCP devices for industrial purposes is discussed.
Figure 1 shows the trajectories of three electrons having different energies which are reflected from the expanding sheaths. This figure demonstrates the physical picture of EBCR effect for r=1 case.

References
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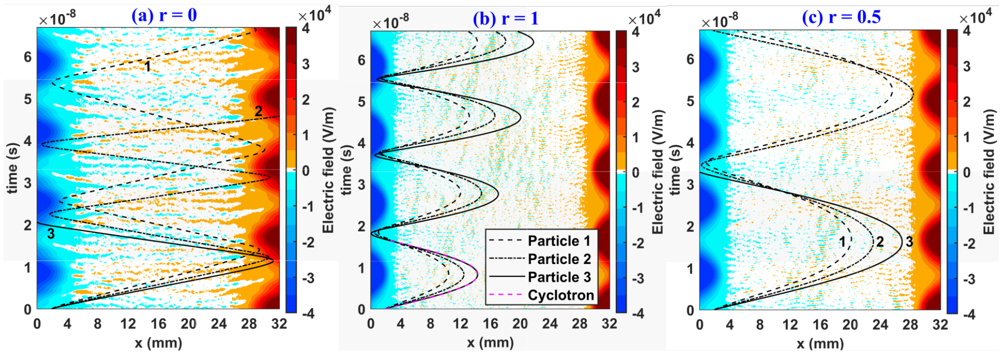

Figure 1. Trajectories of electrons are plotted on the spatiotemporal profile of electric field. The initial energies of electrons 1, 2 and 3 are 4, 8 and 12 eV respectively. For r = 1, dotted magenta line shows pure cyclotron motion of a particle with energy 12 eV.