# Lithographically defined silicon nanowires and quantum dots for quantum devices

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Quantum size effects (quantum confinement) in Si have been well known since the discovery of visible light emission from porous silicon almost twenty years ago [1]. As size of silicon structures is reduced, quantum effects change the optical and electrical properties of bulk Si. There has been a sustained push to develop this technology for useful applications, e.g. light emitting Si devices for optoelectronics. Recent efforts have been focused on both chemically grown compound semiconductor and Si nanowires and quantum dots [2, 3] or structures made by elaborate fabrication techniques. While quantum effects, such as visible light emission, have been observed in such nanostructures, several practical problems such as precise control of size and lack of robust patterning and integration techniques that prevent the adoption of chemically grown nanostructures for useful devices. A lithographic approach for fabricating one and zero dimensional Si nanostructures would be naturally suited to reliable quantum device fabrication, given the maturity of Si and related fabrication techniques. But such a top-down approach has been largely overlooked due to the difficulty in fabricating single-digit Si nanostructures by lithography.

In this study, we use e-beam lithography (EBL) to fabricate single-crystalline Si nanowires and Si quantum dots with critical dimension required for visible light emission (<10 nm) on ultrathin Si (<10 nm in thickness) on insulator (SOI) substrate (Siltron). EBL is performed in HSQ resist on a [100] SOI substrate with 10 nm single-crystalline Si on 150 nm of buried oxide (BOx) to form Si nanowires and nanodots. The patterns were exposed at a dose of 3 nC/cm (nanowires) and 35 fC (nanodots), resulting in ~10 nm nanowires and ~15 nm nanodots, both with a pitch of 500 nm (Fig. 1). Two sets of nanowires were exposed in both [100] and [110] directions to study the effect of crystal direction on luminescence and electrical properties. The patterns were developed in 25% tetramethylammonium hydroxide at 45 ˚C for one minute followed by etching in inductively coupled chlorine plasma to transfer patterns to the top Si. Cross sectional transmission electron microscopy was used to verify nanowire size and crystallinity (Fig. 2). Controlled oxidation of the as-patterned Si nanowires and nanodots is used to further reduce the size of the nanostructures. We will characterize the electronic and optical properties of the Si nanowires and nanodots. This method provides a feasible top-down approach for fabricating Si nanostructures for visible light emission.

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[1] Canham, L. T., *Appl. Phys. Lett.* 57(10), 1046, 1990.
[2] D. P. Yu et al., *Appl. Phys. Lett.*, 73(21), 3076, 1998.
[3] X. F. Duan et al., *Nature*, 409(6816), 66-69, 2001.

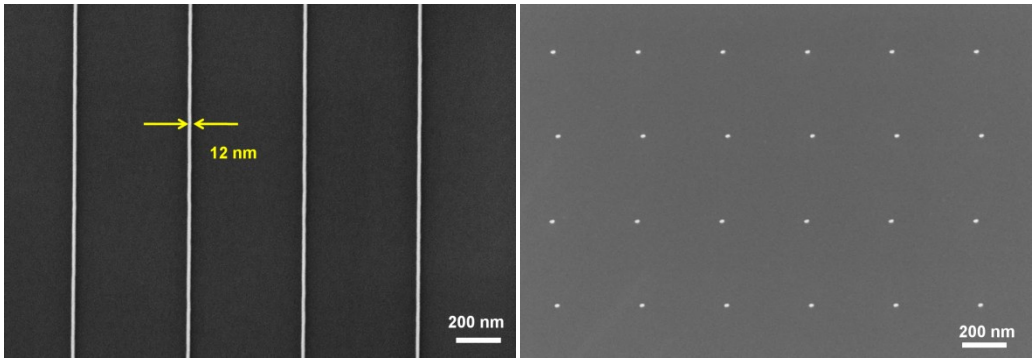


**Fig 1:** SEM images showing (a) patterned Si nanowires, and (b) Si nanodots after chlorine plasma etch to transfer patterns to Si on SOI substrate. HSQ remains on top of the features.

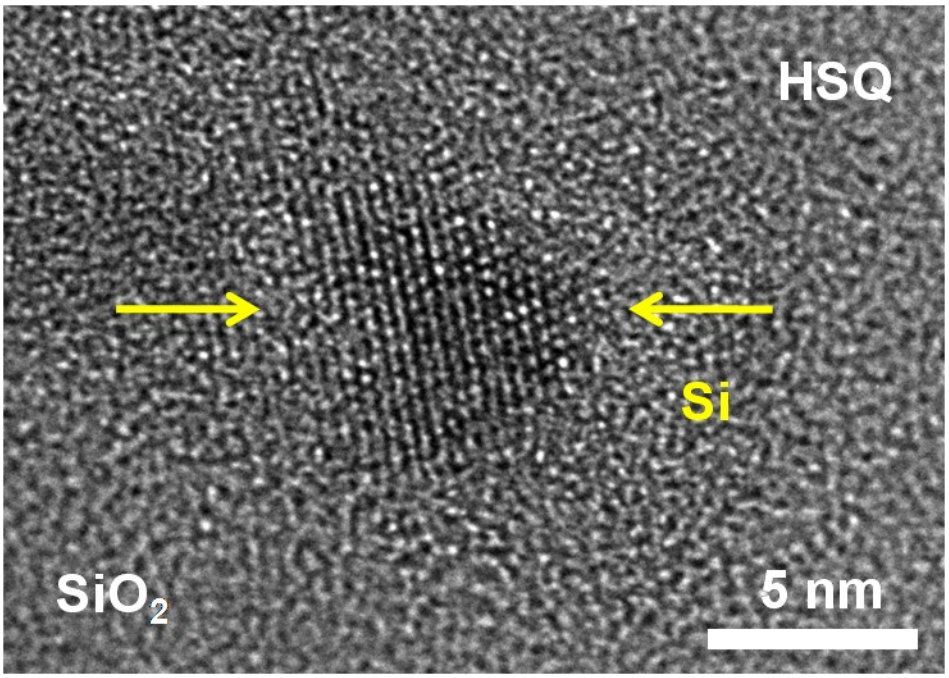


**Fig 2:** TEM image showing a cross section of a Si nanowire, with a ~5 nm pocket of crystalline Si.