Self-excitation of qPlus cantilevers by charge trapping at the silicon surface

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At certain bias ranges, qPlus-based scanning of bare silicon surfaces using STM feedback becomes unstable due to a phenomenon where the cantilever self-excites to large oscillation amplitudes, ranging from approximately 0.1 nm to 10 nm. Unlike previously reported self-excitation mechanisms that are often attributed to hardware limitations [1], the instability observed here arises from intrinsic surface effects. Specifically, it is caused by charge trapping at the silicon surface, initiated by the tunneling current between the tip and the sample. Band bending creates a depletion region that slows the dissipation of surface charge into the bulk. This mechanism is similar to the 'phantom force' effect, also reported on silicon [2]. We demonstrate that self-excitation can be suppressed by hydrogen passivation of the silicon surface, which eliminates surface states and prevents charge trapping, thereby stabilizing the system.

Self-excitation presents as an amplitude instability when the qPlus sensor is operated under STM feedback. While the nc-AFM amplitude controller can be used to partially mitigate the effect by setting a small oscillation amplitude (a common approach in previously reported qPlus work on silicon, see e.g. [3-5]), this approach inherently limits the minimum achievable amplitude. To overcome this limitation, we introduce an alternative lock-in-based control scheme capable of maintaining oscillation amplitudes near the noise floor. This method offers a more robust solution for stable imaging and measurement under conditions where traditional amplitude control fails.

Reference

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