Stochastic Approach to Modeling Line Edge Roughness in Photolithography

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In contrast to continuum modeling, a stochastic approach to modeling chemical events treats each fundamental microscopic event as a probabilistic event, typically represented by a binary random variable. By using the continuum (mean field) result as the probability function for this random variable, the properties of complex chemical reactions can be derived. In this paper, a stochastic modeling approach is used to predict the results of a reaction-diffusion system governing the exposure and post-exposure bake of a chemically amplified photoresist used in semiconductor lithography. Unlike continuum approaches, the stochastic modeling approach allows the prediction of both the mean value and the standard deviation of the resulting chemical concentrations within the resist at the end of the post-exposure bake. In this way, basic predictions can be made concerning line edge roughness based on the fundamental stochastic mechanisms at work.

In particular, the statistics of chemical concentration, photon shot noise, exposure, diffusion, amplification, and full reaction-diffusion for a chemically amplified resist are derived. The result is a prediction of the probability distribution, mean and standard deviation, of the final concentration of blocked and deblocked polymer in the resist using simple, analytical expressions. Combining this result with a prediction of the gradient of blocked polymer concentration at the resist line edge provides a function proportional to the line edge roughness of a resist feature.

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