Integrated tool and feature 2D plasma processing simulator, used for a modeling of cryogenic plasma etching of silicon

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Plasma dry etching of silicon is one of the crucial technological processes, used in the modern manufacturing of very large integrated circuits, providing highly anisotropic profiles of the etched trenches. There are different techniques, used nowadays in a plasma etching of silicon[1]. One of them is a cryogenic etching process, where the substrate, being etched, is kept at a very low temperature, thus influencing the sticking of the neutral radicals.

Development and utilization of a simulation software helps to economize the costs and the time, needed to carry out the real experiments, as well as to get a better understanding of the physical processes, occurring in the plasma reactor. In the context of Nanoplasma, the European Commission sponsored project, new plasma processing simulation software was developed in MNES at Ilmenau University of Technology[2]. The program combines modeling on both, macro (whole plasma reactor) and micro (close the feature) levels, yielding simulated profile due to the initial parameters of a given plasma processing equipment. Our software, which structure is shown in the Figure 1, considers various physical effects, usually accompanying the experiments (ion reflection, electron shading, charging etc.). The gas-phase species concentrations, calculated by the plasma model, are then used to simulate particle transport to the surface to get angle and energy distributions of species in the vicinity of the sample. Feature scale part of the simulation uses this data, to model particle transport directly to the feature surface. Obtained species energy distributions are used to calculate material-specific etching rates for a simulation of the surface profile evolution. The simulator was employed for the simulation of cryogenic etching done at LBNL, shown in the Figure 2. These processes were to optimize and etch nanoscale features 10-100 nm. Simulations of features in this size region will be compared.

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[1] Ivo W. Rangelow, Journal of Vacuum Science & Technology A **21**, 1550 (2003)
[2] M. Hauguth *et al*., Microelectronic Engineering **86**, 976 (2009)

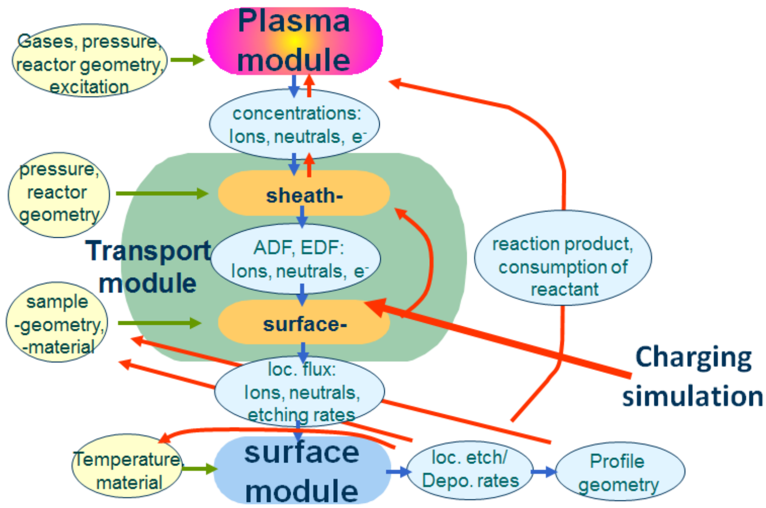
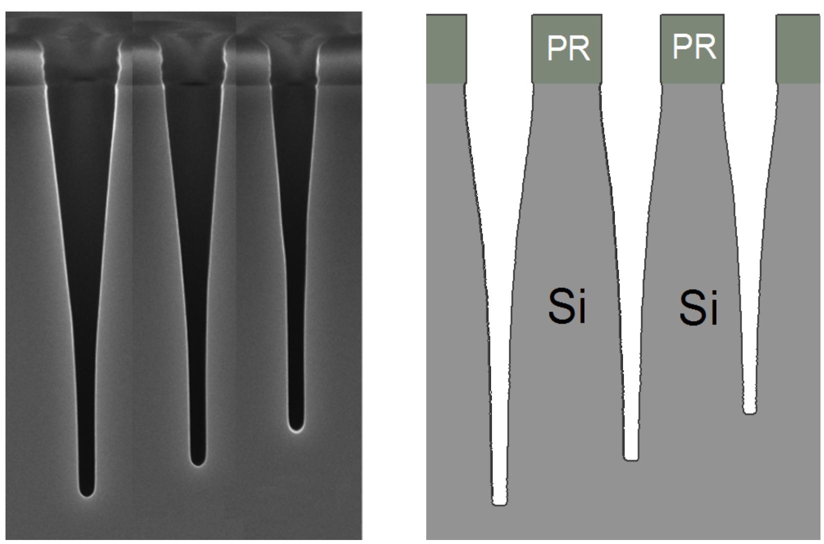


Figure 1: Structure of the implemented software: Combination of various physical models enables deep studies of plasma etching processes.



(a) (b)

Figure 2: (a) Cryogenic etching of 500 nm, 450 nm and 400 nm features in silicon at the temperature of -120° C; *(b)* simulated results