A Machine Learning Process for Flexible Inline Critical Dimensions Measurement from Images

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Accurate and efficient measurement of feature sizes from images taken using various characterization processes such as scanning electron microscopy (SEM) and atomic force microscopy (AFM) images is critical for nanoscale fabrication analysis. Traditional manual measurement methods are labor-intensive, subjective, and impractical for high-throughput scenarios. Developments in image processing strategies for lowering noise have simplified the framework of creating lightweight programs to extract critical dimensions from images acquired at different SEM voltage and acceleration conditions[1]. Furthermore, rapid dissemination of machine learning algorithms has enabled the possibility of training models for various scenarios.

In this work, we present a machine learning framework leveraging the YOLO object detection algorithm, supplemented with the Random Forest model, to create a lightweight program to automate the identification and measurement of various structures in SEM images. In general terms, the user trains the model for a specific case by making annotations on several images detailing the location of the features and the span of the measurement. When measurements are needed, the user then loads the model into the program and takes the measurements.

During both training and detection, our program employed algorithms for denoising, checking the measurement spanned the correct features and filtering false positives. Collectively they helped to achieve an optimal balance between accurate detection and final display.

Testing of our program shows that 25 initial images are adequate to train a model that can achieve high accuracy in detection of true feature instances and their sizes. These results highlight the potential of the proposed machine learning based process for automated and accurate feature-size measurement in various fabrication processes such as inline detection. Future work includes further training and developing for complex structures if encountered.

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[1] R. Paul, A. Kumar, and B. Li, in *SEMICON West 2025*, Phoenix, AZ (2025)

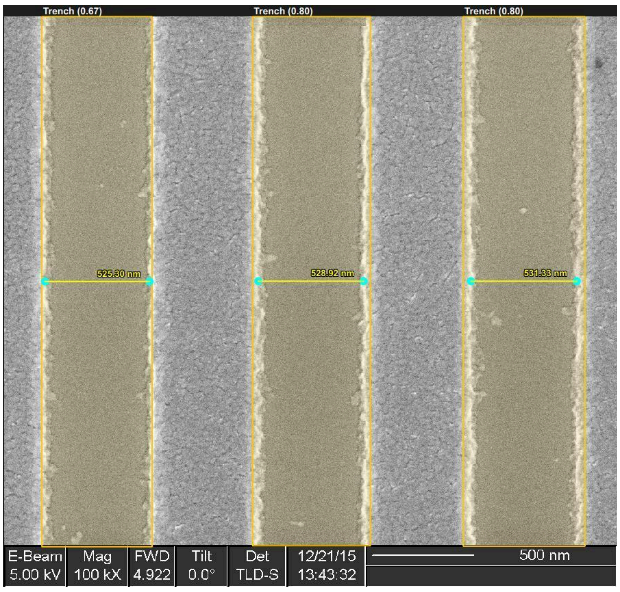

Figure 1: SEM Trenches: The figure shows the width of the trench extracted from an SEM image.

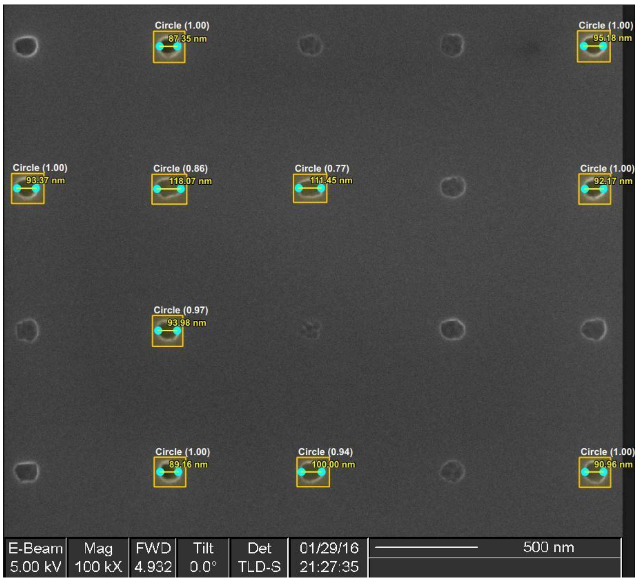

Figure 2: SEM Holes: The figure shows the diameter of holes extracted from an image.