Modeling and Algorithm in Three-dimensional Metrology with Critical Dimension Scanning Electron Microscope

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Critical dimension scanning electron microscope (CD SEM) is one of the most versatile techniques used for in-line integrated circuit measurements to monitor and improve yield and process[1]. Shrinking feature sizes and complex three-dimensional(3D) device structures place increased challenge on conventional CD SEM, particularly for the height, sidewall angel (SWA) measurements[2]. To address this issue, tilt-beam CD SEM was introduced.
Modeling and simulation would be integrated into all aspect of metrology[3]. However, most algorithms and models are focused on trapezoid structures and there is few on inverted trapezoid structures which are common in semiconductor fabrication.

Here, a novel model and algorithm was proposed to investigate height, SWA measurements of trapezoid and inverted trapezoid structures. The study was based on Monte-Carlo simulation, which is considered as a valid tool to study the electron-matter interaction mechanism, the algorithm and model of signal electrons generated in CD SEM. Figure 1(a) and Figure 1(b) schematically depicts the diagram for modeled trapezoid structure and inverted trapezoid respectively. Figure 2 shows secondary electron (SE) intensity distribution for trapezoid structure with geometric parameter $\theta = 10$ deg under different tilted angles α of electron beam. In this study, a parameter y is defined and its value can be extracted from linescan profiles. Figure 3 illustrates the relationship between y and α for trapezoid and inverted trapezoid structure with different θ. According to the extracted parameters y, α and the linescan profiles, height and SWA can be figured out.

Modeling and simulation results based on 3D version of CASINO software shows that height and SWA measurements of trapezoid, inverted trapezoid as well as step structures can be achieved with high accuracy in this study. More results and optimization details of our method will be presented at the conference.

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[1] N. G. Orji *et al.*, *Nat Electron* **1**, 532-547 (2018).
[2] IEEE, “The international roadmap for devices and systems (IRDS): 2021 edition,” 2021, https://irds.ieee.org/images/files/pdf/2021/2021IRDS_MET.pdf
[3] J. P. Cain *et al.*, *J. Micro/Nanolith. MEMS MOEMS* **13**, 4, 041407 (2014).

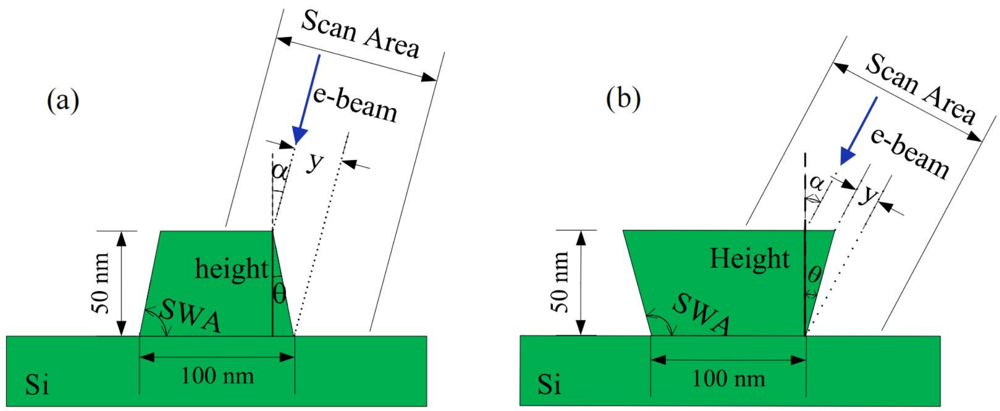

Figure 1: Geometric diagram for (a) trapezoidal and (b) inverted trapezoid.

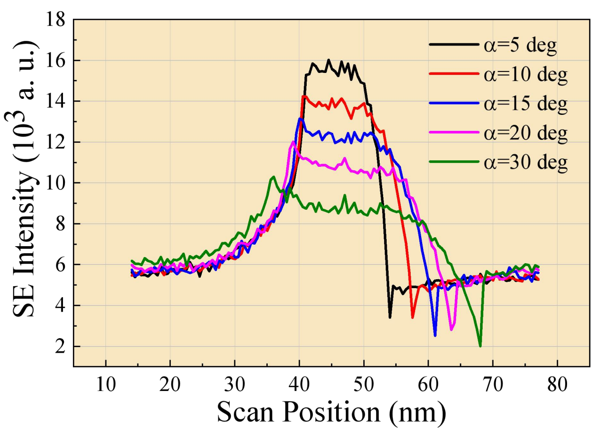

Figure 2: SE intensity distribution with varying tilted angles α of electron beam.

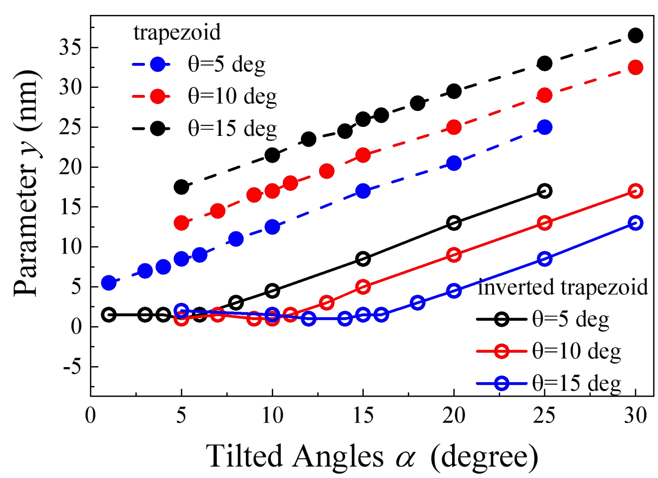

Figure 3: The relation between parameter y and tilted angles α of electron beam in trapezoid and the inverted structure with different θ, respectively.