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The electrical asymmetry effect in capacitive discharges

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One of the major demands in plasma processing has always been the independent control of ion energy and ion flux. Dual-frequency capacitive discharges with one low and one typically an order of magnitude higher frequency are one of the concepts presently applied in industry. However, recent investigations have shown that there is in fact a coupling between the two frequency components that limits independent control by the two RF powers. Here, a novel concept is introduced based on the electrical asymmetry effect (EAE) that provides simple and stable control of ion energy and flux in an almost ideally independent way [1]. Also here two RF frequencies are applied but with the second frequency being exactly the second harmonic of the first and with a fixed but controllable phase. This phase is the control parameter for the ion energy that changes approximately linearly with the phase. Geometrically symmetric discharges can be made effectively asymmetric with one electrode showing a higher sheath potential than the other. Choosing the proper phase allows then to reverse the situation or to make the discharge symmetric. In geometrically asymmetric discharges the wall potential can be raised or lowered. When tuning the phase, the flux stays approximately constant and its absolute value can be set with the RF amplitudes. The concept of the EAE is developed and analyzed by 1) an analytical model, 2) a hydrodynamic and Monte-Carlo (MC) simulation, 3) a self consistent PIC/MC simulation, and 4) an experimental verification in a laboratory experiment. All four approaches show excellent agreement and confirm the above advantages. The technique has found successful application already in an industrial reactor for large area solar cell production (Leybold Optics). Compared to the standard single frequency case at 13.56 MHz the silicon deposition rate was easily more than doubled and the homogeneity improved.

[1] Brian G. Heil, U. Czarnetzki, R. P. Brinkmann, T. Mussenbrock, JPhysD: Appl. Phys. 42, 165202 (2008)