1.5 nm fabrication of test patterns for characterization of metrological systems

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The semiconductor industry is moving toward a half-pitch of 11 nm and 7 nm. The metrology equipment should be at least one order of magnitude more accurate than that. The characterization of metrology systems requires test patterns at a scale one order smaller than the measured features. The fabrication of test patterns with linewidths down to 1.5 nm is described. The lamellas of the test samples were imaged using transmission electron microscope (TEM). TEM images of the test sample at two magnifications is shown in Figure 1. The scale bar on the image 1b is 50 nm. The test pattern contains alternating lines of silicon and silicon-tungsten, this resulted in a good contrast of images. The size of the test sample was approximately 6x6 microns, and involved thousands of lines, each according to its designed width.

The test sample was designed in such a way that the distribution of linewidths appears to be random at any location.[1,2] This pseudo-random test pattern is used to characterize metrological equipment. The power spectral density of such a test pattern is inherently flat, down to the minimum size of lines. Metrology systems add a cut-off to the spectra at high frequencies; the shape of the cut-off characterizes the system, resulting in the modulation transfer function (MTF), or contrast transfer function. The MTF is widely used to characterize optical systems, and has allowed optical systems to be perfected down to their diffraction limit. There were attempts to use the MTF to characterize nanometrology systems such as SEMs,[3] but the absence of natural samples with known spatial frequencies in the required dimensional range was a common problem. Using the pseudo-random test pattern, nano-metrology systems can be characterized over their entire dynamic range. Examples of a section of the ideal test pattern and a SEM image of the test sample are shown in Figure 2. A comparison of the power spectra from such images results in the MTF of the microscope and describes the loss of sensitivity as the linewidth decreases.

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2. S. K. Barber, e.a., JVST B, (2009) v. 27 N6 3213 (2009)
3. J. Michael, Scanning, v.33, N3, 147 (2011)

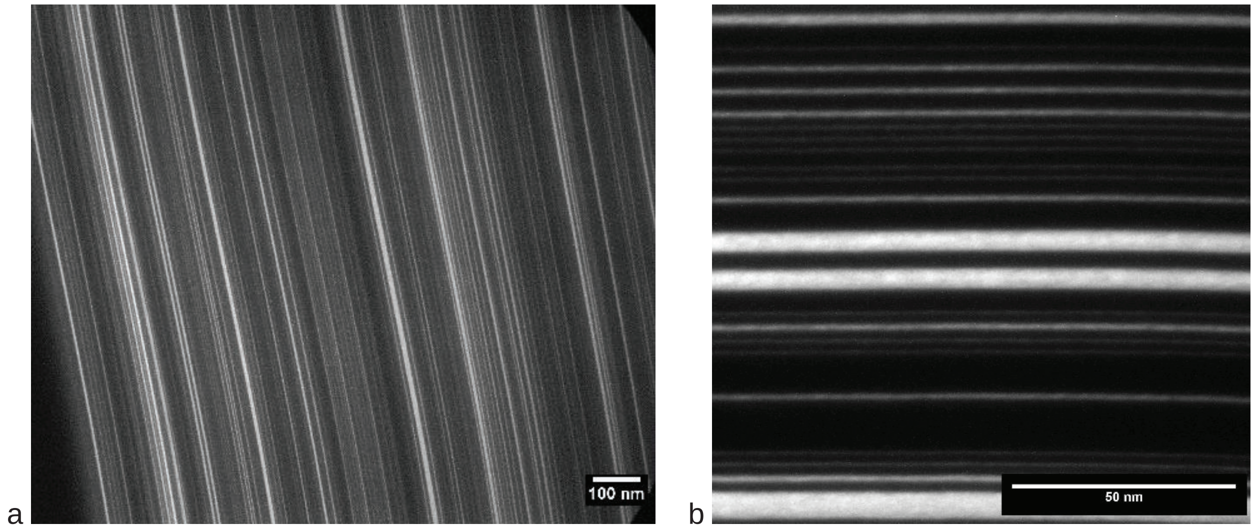

Figure 1. TEM images of the test pattern with linewidths down to 1.5 nm. The width of the lines was designed to form a pseudo-random test pattern; the pattern is used to characterize metrological instrumentation. The scale bars on the image (a) is 100 nm, on the image (b) is 50 nm.

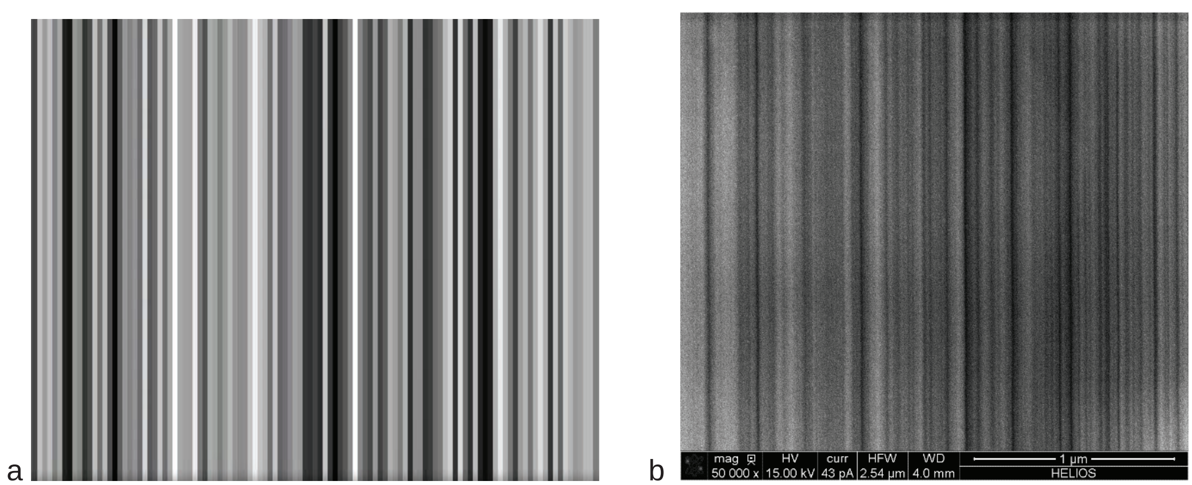

Figure 2. a) a section of the designed pseudo-random test sample; b) SEM image of a test sample.