Investigations on Optical Microscopy Capabilities during Initiated Chemical Vapor Deposition(iCVD) Experimentation

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Abstract:

In situ monitoring of reactive systems is essential for efficient research, allowing the observations made during trials to influence how the research will adjust and improve over time. It also limits the need to transport samples between devices, reducing the odds of outside contaminants/impacts disturbing the sample's features including size distribution and structure. However, real time imaging using optical microscopy in high vacuum systems is challenging owing to poor resolution of microstructures, significantly reducing the ability to characterize samples throughout the duration of synthesis. Here, we evaluate the constraints that lead to degradation of image quality during in situ optical imaging of an initialized chemical vapor deposition reactor system and establish image processing–based methodologies for improving the resolution of the synthesized microstructures. By capturing images across various physical arrangements of the system setup, we systematically isolate variables contributing to image degradation including external vibrations caused by the chamber's vacuum pump and the quartz glass cover used contain the reaction. The resulting images are processed and evaluated using ImageJ/Fiji to perform automated particle analysis and extract line-intensity profiles. These processed images are then quantitatively compared against high-quality reference images (ex-situ ground truth images) to assess the accuracy of the modified system arrangements and image processing techniques. Alongside this approach, a standard line-grating was imaged and compared under various reactor conditions to directly review the optical capabilities of the iCVD reactor. This test determined significant loss in optical resolution ability was attributed to distortion caused by the glass lid.

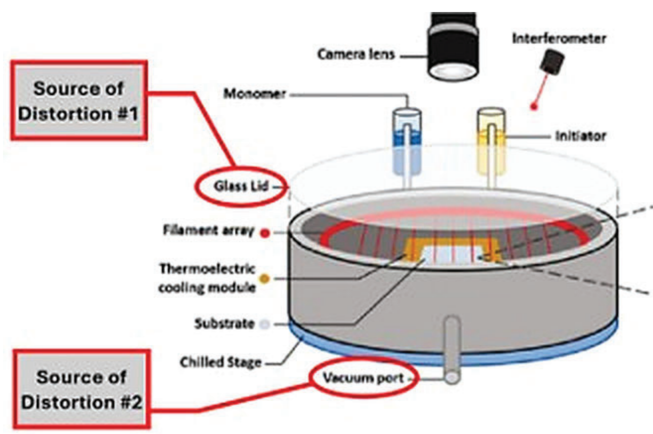

Figure 1: Labeled diagram of the iCVD reactor system studied. Two major sources of optical distortion are labeled.

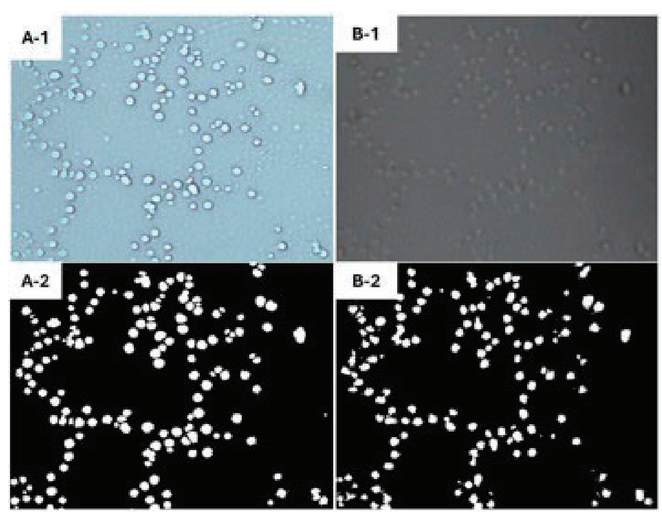

Figure 2: Initial attempts at segmentation and comparison between ex-situ(A) and in-situ(B) images.

Summary of Research:

The direct *ex-situ* to in-situ image comparison method proved certain limitations to certain methods involving computer-aided segmentation was not conclusive. Though the method was theoretically sound, comparing a software's ability to properly perform segmentation on a low-resolution in-situ image and compared to the corresponding high-resolution *in-situ* reference, several issues arose throughout attempts to pursue this task. The research was unable to feasibly utilize Fiji's trainable segmentation software to create a model with both flexibility and accuracy. When the models could identify and divide particles from images, they were unable to perform the same task for different image types (*in-situ vs ex-situ*), and vice versa.

