Biases in the use of height-to-height correlation to characterize roughness

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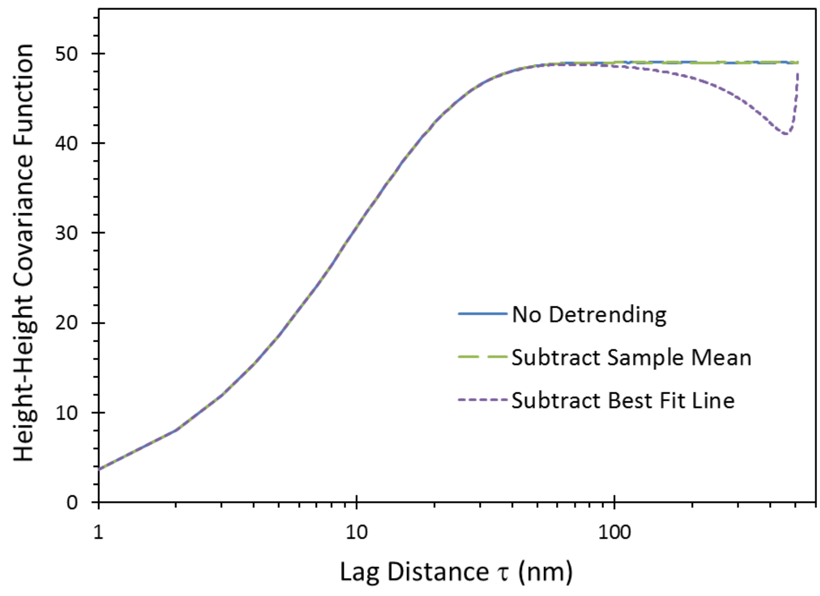
Extended Abstract

Measurement and characterization of the roughness of a surface or feature can be done in several ways, including the use of the power spectral density (PSD) and the height-to-height correlation function (HHCF). However, such measurements involve large random and systematic errors. While random errors can be reduced by averaging together many PSDs or HHCFs, systematic errors can be reduced only by carefully studying and understanding the sources of these systematic biases. In previous studies, [1,2] several significant sources of systematic bias in the measurement of the PSD for line-edge roughness (LER) or linewidth roughness (LWR) measurements were identified and characterized. Spectral leakage is caused by the measurement of a finite length of line and can be mitigated through the use of data windowing. Aliasing is caused by the use of a non-zero sampling distance and can be mitigated by adjusting the sampling distance in relation to the interaction range of the SEM measurement spot (or the tip size for AFM). SEM measurement noise has also been characterized as a source of bias. [3] Unlike LWR measurement, LER involves the fitting of a line to a measured edge and using the residuals to calculate the roughness and the PSD. The use of an arbitrary best-fit line allows for the possibility of SEM sample rotation, which is taken out because of the arbitrary slope of the best-fit line, but causes roughness with a wavelength on the order of the measurement length to be removed. Thus, this best-fit line biases the lowest frequencies of the PSD measurement downward, and systematically changes the shape of the autocorrelation function extracted from a PSD. [2]

The height-to-height correlation function does not suffer from several of the biases that plague the PSD. This paper will fully explore the biases found in the measurement of the HHCF of a rough lithographic feature through the use of simulation and analytical derivations. A comparison to PSD measurements will be made, and recommendations for best methods in the use of PSD or HHCF to characterize roughness will be given.

[1] Chris A. Mack, "Systematic Errors in the Measurement of Power Spectral Density", *Journal of Micro/Nanolithography, MEMS, and MOEMS*, **12**(3), 033016 (2013).
[2] Chris A. Mack, "More systematic errors in the measurement of power spectral density", *J. Micro/Nanolith. MEMS MOEMS,* **14**(3), 033502 (2015).
[3] J. S. Villarrubia and B. D. Bunday, "Unbiased Estimation of Linewidth Roughness", *Proc. SPIE*, **5752**, 480-488 (2005).


Height-Height Covariance Function
50
40
30
20
10
0
1
10
100
Lag Distance τ (nm)
No Detrending
Subtract Sample Mean
Subtract Best Fit Line