Si-SiO_2 Interface Defect Density Characterization by fm-AFM

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As silicon-based devices continue to shrink to the nanoscale, traps at the Si-SiO2 interface pose increasing challenges to device performance. Knowledge of the precise location of such traps aids in understanding their influence on device performance. Frequency-modulated atomic force microscopy (fm-AFM) can spatially map locations of interfacial traps through dissipation scans [1, 2]. In this presentation, we demonstrate how this method can be used to spatially map and quantify traps in both conventionally prepared ("pristine") silicon samples and those processed under ultra-high vacuum for hydrogen resist lithography (HRL). We confirm previous studies demonstrating hydrogen passivation of traps and find that hydrogen termination further reduces the donor-like trap density [3]. We also observe a significant reduction in two-level donor-like traps in the hydrogen-terminated samples compared to pristine silicon samples. These findings suggest that HRL-prepared silicon may offer advantages for high-performance nanoscale and atomic-scale devices due to reduced trap densities. More broadly, this fm-AFM technique provides a non-destructive, spatially resolved tool for probing defect landscapes in nanoscale devices.

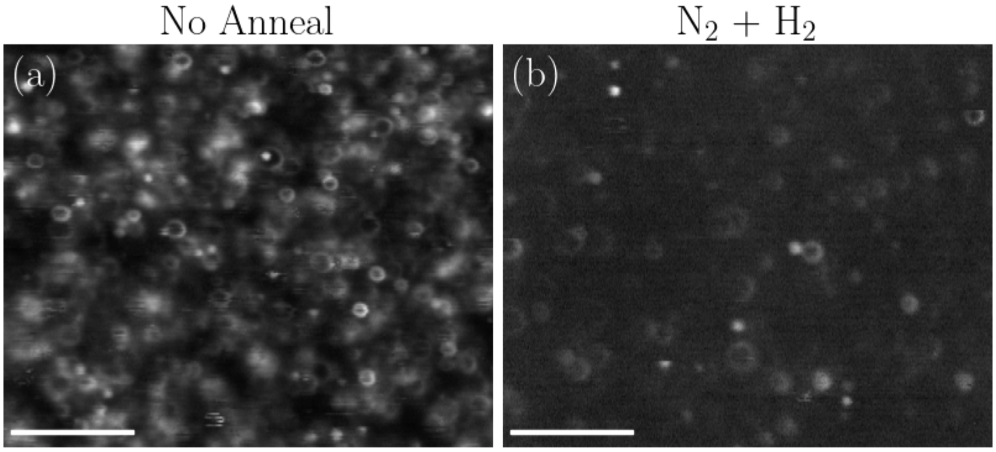

Figure 1. fm-AFM dissipation scans reveal rings due to traps. Shown is a dissipation scan done on **(a)** a non-annealed pristine silicon sample and **(b)** a pristine silicon sample annealed in N_2+H_2 forming gas, each conducted at a bias of -3 V and Δ f setpoint of -300 Hz. Scalebar is 200 nm.

[1] M. Cowie, T. J. Z. Stock, P. C. Constantinou, N. J. Curson, and P. Grütter, "Spatially resolved dielectric loss at the Si/SiO2 interface," Phys. Rev. Lett. 132, 256202 (2024).

[2] M. Cowie, P. C. Constantinou, N. J. Curson, T. J. Z. Stock, and P. Grütter, "Spatially resolved random telegraph fluctuations of a single trap at the Si/SiO2 interface," Proceedings of the National Academy of Sciences 121, e2404456121 (2024).

[3] A. J. Czarnecki, N. L. Kolev, P. See, N. Sullivan, W. A. Behn, N. J. Curson, T. J. Z. Stock, and P. Grütter. 'Si(100)-SiO2 Trap Density Dependence on Sample Processing'. arXiv [Cond-Mat.Mtrl-Sci], 2025. arXiv. http://arxiv.org/abs/2505.23574.