The line-profile test proved much more conclusive. By imaging the standard line grating at maximum (500x)

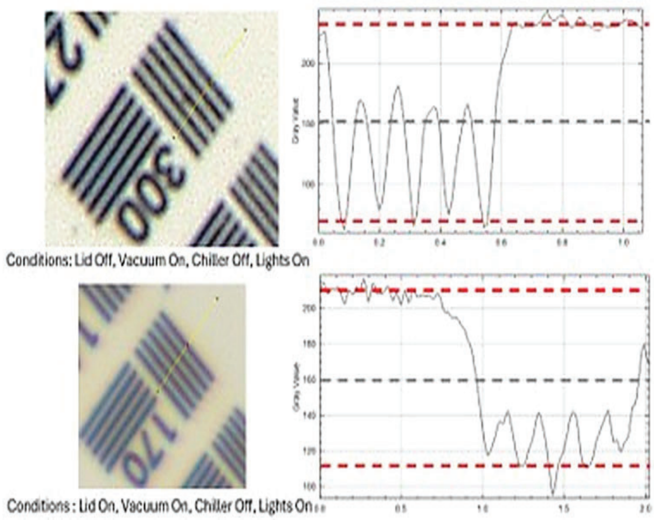

Figure 3: Visual aid displaying line-profile intensity analysis procedure with analysis images on left-hand side and corresponding gray-value plot on right-hand side.

magnification under specific conditions of the reactor (presence of glass lid, status of vacuum pump, status of chiller, & ambient lighting conditions), the measure of gray value was able to be extracted across the grating to determine what spacing of features was resolvable as seen in figure 3. By analyzing the line profiles and measuring to see a 50% gray value recovery relative to the average minimums(troughs) & maximum values, a consistent measure to claim whether the features were resolved was used to determine the relative contributions to distortion. The results expressed that both ambient lighting and external vibrations sourced from instruments besides the vacuum pump were both negligible, while the glass lid contributed significantly higher than all other sources of distortion. The presence of the glass lid reduced the microscope's capability to resolve images by nearly half (from being able to resolve features at 330 lines/mm down to only around 160 lines/mm). The main phenomena caused by these distortions were deduced to be chromatic aberration and some astigmatism as seen in figure 4. The vacuum pump's vibrations only contributed to approximately a 10% to 15% loss in resolving ability.

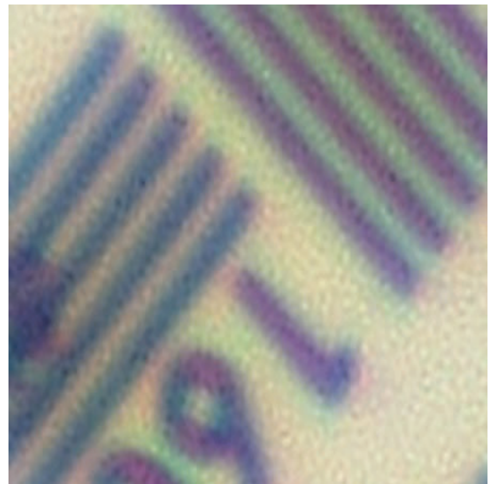

Figure 4: Image capture displaying optical aberrations attributed to glass lid.

Conclusions and Future Steps:

Future investigation should involve the application of any methods deemed appropriate to bypass/mitigate the optical distortion. Discussions within the group have began looking into cameras to be positioned within the chamber, bypassing the glass lid entirely, as well as potentially implementing monochromatic lighting to minimize chromatic aberration.

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References:

[1] Jain, A.; Pal, S.; Li, S.; Abbott, N. L.; Yang, R. Single-Step Synthesis of Shaped Polymeric Particles Using Initiated Chemical Vapor Deposition in Liquid Crystals. Sci. Adv. 2024, 10 (45), eadp5573 DOI:10.1126/sciadv.adp5573

[2] Park, Kwang-Won, Karen K. Gleason, and Rong Yang. Dec 30. 2024, "Advanced morphological control of polymeric surfaces using initiated chemical vapor deposition (iCVD)." Advanced Functional Materials 35, no. 24 (2025): 2417620.

[3] J. Schindelin et al., Fiji (Version 2.15.0). (2024). Accessed: Jul. 20, 2026. [Online]. Available: https://imagej.net/software/fiji/