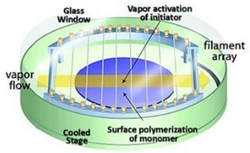
System Optimization of Initiated Chemical Vapor Deposition (iCVD) Reactor

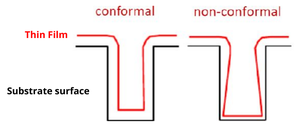
Isaiah Hansink, Rajiv Mangukia, Anh Tran, Ignacio Carrillo, Jesse Gomez

Abstract

Initiated Chemical Vapor Deposition (iCVD) is a versatile and scalable thin-film deposition technique that enables the synthesis of polymeric coatings directly from gaseous monomers. By using a thermal initiator to generate free radicals, the process facilitates surface polymerization without requiring high temperatures, making it suitable for temperature-sensitive substrates. iCVD provides excellent control over film thickness, uniformity, and chemical composition, enabling its application in diverse fields such as electronics, biomedical devices, and barrier coatings. This abstract emphasizes the principles, advantages, and wide-ranging applications of iCVD in advanced material development.

To ensure successful deposition in our Chemical Vapor Deposition (CVD) reactor, several critical objectives were addressed. A 220V vacuum pump was installed and operated safely, enabling effective evacuation of the reactor chamber. The system achieved and maintained a base pressure of 10 ± 5 mTorr, ensuring optimal deposition conditions. Leak rates were rigorously verified and minimized, meeting the target of 10 mTorr/min or less to preserve vacuum integrity. Additionally, a protective enclosure was developed to safeguard operators from harmful fumes, enhancing safety during reactor operation. These measures collectively ensured reliable and efficient CVD reactor performance.

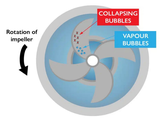




Testing

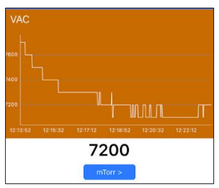
Our goal was to diagnose the problems of the reactor chamber and vacuum system to determine what state the reactor was in.

- 220V vacuum pump did not operate correctly and experienced cavitation.
- Once fixed, we prepared the reactor for testing.
- Initial tests were to achieve the lowest base pressure and observe the leak rate.

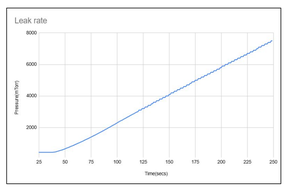


Cavitation Illustration

220V Vacuum Pump

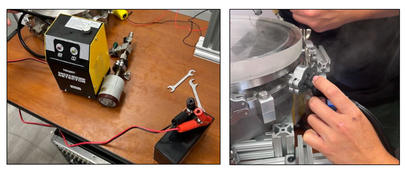


Initial Pressure



Initial Leak Rate (33.74 mTorr/min

After our initial values shown above, we knew we had a large leak somewhere in our reactor system. We decided to test with a smoke machine and 99% Isopropyl alcohol to detect exactly where the leak was coming from. The smoke machine would detect larger leaks and the alcohol detected the smaller leaks in our components.

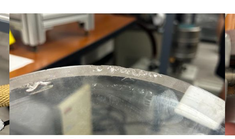


Smoke Machine

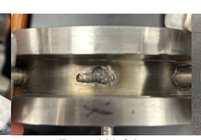
99% Isopropyl Alcohol

We found many sources of leaks in our system including chipped glass, poor welds, poor kf flange surfaces, and poor surface contact on some of our components.

