Stochastic Approach to Modeling Photoresist Development

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Most theoretical descriptions of lithography make an extremely fundamental and mostly unstated assumption about the physical world being described: the so-called *continuum approximation*. Even though light energy is quantized into photons and chemical concentrations are quantized into spatially distributed molecules, the descriptions of aerial images and latent images ignore the discrete nature of these fundamental units and use instead continuous mathematical functions. For example, the very idea of chemical concentration assumes that the volume one is interested in is large enough to contain many, many molecules so that an average number of molecules per unit volume can be used. While we can mathematically discuss the idea of the concentration of some chemical species at a point in space, in reality this concentration must be an average extended over a large enough region. While in most cases the volumes of interest are large enough not to worry about this distinction, when trying to understand lithography down to the nanometer level the continuum approximation begins to break down.

When describing lithographic behavior at the nanometer level, an alternate approach, and in a very real sense a more fundamental approach, is to build the quantization of light as photons and matter as atoms and molecules directly into the models used. Such an approach is called *stochastic modeling*, and involves the use of random variables and probability density functions to describe the statistical fluctuations that are expected. Of course, such a probabilistic description will not make deterministic predictions – instead, quantities of interest will be described by their probability distributions, which in turn are characterized by their moments, such as the mean and variance.

While stochastic modeling has been successfully applied to photoresist exposure and post-exposure bake processes in recent years, the stochastic behavior of resist dissolution is much less understood. Dissolution rate variance comes from both the variance in the polymer solubility itself and the resulting variation in the development path required to bypass randomly insoluble polymer molecules. Percolation theory, where the percolation probability is equal to the probability that a polymer molecule will become soluble, has the potential for providing the theoretical framework required to solve this problem, and will be applied to the problem of photoresist development in order to predict line-edge roughness. In particular, fractal surface growth/etching models [1] will be applied to photoresist dissolution to predict the difference in dissolution rates between the stochastic and continuum models, and to predict the resulting surface roughness.

1. Barabasi A. L. and Stanley H. E., *Fractal Concepts in Surface Growth* Cambridge University Press, Cambridge (1995).

Keywords:

Line-edge roughness, LER, stochastic modeling, percolation, chemically amplified resist