Direct Hard Mask Patterning by Focused Ion Beam (FIB)

S. Waid, H. D. Wanzenboeck, E. Bertagnolli
Institute for Solid State Electronics, Vienna University of Technology, Florag. 7 1040 Vienna, Austria
simon.waid@tuwien.ac.at, heinz.wanzenboeck@tuwien.ac.at

A. Koeck
Austrian Institute of Technology GmbH, Donau-City-Str. 1 1220 Vienna, Austria

Focused ion beam (FIB) direct milling is employed for trench fabrication in a number of applications[1,2] where resist based processes are not applicable or inconvenient. However, this patterning method is a serial process and thus the processing speed is inherently low.

In this paper we propose the direct patterning of inorganic hard mask materials by FIB and subsequent pattern transfer by reactive ion etching (RIE) as an alternative to FIB direct milling. Since only thin films in the nm range need to be patterned by a serial process the patterning speed is significantly increased while many advantages of the direct patterning method are preserved.

FIB direct milling of inorganic hard mask materials was evaluated as a simple and quick method. We found that beside the etch resistance, the flatness of the hard mask after milling is of outstanding importance if high speed patterning and low line edge roughness is desired. Fig. 1 illustrates the roughness of different hard mask layer after milling. Among the investigated materials AZO showed the best performance regarding both etch resistance and flatness.

FIB gas assisted etching (GAE) of hard mask materials is investigated as a way to increase the patterning speed even further. Etching experiments were performed on Ni, Al, W and silicon oxide using XeF_2 as an etch gas. While the gas displays no effect on Ni and Al, a significant improvement of etch rates by a factor of up to 30 for W and a factor of up to 9 for SiO_2 was observed. The employment of SiO_2 can be recommended while W was also etched spontaneously and thus can only be recommended if short FIB exposure times are feasible.

Direct deposition of the hard mask material by FIB gas assisted deposition (GAD) is evaluated as a way to avoid the mask application step. This is particularly useful if only small areas need to be covered by the mask material. We employed both a W precursor and a Pt precursor. We found that the Pt precursor outperformed the W precursor in both speed and etch resistance.

We conclude that the direct patterning of hard mask materials and subsequent pattern transfer by RIE can help to speed up patterning compared to direct FIB milling. We believe that this method is useful for a number of applications including the patterning on uneven surfaces as required by the fabrication of special atomic force microscope (AFM) tips.

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[1] A. Fujimoto, L. Zhang, A. Hosoi, Y. Ju, Microsyst. Technol., **1** 1-6 (2010)
[2] S. Zhu,W. Zhou, Key Eng. Mat. **447 448**, 584-589 (2010)

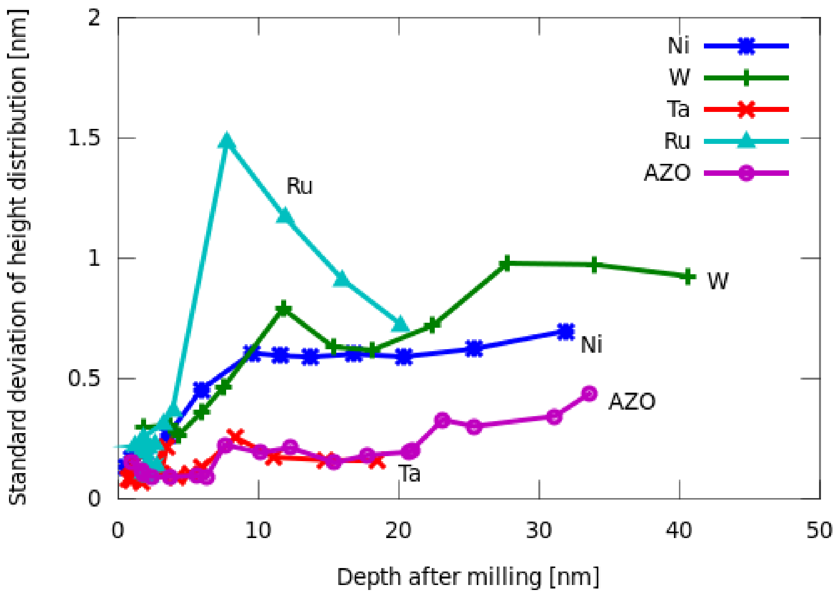

Figure 1: Roughness after FIB milling: 2x2 µm² squares were milled into nominally 10nm thick hard mask layers using. The exposure time was varied for each square. The topography of the squares was acquired after milling using an atomic force microscope (AFM) and the height distribution inside the milled area was analyzed.

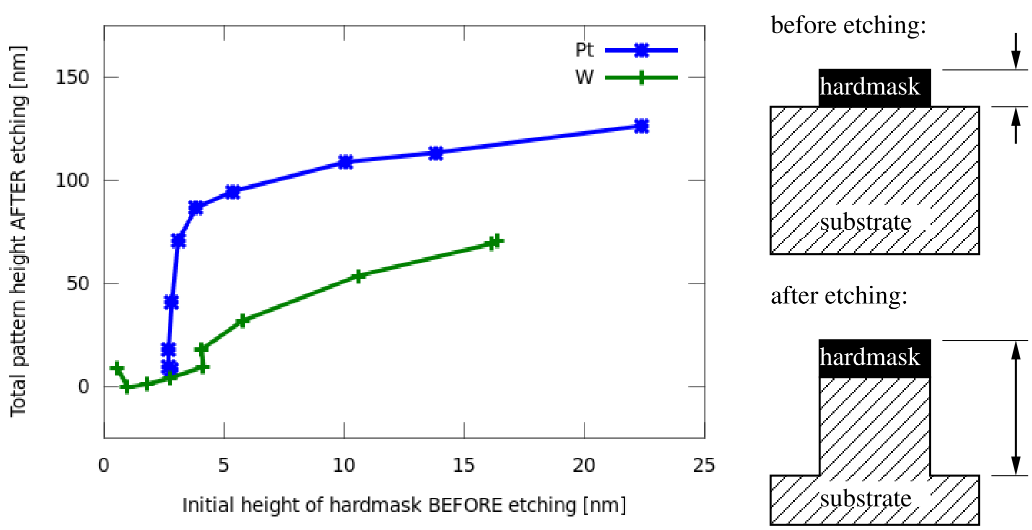

Figure 2: Etch selectivity of W and Pt deposited by FIB GAD against Si: Pt and W were deposited by FIB-GAD on a Si substrate with different exposure times on 1x3 µm² rectangles. The height of the deposited rectangles was then acquired using an atomic force microscope (AFM). The sample was etched by RIE and the topography was again acquired by AFM. In case of the Pt precursor the deposition of a 5 nm layer was sufficient for patterning a 100 nm deep trenches. In case of W even a 17 nm thick layer did not survive the complete etching process.