Direct writing of nanoscale hafnium diboride metallic nanostructures on hydrogen passivated silicon (100) surfaces using a UHV-STM

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The patterning of metallic nanostructures on surfaces is of great interest for a wide range of nanoelectronic and molecular electronic applications. In this work, we describe the fabrication and characterization of sub-5 nm linewidth metallic hafnium diboride (HfB_2) nanostructures on H-Si(100) surfaces using scanning tunneling microscopy (STM) and scanning tunneling spectroscopy (STS).

HfB_2 nanostructures are deposited on silicon surfaces by STM-assisted chemical vapor deposition (CVD) from the single-source precursor $Hf(BH_4)_4$ at room temperature. The delivery of $Hf(BH_4)_4$ vapor is realized by pointing a capillary doser directly at the tip-sample junction. At positive sample bias, the tunneling current initiates the local CVD by the decomposition of $Hf(BH_4)_4$ under STM tip. By repeatedly scanning the STM tip along a specific path, well-defined HfB_2 nanostructures can be directly written onto the surface. Spatially resolved tunneling current-voltage (I-V) spectroscopy is used to characterize the electronic properties of the nanostructures.

We have achieved 3 nm linewidths and complete selectivity relative to adjacent H-Si(100) regions. The thickness of the HfB_2 nanowire is controlled by the exposure time to the electron beam from STM tip, while the width is controlled only by the geometry of the tip apex and the sample-tip separation. STS data confirm that the HfB_2 nanostructures deposited are purely metallic, indicating minimum contaminations in the nanostructures, which we attribute to the carbon-free nature of the CVD precursor. To our knowledge this is the first demonstration of sub-5 nm metallic nanostructures in a STM/CVD experiment.