Nanofabrication of high aspect ratio structures using evaporated polystyrene resist containing metal

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Direct etch using the resist as mask or liftoff are two popular pattern transfer processes. To pattern deep structures using direct etch method, an intermediate hard mask is often needed due to low plasma etch resistance of resists, which adds multiple steps for the process [1]. Moreover, the required high resist patterns may collapse easily due to capillary force during post-development drying. To overcome such problems, a single resist layer for both defining patterns and using it as the dry etch mask becomes very desirable, which has been realized previously using atomic layer deposition (ALD) infiltration of metal oxide Al_2O_3 into the resist [1-2]. Here we show that polystyrene electron beam resist can become a superior dry-etch mask by incorporating metal into it, which can be done simply by co-evaporation of polystyrene and metal as we have shown previously that polystyrene can be thermally evaporated [3].

To validate our idea, we deposited a mixture of polystyrene and chromium film by co-evaporation of 1.2 kg/mol molecular weight polystyrene resist and Cr metal with a total thickness of 220 nm with 15:1 (resist : metal) ratio. After deposition, we exposed line arrays with 500 nm period using Raith 150^{TWO} system at 5 keV. Upon exposure, the film was developed by soaking in xylene for 1 minute in an ultrasonic bath, followed by rinsing with IPA for 20 seconds. Next, we etched the under-layer silicon using an Oxford Instruments ICP-RIE with SF_6 and C_4F_8 gas for 8 min, which has demonstrated ultra-high aspect ratio etching with smooth walls [4]. As seen in Figure 1, we achieved 100 nm line-width and 3.5 μm height (aspect ratio 1:35); and there is still a thick (100 nm) resist/metal left. For pure polystyrene, the etching selectivity to silicon is 1:2.6, thus 220 nm mask can etch silicon at most 586 nm.

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[2] M. M. Mirza, H. Zhou, P. Velha, X. Li and K. E. Docherty, J. Vac. Sci. Technol. B 30(6), 06FF02, Nov/Dec 2012.
[3] J. Zhang and B. Cui, presented at EIPBN 2012 and manuscript to be submitted.
[4] M. Khorasaninejad, J. Walia and S. S. Saini, Nanotechnol., 23, 275706 (2012).

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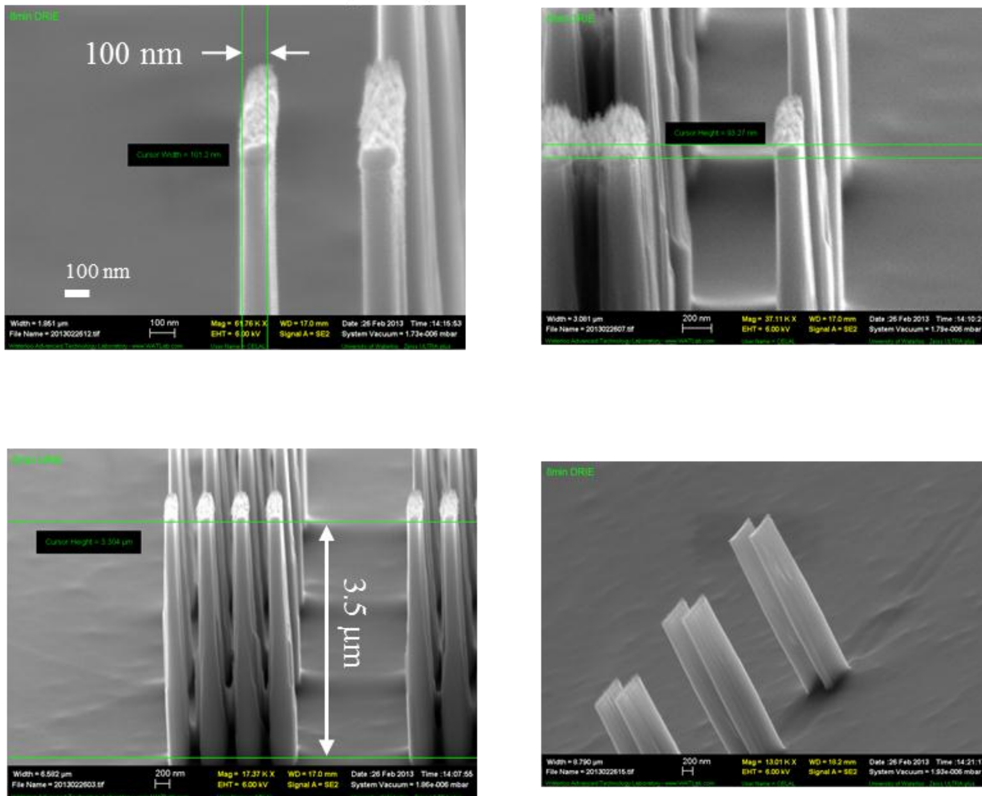

Figure 1. SEM images of etched silicon structure, with sample tilt angle of 70 degree. The etch mask is a mixture of polystyrene and chrome patterned by electron beam lithography. The measured line-width, line-height, and remaining resist/metal thickness are approximately 100 nm, 3.5 µm and 100 nm, respectively.