Development of Pseudo-random Binary Gratings and Arrays for Calibration of Surface Profile Metrology Tools

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Optical Metrology tools, especially for short wavelength (EUV and X-Ray), must cover a wide range of spatial frequencies from the very low, which affects figure, to the important mid-spatial frequencies and the high spatial frequency range, which produces undesirable flair. A major difficulty in using surface profilometers arises due to the unknown Modulation Transfer Function (MTF) of the instruments. Therefore, accurate calibration of profilometers, the understanding of their MTF limitations, and cross calibration between tools represents a considerable challenge for quantitative optical metrology. In previous work[1] the instrumental MTF of a surface profiler was precisely measured using reference test surfaces based on binary pseudo-random (BPR) gratings. Here, we present results of fabricating and using two-dimensional (2D) BPR arrays that allow for a direct 2D calibration of the instrumental MTF. BPR sequences are widely used in engineering and communication applications such as Global Position System, and wireless communication protocol. The ideal BPR pattern has a flat "white noise" response over the entire range of spatial frequencies of interest. The BPR array used here is based on the Uniformly Redundant Array prescription[2] initially used for x-ray and gamma ray astronomy applications. The URA's superior imaging capability originates from the fact that its cyclical autocorrelation function very closely approximates a delta function, which produces a flat Power Spectrum Density (PSD).

Three different BPR array patterns were fabricated by electron beam lithography and ICP etching of silicon. The basic size unit was 200 nm, 400 nm, and 600 nm. Figure 1 shows the fabrication sequence.

The 2D BPR arrays were used as standard test surfaces for MTF calibration of the MicroMap™-570 interferometric microscope with all available objectives. Figure 2 shows representative scanning probe height data for the 400 nm BPR sample. Figure 3 shows the raw Power Spectral Density for 5 different objectives. We demonstrate that the two dimensional BPR array is a very effective calibration standard. However, departures from ideal, such as square sidewall, and uniform etch depth ultimately can limit the accuracy of the calibration. The effects of fabrication imperfections on the efficiency of calibration will be discussed.

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1. V. V. Yashchuk, W. R. McKinney, P. Z. Takacs, *Binary pseudo-random grating as a standard test surface for measurement of modulation transfer function of interferometric microscopes,* Proc. SPIE **6704**, 670408 (2007).
2. E. E. Fenimore and T. M. Cannon, *Coded aperture imaging with uniformly redundant arrays,* Applied optics **17**(3), 337-47 (1978).

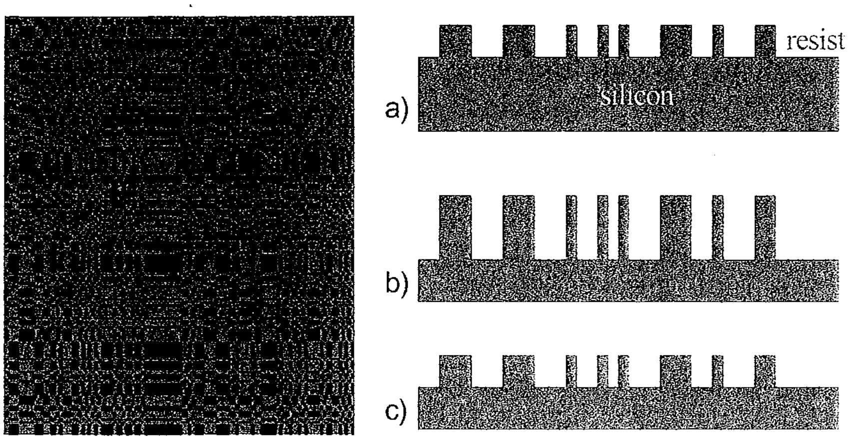

Figure 1: The pseudo-random pattern and the process used to fabricate the test samples. Datasets were generated with a fundamental rectangle size of 200 nm, 400 nm, and 600 nm. The process involves a) exposing and developing a modest resolution resist, b) etching in fluorine, and c) etching in oxygen to remove the resist.

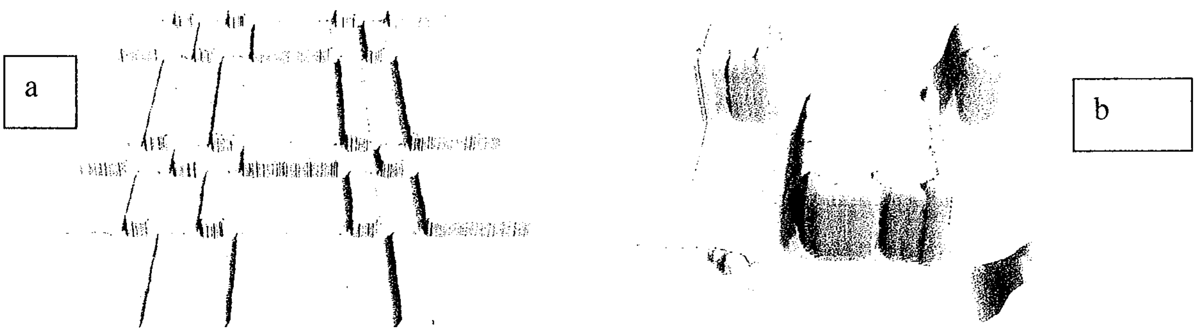

Figure 2: Surface height distribution of 400 nm fundamental pixel BPR array as measured on a scanning probe microscope. a) 5 μm x 5 μm area drawn to scale. The average height of a peak is ~185 nm. b) A magnified section illustrating the shape of an elementary pixel of the BPRA.

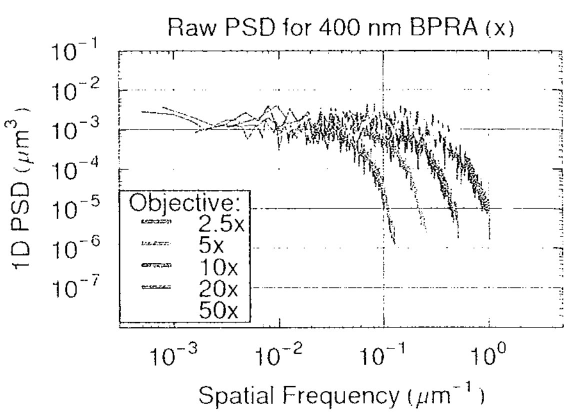

Figure 3: Raw uncorrected Power Spectral Density (PSD) of 400 nm base unit BPR array.