Line Edge Roughness Frequency Analysis during Pattern Transfer in Semiconductor Fabrication

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The line edge roughness (LER) is a critical yield-limiting factor in the fabrication of semiconductor devices. The most popular LER characterization methodology is still standard deviation method, in which three times the root mean square (RMS), 3σ, calculated in the spatial domain is used to represent LER. However, a single number LER method is not good anymore when people continue to reduce LER and decompose it in frequency domain. For example, the power spectral density (PSD) method is used to characterize LER reduction. When LER transfers from mask to wafer and from lithography to etch step, different frequency region usually has different response to process. In 2015, L. Sun, et al, proposed frequency analysis based 3 sigma LER characterization methodology [1]. The standard deviation is calculated in the frequency domain instead of the spatial domain as in the conventional method. The power spectrum of the LER is divided into three regions: low frequency (LF), middle frequency (MF) and high frequency (HF) regions. The frequency region definition is based on process comparisons. Three standard deviation numbers are used to characterize the LER in the three frequency regions, which are shown in Figure 1. With the new methodology, the LER value for each frequency region can be quantified separately.

The LER transfer during etch processing will be discussed in this paper. The LER standard deviation will be presented as a function of process steps for different frequency regions. If the LER in a certain frequency region, for example, the high frequency region, is clearly blocked by the process, people can no longer care about it and can focus on the dominating frequency. This feature of the new characterization methodology could be very useful for photoresist vendors and foundries.

Wiggling effect is the severe pattern deformations induced by the substrate etching process. The method to detect wiggling effect is still visual inspection. However, the residual wiggling which cannot be detected by visual inspection, is a source for LER during etch transfer. With the frequency analysis based 3 sigma LER methodology, residual wiggling can be detected and process optimization to reduce residual wiggling becomes possible.

Finally, different-frequency LER impact to device will be discussed.

Ref. 1. L. Sun, W. Wang, O. R. Wood, R. H. Kim, "Application of frequency domain line-edge roughness characterization methodology in lithography", SPIE Advanced Lithography, 9424-4, 2015

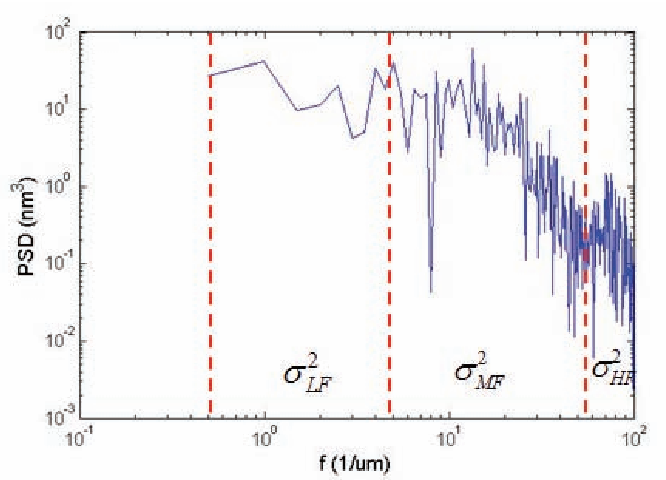

Figure 1: The power spectral density of the LER of a pitch 36-nm line and space is plotted as a function of frequency. The total PSD is divided into three regions: LF, MF and HF.