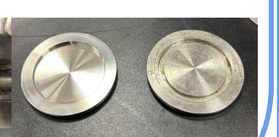
Leak Area



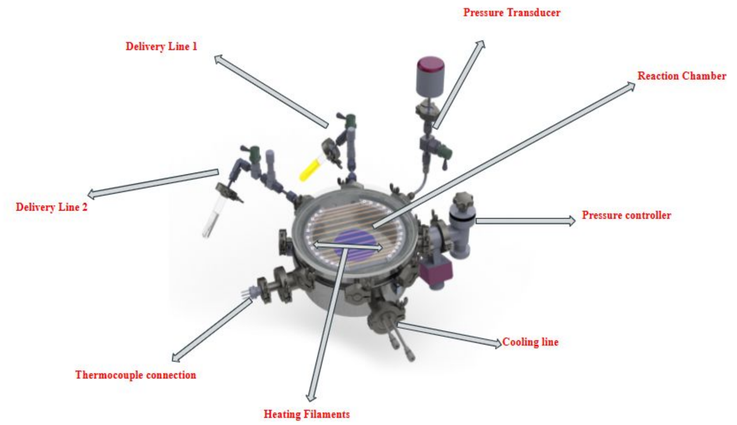
Chipped Glass



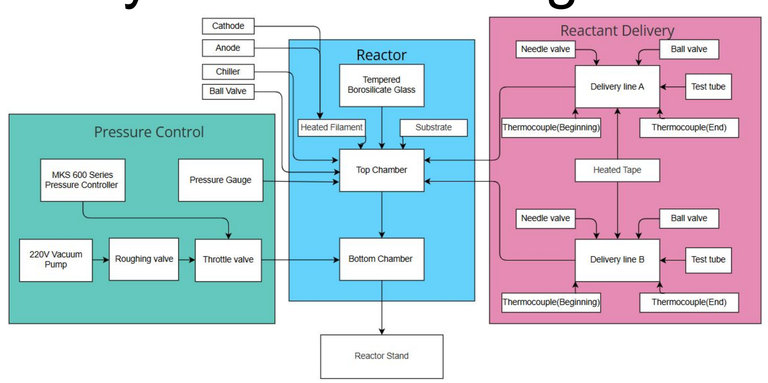
Poor Welds



kf Flange Caps

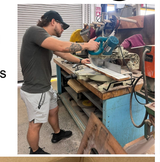


System Level Diagram



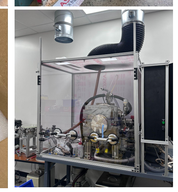
Manufacturing

- The top chamber of the reactor was successfully redesigned and manufactured with the invaluable support of Yamuna Machine Works Ltd., whose expertise ensured precision and quality. Additionally, a new borosilicate glass cover was procured to enhance the reactor's performance, leveraging its superior thermal and chemical resistance for optimal operation. These upgrades have significantly improved the reactor's efficiency and reliability.
- Precision built enclosure to trap any harmful gasses.



New Manufactured Chamber

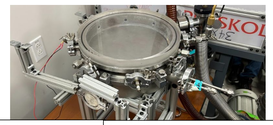
New Glass

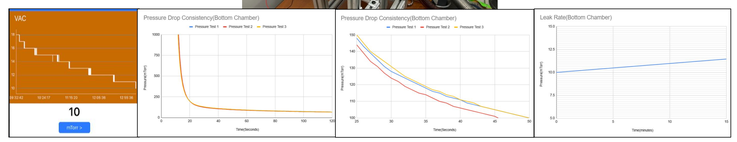


Enclosure

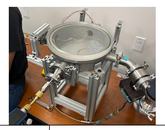
Results

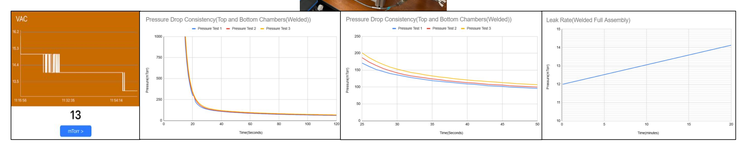
Bottom Chamber (Base Pressure: 10 mTorr Leak rate: 0.097 mTorr/min)



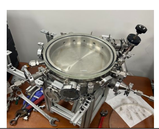


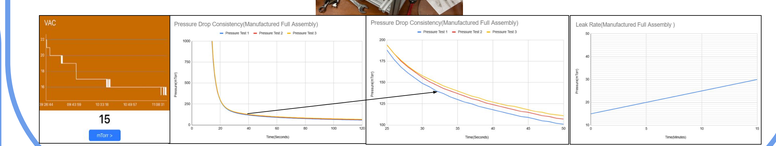
Full Assembly (Welded Top Chamber Base Pressure:13 mTorr Leak rate: 0.107 mTorr/min)





Full Assembly (Manufactured Top Chamber Base Pressure: 15 mTorr Leak rate:1 mTorr/min)





Conclusion

This CVD reactor project challenged us to think creatively and tackle unexpected issues that led to bigger problems. We successfully identified and fixed all leak sources in the reactor chamber, achieving a stable base pressure of 10 mTorr with a leak rate below 10 mTorr/min. Thanks to teamwork, persistence, and the unwavering support of our sponsor, we now have a fully operational iCVD reactor, ready to deliver reliable and precise performance. We would like to acknowledge Dr. Lehman, Dr. Heydari Gharahcheshmeh, Mr. Ken Miller(Welding), Mr. Mike Lester, and Yamuna Machine Works Ltd. for their help with our project.

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