RF BREAKDOWN IN LOW PRESSURE GASES IN SMALL (MILLIMETRIC) GAPS WITH NON-PLANAR SURFACES

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Small gaps are present in plasma-enhanced chemical vapor deposition reactors to isolate the RF electrode from the grounded parts of the reactor. These gaps are supposed to be small enough so that no glow discharge can form (dark space shielding), but wide enough to avoid problems of mechanical tolerance and thermal expansion, as well as to limit large capacitive currents and prevent metal vapor arcing due to field emission. RF breakdown in these small gaps is of high interest for the thin-film industry, since arcing and parasitic plasmas in small gaps in PECVD reactors represent a failure point preventing the upscaling to larger substrates and/or higher power regimes for micro-crystalline silicon deposition.

This paper presents an experimental investigation into RF breakdown for electrodes with holes or protruding features, approximating the situation in real reactors, and providing a benchmark for fluid simulations using a drift-diffusion model with a finite-element solver.

RF breakdown curves (voltage vs. pressure) have more complex features than DC Paschen curves, but generally show a steep left-hand branch at low pressures and a flatter right hand branch at higher pressures. Introducing protrusions or holes in parallel plate electrodes will lower the breakdown voltage in certain conditions. However, experiments in argon and hydrogen show that the breakdown curves are not perceptibly influenced by the increased electric field at sharp edges or ridges. Instead, both experiments and simulation show that, in general, breakdown at high pressure will occur at the protrusion providing the smallest gap, while breakdown at low pressure will occur in the aperture providing the largest gap. This holds true as long as the feature in question is wide enough to provide breakdown: Features that are too narrow will lose too many electrons due to diffusion, either to the walls of the apertures or to the surroundings of the protrusion, which negates the effect on the breakdown voltage. The simulation could be developed into a tool to aid the design of complex RF parts for dark-space shielding.