Plans and Development of a Plasma-Enhanced Chemical Vapor Deposition System for High-Performance SRF Cavities

CLASSE
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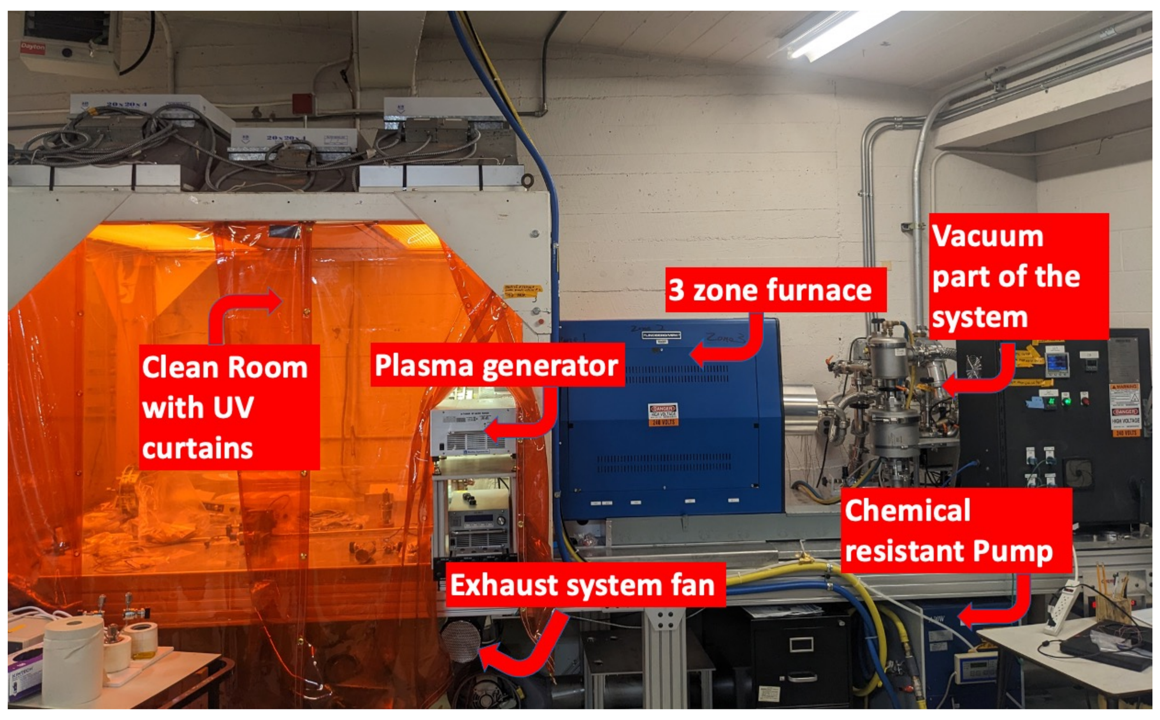
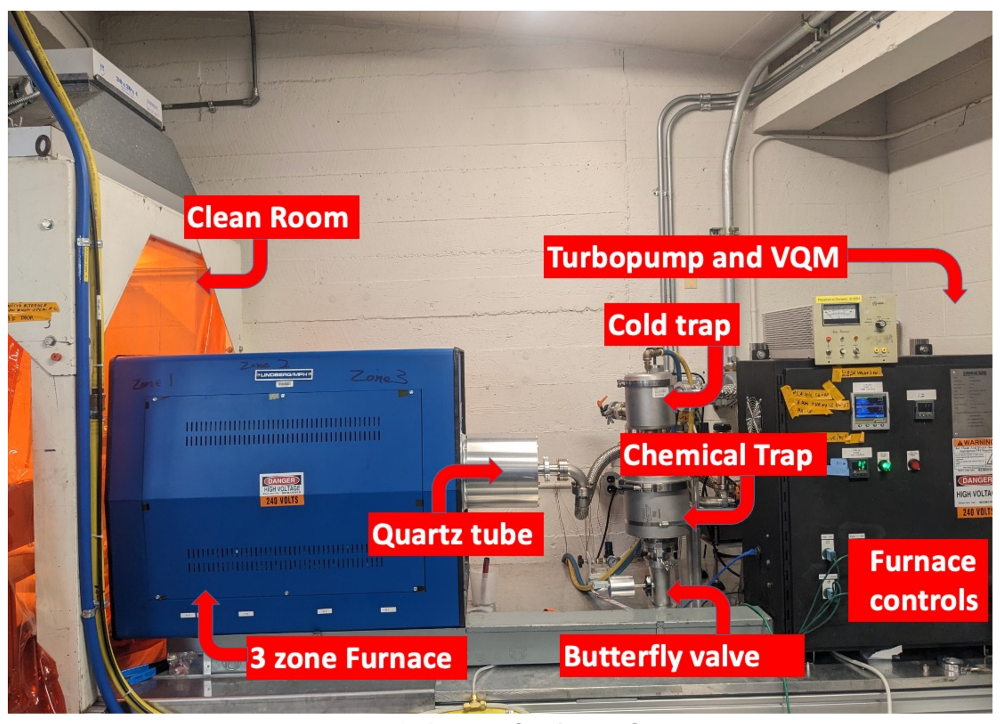
Progress on commissioning and control for chemical vapor deposition system (CVD)

