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Fabrication of Silicon nanostructures by UHV-STM lithography in Self-Assembled Monolayers

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The fabrication of nanostructures with lateral dimensions down to a few nanometers in single-crystalline silicon substrates is a key technology for many applications ranging from nanoelectromechanical devices (NEMS) to nanofluidic systems for biological applications.
High resolution lithography as provided by direct e-beam writing or scanning probe writing in suited resists in combination with optimized dry or wet etch procedures for pattern transfer are among the most promising techniques for the fabrication of arbitrary shaped nanostructures in various materials.
Our approach utilizes UHV-STM writing in Self-Assembled Monolayers (SAM). SAMs form highly-ordered ultrathin (~2-3 nm) monomolecular layers ontop of preactivated Si(100) or Si(111) surfaces. After patterning by UHV-STM writing in constant-current mode at different write parameters (gap voltage, electron dose) the modified Self-Assembled Monolayer serves as an etch mask for an anisotropic wet etch transfer (two-step etch process in aqueous solutions of 5 % HF and 1 M KOH), of the write structure into the silicon substrate. The corresponding silicon nanostructures have been analyzed afterwards by AFM or SEM to characterize the pattern accuracy.
We have studied the suitability of three different types of SAMs on silicon single-crystals :
Alkylchain-type SAMs like Octadecylsilane (ODS) monolayer have been formed by immersion of hydroxilated Si(100) in Octadeclytrichlorosilane ($CH_3(CH_2)_{17}SiCl_3$) while SAMs with aromatic spacer groups such as Hydroxybiphenyl (HBP, $(C_6H_6)_2OH$) and Ethoxybiphenylsilane (EBP, $(C_6H_6)_2O(CH_2)_3Si(OCH_3)_3$) are formed on Si(111).
Depending on the applied write parameters, significant differences in SAM resist modification (e.g. positive tone vs. negative tone) have been found and models of the underlying write process are proposed. The implications of the azimuthal orientation of the resist pattern with respect to the underlying crystal structure are also discussed.
The minimum line width which could be achieved in dense line patterns with an etch depth of about 30 nm, are around 35 nm in Si(100) and in the range of 26-31 nm for Si(111). The edge accuracy of the line patterns has been measured to be about 5-7 nm displaying the excellent high-resolution capability of the process.

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