Prediction of Critical Dimensions of 3D Structures in CD SEM Metrology Based on LSTM Neural Network

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With advances in semiconductor fabrication processes, the development of integrated circuits has shifted from reducing channel dimensions to establishing three-dimensional (3D) structures (FinFET)[1]. How to obtain critical parameters of three-dimensional structures via Critical dimension scanning electron microscopy (CD SEM) has become a key consideration. The schematic diagram of a typical structure is shown in Figure 1, where four key dimensions are defined: BCD (bottom critical dimension) is the bottom width of the line, SWA (sidewall angle) is the sidewall angle, h (height) denotes the height, and r (radius) represents the radius of the top and bottom fillet corners. To address this challenge, a cascaded model based on Long Short-Term Memory (LSTM) networks, which aims to enhance accuracy[2], is proposed for predicting three-dimensional critical dimensions of silicon-based line structures. The cascaded model architecture in this study is illustrated in Figure 2. In this study, models of line structures with different critical dimensions were established, and the Nebula Monte Carlo electron simulator was used to generate corresponding secondary electron data. Four sub-models were constructed using LSTM neural networks, followed by a step-by-step prediction implemented through model cascading. The result from the previous prediction is used as a feature and added to the input of the subsequent model, adding constraints to further enhance prediction accuracy. Figure 3 illustrates the relative error distribution for the four predicted values（Radius、BCD、Height 、 SWA） of the cascaded model; the errors are distributed around the 0% value (indicated by the red dashed line), indicates that the model's predictive method has high accuracy[3]. Within a given relative error pattern, a wider horizontal bar indicates a higher proportion of that error within the overall error distribution. This study provides a novel methodology for measuring the critical dimensions of 3D structures using CD-SEM.

1.Zhou, Jingfeng. "Advantages, manufacturing processes and challenges of FinFET technology." Journal of Physics: Conference Series. Vol. 2798. No. 1. IOP Publishing, 2024.

2.De Zarzà, I., et al. "Cascading and ensemble techniques in deep learning." Electronics 12.15 (2023): 3354.

3. Villarrubia, John S., and Zejun J. Ding. "Sensitivity of scanning electron microscope width measurements to model assumptions." Journal of Micro/Nanolithography, MEMS and MOEMS 8.3 (2009): 033003-033003.

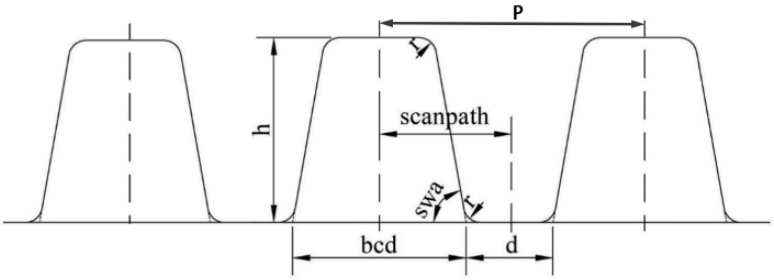

Fig. 1. Schematic Cross-Section of Silicon-Based Line Structure

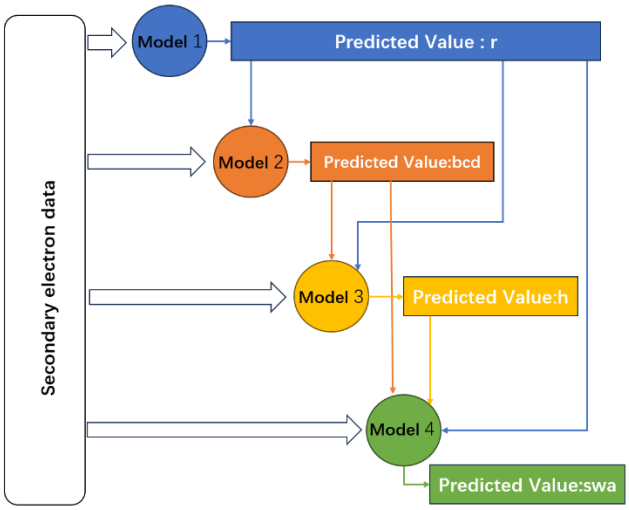

FIG. 2. Diagram of cascade model training and architecture.

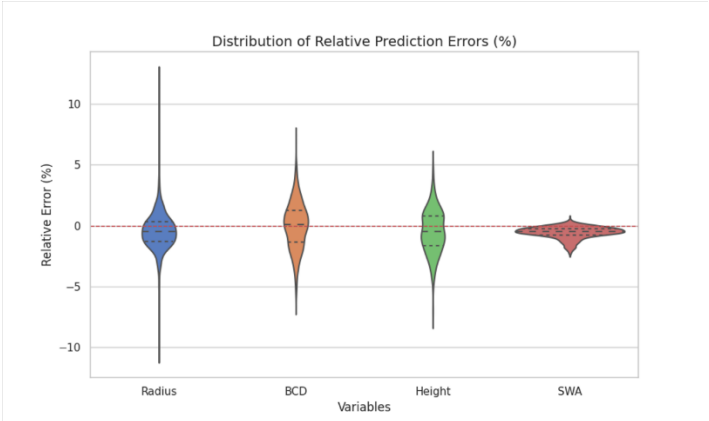

FIG. 3. Violin plot of relative error distribution.