**Wet Etch Dynamics of Silicon Nanopillars Visualized in the TEM**

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Three-dimensional (3D) gate-all-around device architectures based on vertical semiconductor nanopillars(1) have been proposed as a possible route for densely-packed, next-generation transistors and memory devices. One potential way to efficiently fabricate densely packed vertical nanostructures suitable for future 3D devices is through combining low-cost, gentle chemical wet etching with a pre dry-plasma etching. This approach produces damage-free smooth surfaces and thinner nanostructures. However, despite the technological importance of chemical wet etching in semiconductor micro- and nanofabrication, our understanding of wet etching at the nanoscale is inferred from studies in bulk etching conditions.

In this work, using in-situ transmission electron microscopy (TEM)(2), we follow the nanoscale wet etch dynamics of Si nanopillars in real-time. Time-resolved TEM images show that the reaction intermediates generated during alkaline potassium hydroxide (KOH) wet etching of Si nanopillars first aggregate as nanoclusters on the Si surface before diffusing and finally dissolving in the etchant solution. Control experiments with tetramethylammonium hydroxide (TMAH) as well as with isopropyl alcohol (IPA) and molecular dynamics simulations(3) suggest that hydroxyl groups ($OH^-$) on the Si surface are primarily responsible for holding the nanoclusters of the reaction intermediates at the nanopillar surface. These results suggest that interaction of reaction intermediates with etching surfaces is an important aspect in fabricating densely packed 3D nanostructures for future generation microelectronics.

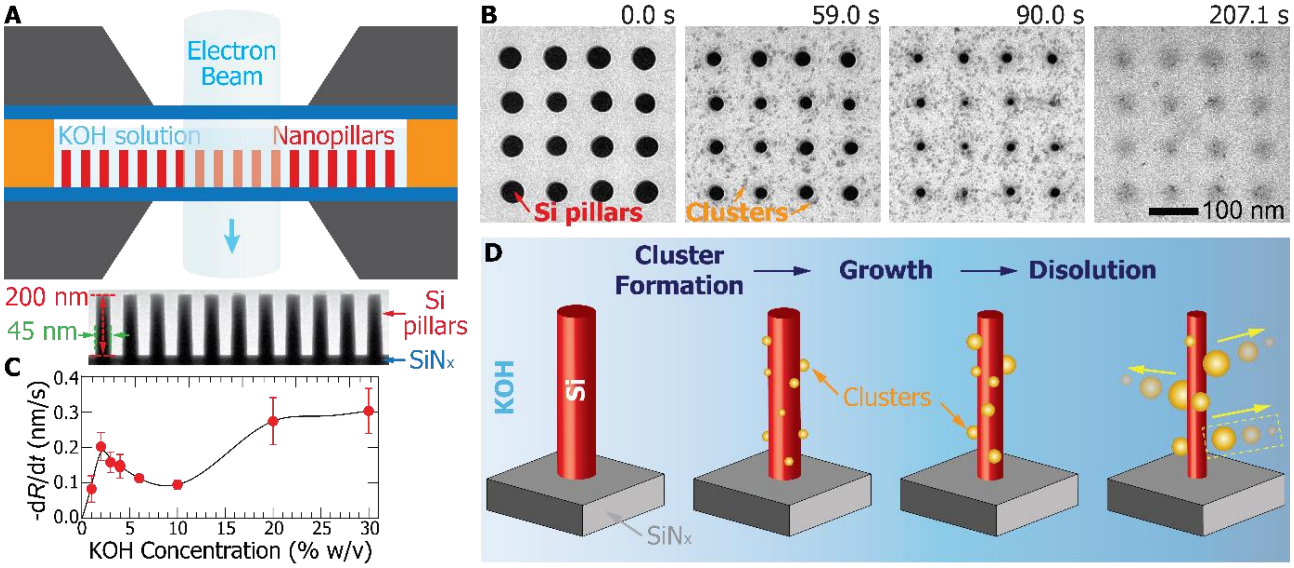


**Figure 1.** (**A**) Schematic of the in-situ liquid cell platform and side-view TEM image of free-standing Si nanopillars on a $SiN_x$ membrane. (**B**) A series of TEM images showing the etching process of Si nanopillars in 4% aqueous KOH solution and nanoclusters formation. (**C**) Si etch rate vs. KOH concentration at room temperature and (**D**) Schematic illustration of the three-step Si etching mechanism and clustering of reaction intermediates.

**References:**

(1)Tomioka K., Nature 488, 189 (2012).
(2)Ross F. M., Science 350, 6267 (2015).
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