

375a Using High Fidelity Simulation in the Design of Experiments for Optimizing Etch Uniformity in Plasma Etching Reactors

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The nature of plasma etching of semi-conductor wafers coupled with lack of instrumentation to provide real-time process information usable for feedback control imply that optimal conditions for uniform etching must be designed into the plasma etching reactors and recipes. Such optimal conditions are determined through either trial-and-error experiments or using traditional statistical methods (response surface methodology - RSM) for design of experiments. However, both approaches have significant shortcomings, in that they may be inefficient, and may not even identify optimal conditions, because of nonlinearities. In our previous work we developed a hybrid approach to the design of experiments for efficient determination of conditions for optimal uniformity in plasma etching reactors. In this presentation (a) we show how this approach can be coupled with a high-fidelity plasma etching simulator for an inductively couple plasma (ICP) reactor, and (b) demonstrate how the approach would perform under realistic conditions by using the simulator as a virtual reactor. The finite element simulation uses Maxwell's equations to determine the electromagnetic fields and the power deposition profile. The power deposition profile is then used to solve the energy equation to calculate the electron temperature and hence the species rate coefficients for electron impact reactions. These are in turn used to compute the source terms for ion and neutral species densities. The simulator repeats these calculations cyclically until convergence. The etch rate and the uniformity along the wafer are calculated from the converged solution. In studies using the simulator as a virtual reactor process noise is added to simulator outputs. Through our simulations we demonstrate that RSM is efficient only when one is very near the optimum and the form of the optimized function is known (parametric optimization), which is not the case for the kind of experiments we perform. Traditional RSM turns out to be unnecessarily wasteful when one starts away from the optimum and the optimized function is strongly nonlinear and uncertain. Our hybrid approach employs non-parametric stochastic models to determine optimal settings for decision variables, particularly at early experiments, and may switch to traditional RSM when experiments are judged to be close enough to the optimum and the response surface is close to quadratic. The successful treatment of non-trivial constraints (e.g., etch rate, power) by the proposed method is also demonstrated.