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# Nanoscale molecular analysis with Nano-projectile SIMS

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Examining molecular arrangements within a few nanometers is a challenging proposition. However, such analysis is critical for understanding fundamental processes occurring at the nanoscale. Traditional analytical approaches often lack the spatial resolution or sensitivity required to assess critical information related to molecular interactions at scales below 20 nm. The analytical approach here is based on a variant of secondary ion mass spectrometry termed Nano-projectile SIMS, where instead of using a focused ion beam, a surface is analyzed stochastically with a suite (106-7) of nanoprojectiles separated in space in time. Each of these projectiles samples a nanovolume (~10-15 nm in diameter) and the ionized ejecta are collected, mass analyzed, and stored as an individual mass spectrum. Examining the spectra one by one avoids ensemble averaging and allows for data arising from a specific nanofeature to be examined. I will describe my recent work on understanding fundamental and material processes occurring in extreme ultraviolet (EUV) photoresists, which are a key component to developing next-generation semiconductor devices. During production of these devices, two types of variations affect their quality: shot noise during irradiation, and chemical variability in the resist. The latter has been generally perceived as a “black box” as it was difficult or impossible to track the molecular composition at the scales of the desired features. Using Nano-projectile SIMS the uniformity of the acid catalyzed deprotection reaction occurring during treatment and production of byproduct species as a function of resist formulation and homogeneity were studied. We found the homogeneity of the photoacid generator and base quencher had an important impact on the resulting uniformity of the deprotection reaction and the formation of byproduct species. We examined three types of resists for byproduct formation with NP-SIMS: (1) deep UV resist with an acrylate based-polymer; (2) EUV resist with an amine-based quencher; and (3) EUV resist with photodecomposible quencher, PDQ. The abundance and uniformity of byproduct species in these resists depended strongly on the type of resist and dose. All three resists displayed increased production of byproducts versus photon dose, and we found that EUV treatment resulted in the formation of additional byproduct species. For example, an EUV resist with a PDQ resulted in reduced aggregation of byproducts. NP-SIMS can provide insights which are critical to developing next generation semiconductor devices where the production of sub-10 nm features is necessary for continued progress in the performance of computational devices.