Machine learning for automated categorizing various defect types in KOH-etched microscopy images of 4H-SiC wafers

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Abstract

In semiconductor materials, defects are imperfections of the crystal lattice that can negatively affect the performance of electronic devices. Understanding these defects, particularly dislocations, is important for optimizing the production of high-quality semiconductor materials. However, with the rapid growth of experimental data, manually analyzing and detecting defects has become impractical and unable to keep pace with advancements. In this work, we developed an automated image analysis pipeline that combines various techniques and deep learning methods to extract critical defect information from KOH-etched microscopy images of 4H-SiC wafers. There we focus on the three most common dislocation types seen in these etch-pits: the basal plane dislocation (BPD), threading edge dislocation (TED), and the threading screw dislocation (TSD).

In our application of the methodology, we start by extracting millions of image regions containing a single dislocation etch-pit image [1]. With an unsupervised clustering approach, etch-pits are automatically sorted into categories with corresponding line types to form an image dictionary pool. This pool serves as a source to generate a synthetic dataset, which is used as a training dataset for an instance segmentation task of a deep learning framework. The total time required for the prediction across the 100 mm wafer is roughly 75 min. During this time, around 1.7 million etch pits were identified and located, allowing us to quantitatively compute the distribution of dislocation density distributions of the three dislocation types. Our approach enables the rapid and accurate analysis of large numbers of microscopy images, providing accurate, spatially resolved information about the distribution of different defect types.

References

[1] Nguyen, B.D., Roder, M., Danilewsky, A., Steiner, J., Wellmann, P. and Sandfeld, S., *Journal of Materials Research*, *38*(5), 2023 page 1254-1265.