Reconstructing Cross-Sectional Profiles from Top-View SEM Images Using Edge Fluctuation Characteristics

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Top-view images captured in CD-SEM have widely been used for measuring CD and line-edge roughness (LER). This paper explores a further possibility for extracting information hidden in the images. Cross-sectional profiles are reconstructed from top-view SEM images using edge fluctuation characteristics.

Fluctuation in three-dimensional pattern shape Z(x,y) is decomposed into two components, a shift along the x-axis of an averaged cross-sectional profile (1) and deviation in cross-sectional profile from its average at each y-position (2) as,
$Z(x,y) = \langle Z\rangle(x+\Delta x) + \Delta Z(x,y)$. (Fig.1a)
The each component independently affects a SEM signal profile and detected edge position. Consequently, fluctuation in the detected edge position (usually called LER) is decomposed similarly as,
$\sigma^2 = \sigma_y^2 + \sigma_{xz}^2 + \sigma_{noise}^2$,
where σ_y, σ_{xz}, and σ_{noise} are variations caused by a shift along x-axis of the averaged profile, by deviation of cross-sectional profile from its average, and by random image noise, respectively. σ_{xz} is further decomposed as
$\sigma_{xz}^2 = \sigma_{xz\_near}^2 + \sigma_{xz\_far}^2$,
where σ_{xz_near} is a variation caused by the surface morphology near the incident point of electron beam, and σ_{xz_far} is by deviation in surface shape (e.g. sidewall) from its average far from the incident point. Here, we obtain σ_{xz_near} by subtracting σ_y (extracted as component with 1/f characteristics), σ_{noise} (depending on the image slope), and σ_{xz_far} (derived from sensitivity study using Monte-Carlo simulation and fed into an empirical rule) from measured σ. Then, a local slope angle θ of the pattern surface is estimated by modeling the relationship between σ_{xz_near} and θ, as shown in (but not limited to) Fig.1b. By varying the threshold levels for edge detection, the variations σ corresponding to different signal level (or x-position) are obtained [1], and corresponding local sidewall angle is calculated for each x-position. Integrating the obtained angle along x-axis, cross-sectional profile is reconstructed.

Resist samples A and B exposed under different focus conditions were measured and σ were decomposed into the four components (Fig.2a). Reconstructed cross-sectional profiles showed good agreements with the results separately obtained by AFM (Fig.2b).

References

[1] A. Yamaguchi, et al., Proc. SPIE 7971, 797110A (2011).

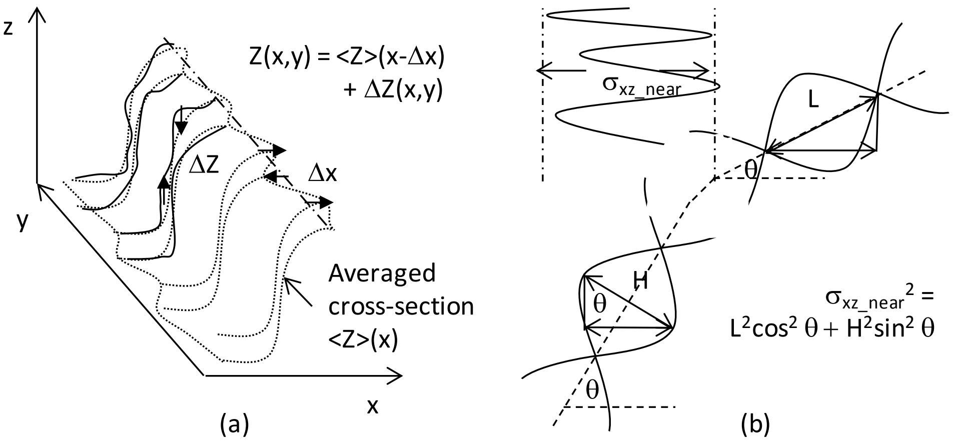

Figure 1:
Method for decomposing variations in 3D-pattern shape (a), and model relationship between local angle of pattern surface and edge fluctuation σ (b).

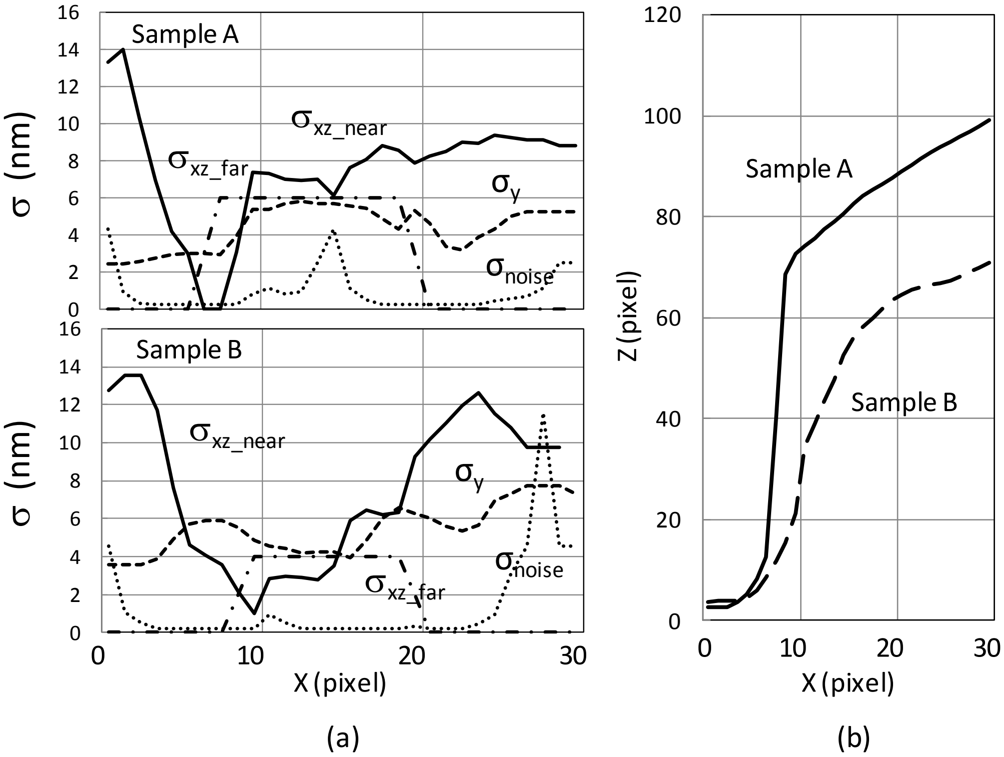

Figure 2:
Distributions of decomposed edge-fluctuation components along the x-axis (a), and reconstructed cross-sectional profiles (b), for the two resist samples exposed under different focus settings. (1 pixel = 1.3nm)