Machine Learning in Critical Dimension Measurement by CD-SEM

P. Guo[1], **Z. J. Ding**[2*]

[1]Department of Modern Mechanics, University of Science and Technology of China, Hefei, Anhui 230027, China

[2]Department of Physics, University of Science and Technology of China, Hefei, Anhui 230026, China

Machine learning (ML) algorithm can be an effective adjunct to the model-based library (MBL) approach for nanometrology. This paper presents an innovative approach that marries a Monte Carlo simulation method with ML algorithms to extend the MBL database, which is crucial for accurate critical dimension (CD) measurement from CD-SEM images. By focusing on the precise calculation of secondary electron linescan curves in a CD-SEM image of a semiconductor line structure, we meticulously explore the effects of varying geometrical and electron beam parameters. This methodological development enables the quick generation of a rich MBL dataset.

The basic principle of the MBL algorithm is to calculate the linescan curve under different geometric parameter structures and electron beam parameter conditions through the Monte Carlo method, thereby establishing the corresponding relationship between the parameters and the curve shape. Then compare the experimentally measured curve with the curve in the database to infer the linewidth parameters of the sample to be measured. In order to obtain more accurate measurement results, it is necessary to pay a large computational cost to build a database with complete and detailed parameter classification.

Utilizing the Monte Carlo directly generated MBL dataset, our study pioneers the application of neural networks to predict and extend the MBL database with high fidelity. The approach is validated through rigorous testing on trapezoidal line structures of single-layer Au and double-layer Si lines, demonstrating a remarkable prediction accuracy with standard deviations of 0.1% and 6% for relative error distributions, respectively. These results underscore the potential of ML to revolutionize CD measurement by significantly enhancing the precision of the MBL method. By drastically reducing the computational load and storage requirements conventionally associated with expanding the MBL database, our ML-integrated approach offers a scalable and efficient solution to the challenges of semiconductor metrology. It enables the MBL database to accommodate a broader array of geometrical configurations without the prohibitive costs of intensive simulations, facilitating a more adaptable response to the diverse requirement of semiconductor fabrication.

---

[*] Corresponding author: zjding@ustc.edu.cn

Fig. 1(a) presents the simulation results for a series of T-values ranging from 30 nm to 75 nm, with increments of 5 nm, keeping all other parameters constant. Figs. 1(b)-1(d) display comparisons across three scenarios between direct Monte Carlo simulations, machine learning predictions, and simple interpolation. Linear interpolation is employed to calculate the interpolated values of a bivariate function at a specific point, ensuring that the outcome intersects with the original function sampling points. It is observed that the machine learning predictions consistently show excellent agreement with the Monte Carlo simulations, whereas interpolation exhibits certain discrepancies, notably in the peak positions in Figure 1(c) and the peak heights in Figure 1(d). Thus, the accuracy of the neural network approach significantly surpasses that of the interpolation method.

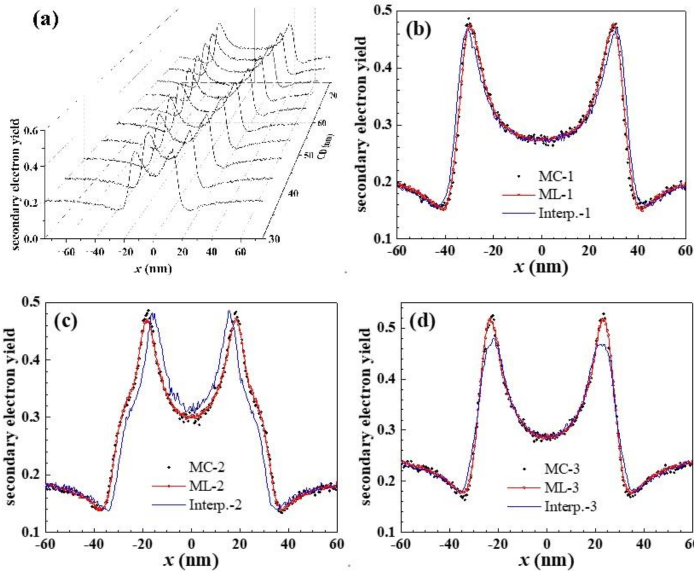

Figure 1. Comparison of the direct Monte Carlo calculated linescan with the ML predicated linescan curves for a Si double-layer trapezoidal line structure.

The successful application of ML to extend the MBL database not only streamlines the process of CD measurement but also establishes a solid groundwork for the practical implementation of advanced metrological techniques. Ultimately, this integration paves the way for future advancements in semiconductor manufacturing, promising significant contribution to the ongoing evolution.

Keywords：CD-SEM; Monte Carlo; secondary electrons; machine learning; neural network

REFERENCES

[1] Microbeam analysisScanning electron microscopyMethod for evaluating critical dimensions by CD-SEM, ISO 21466:2019E (2019).

[2] Y. B. Zou, M. S. S. Khan, H. M. Li, Y. G. Li, W. Li, S. T. Gao, L. S. Liu and Z. J. Ding, *Measurement*, **123** (2018) 150-162.

[3] Z. J. Ding, X. D. Tang and R. Shimizu, *J. Appl. Phys*. **89** (2001) 718.

BIOGRAPHY

Guo Peng is now a doctoral student at the Department of Modern Mechanics of the University of Science and Technology of China.