Improving single crystal diamond size and quality via image based artificial intelligence

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Single crystal diamond (SCD) wafers have been researched as an alternative wide bandgap semiconductor material for their optimal electrical, optical, and physical properties. Currently, the performance of these SCD wafers match, if not exceed, the performance of commercial semiconductors. However, the size of these wafers is a big limitation. Prototypes of these wafers with suitable quality are typically on the scale of 3 mm x 3 mm with some reaching up to 1 inch. Commercial semiconductors are available in up to 6-inch wafers and there is currently a barrier to reaching that size and acceptable quality with SCD wafers. One method that has been gaining momentum is SCD growth via the chemical vapor deposition (CVD) technique. CVD grown diamonds have the potential to match the size of commercial semiconductors via epitaxial layer outgrowth or tiled wafer growth, however, some developments to these processes is needed to achieve a suitable quality. One way we are doing this is via image based artificial intelligence (AI) to predict the growth of the SCD and manipulate the process conditions via a control system integrated with the AI. With our work, we are utilizing microwave plasma-assisted chemical vapor deposition (MPCVD) to synthesize the wafers and capturing image data of the diamond as the growth proceeds. Three inter-connected thrusts work in conjunction to produce the predictive models. This consists of the feature extraction pipeline, to extract geometric features of the captured image, defect detection pipeline, to extract macroscopic defect features of the capture image, and frame prediction pipeline, which uses features, defects, and reactor telemetry, to predict the growth of the SCD wafer up to 12 hours in advance. With the model, prediction accuracy of ~99.9999% was achieved. We are reporting on our recent advances in the AI algorithm development and reactor implementation. Specifically, we will discuss the validation and stress testing of the prediction mechanism. We are also reporting on the latest advances to our autonomous feature and defect segmentation techniques. Finally, we also started exploration of tying together ex-situ materials analysis, such as X-Ray rocking curve mapping with the prediction mechanisms.