Investigating Nitrogen Diffusion in Silicon through Scanning Tunneling Microscopy

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The movement of dopants in silicon is a critical field of study for the fabrication of novel electronic devices. This movement of dopants is particularly concerning for atomically precise advanced manufacturing (APAM)-based devices[1], as the small number of dopants and nanometer-scale areas of interest mean that the movement of even one dopant atom may change the intended device properties dramatically.

Diffusion of commonly-used APAM-compatible dopants like phosphorous and boron has been previously studied, but nitrogen has generally been overlooked. While nitrogen has difficulties in achieving high electrical activity, the fact that ammonia (NH_3) readily dissociates onto Si (100) and the potential advantages of nitrogen for nanoscale devices[2] makes the study of its diffusion highly interesting. Nitrogen also has similar issues of complexation as has been proposed for boron and phosphorous[3] , and thus studies of its diffusion may provide insights into the movement of currently used donors. While general diffusion coefficients have been extracted for annealed N in Si[4], detailed imaging of chemical changes and their relation to N diffusion would be valuable.

We have combined scanning tunneling microscope (STM) observations of the dissociation of NH_3 with TOF-SIMS depth profiles to further elucidate the relation between the structure of N and its ability to diffuse in Si. STM images of ammonia-dosed surfaces annealed at 450ºC and 700ºC show both substitutional and interstitial N. However, up to an anneal temperature of ~600ºC and regardless of molecular structure, N does not diffuse long distances in silicon during annealing or cap growth. The data presented may help to explain diffusion patterns in common dopants and help in targeting future APAM-compatible donors.

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