Using block-copolymer nanolithography as a tool to sensitively evaluate variation in chemical dry etching rates of semiconductor materials with sub-5 nm resolution

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Block-copolymers (BCP) are materials that tend to microphase separate into a diverse variety of nanostructures. The nanostructures formed by BCPs have well-defined domain sizes in the <50 nm regime that can cover areas as small as a few micrometers or as large as tens of millimeters, making them attractive nanotemplating masks[1]. Recent literature shows that BCPs containing a polar moiety can be converted into AlO_x via a process called sequential infiltration synthesis (SIS)[2]. The hybrid inorganic template can then be used as a mask for deposition or etching[4].

We present a method in which cylinder forming PS-b-PMMA is used to pattern-transfer hexagonally packed holes spaced at 37.5 nm into silicon. The hole dimensions were then evaluated via SEM and image analysis, and the average hole radii and overall porosity of the nanostructures were extracted with a resolution on the order of a couple nanometers. In this work, we demonstrate a way to measure how the lateral, chemically dominated etch rate across a variety of materials – including p- and n- type doped silicon, and intrinsic silicon – is influenced by surface charge and the material electronic properties during dry etching[5].

We also demonstrate that these sensitive etch rate measurements can be done with EBL-patterned hexagonal hole arrays, so any facility with an e-beam writer could use our method to evaluate nanoscale dry etch rate variations for complex processes. Image analysis on hexagonal hole arrays is thus a novel and sensitive metrology technique that could be used to characterize a wealth of nanoscale parameters including sub-nm variations in chemical dry etching rate between similar materials.

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1. Stoykovich, M. P. & Nealey, P. F. Block copolymers and conventional lithography. *Mater. Today* **9**, 20–29 (2006).
2. Tseng, Y.-C., Peng, Q., Ocola, L. E., Elam, J. W. & Darling, S. B. Enhanced Block Copolymer Lithography Using Sequential Infiltration Synthesis. *J. Phys. Chem. C* **115**, (2011).
3. Zhou, C. *et al.* Cite This: ACS Nano 2020, 14, 6980−6989 ACS Nano 2020, 14, 6980−6989 Downloaded via UNIV OF CHICAGO on. (2020). doi:10.1021/acsnano.0c01463
5. Winters, H. F. & Haarer', D. Influence of doping on the etching of Si(111). *PHYSICAL REVIEW B* **36**,

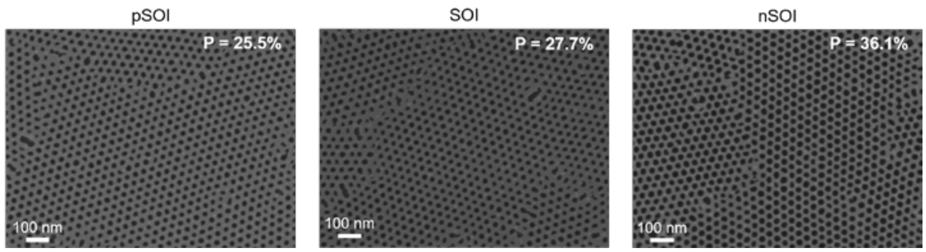

Figure 1 SEM micrographs of the nanoporous p-doped, n-doped, and undoped SOI substrates. From left to right, a clear trend of increasing porosity is observable, with n-doped Si having the largest porosity and p-doped Si having the smallest porosity. As all substrates were etched simultaneously for the same amount of time, the porosity difference is a result of differences in the chemical etching rate of doped Si in plasma etching.