Remote Plasma Chemical Vapor Deposition (CVD) system



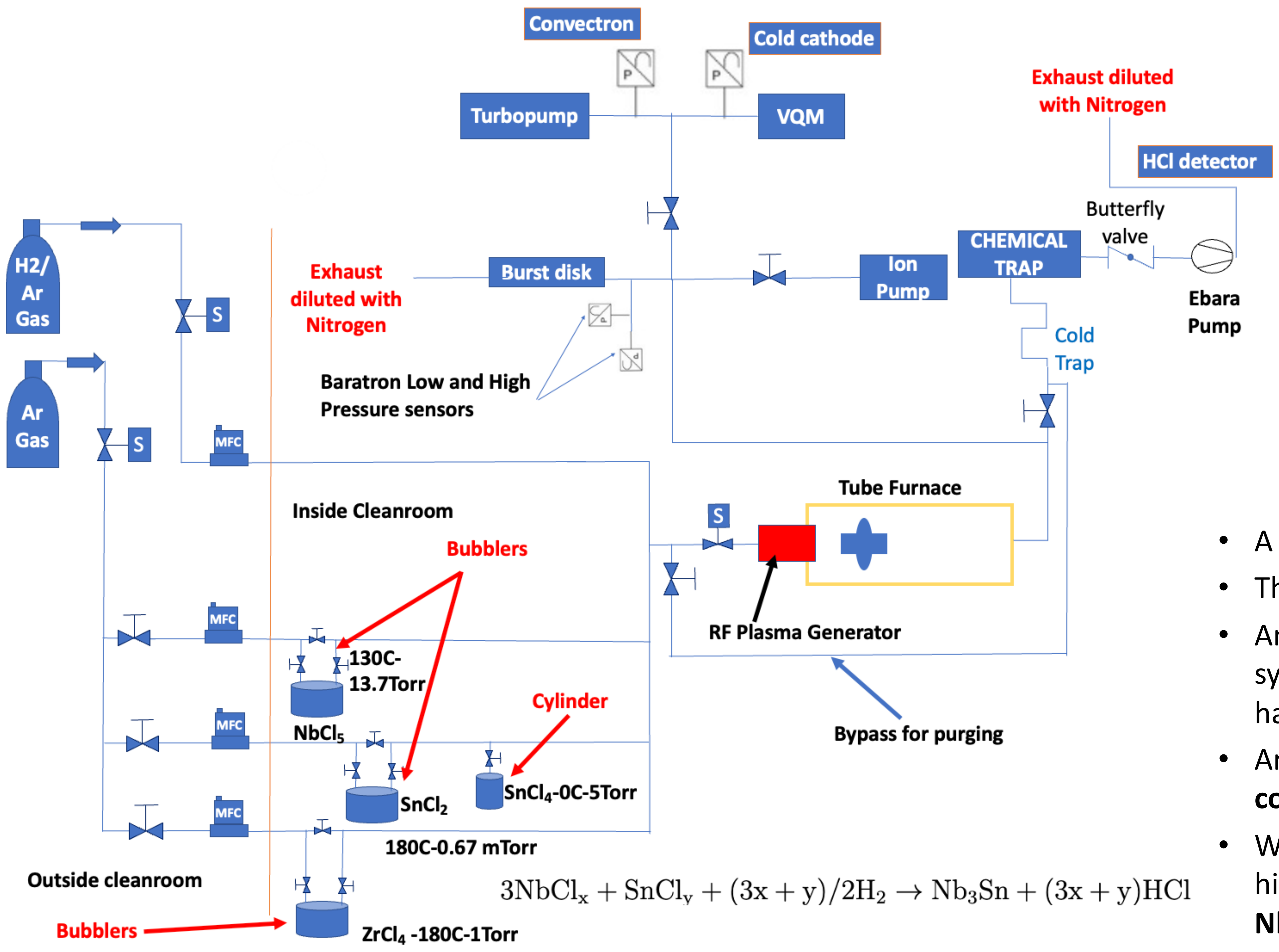
CVD system overview



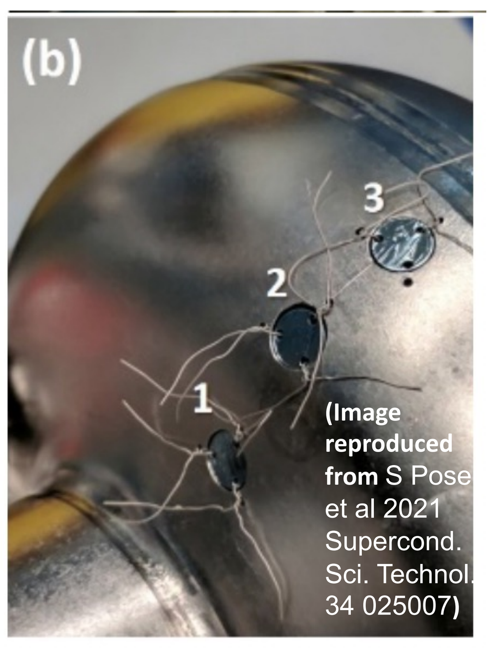
Pump side of the furnace

- CVD is a vacuum deposition method and it offers a potential path to grow high-quality films of **Nb_3Sn**, **NbN**, **NbTiN** on various substrates including **niobium** and **copper**.
- We use both solid (**$NbCl_5$, $SnCl_2$, $ZrCl_4$**) and liquid precursors(**$SnCl_4$**). These can corrode stainless steel when exposed to humidity so hastelloy bubblers are used to prevent corrosion.
- **Small samples** and cavities of **2.6GHz** and **3.9GHz** can be coated in this furnace.
- The system can be used for both **CVD** and **annealing.**

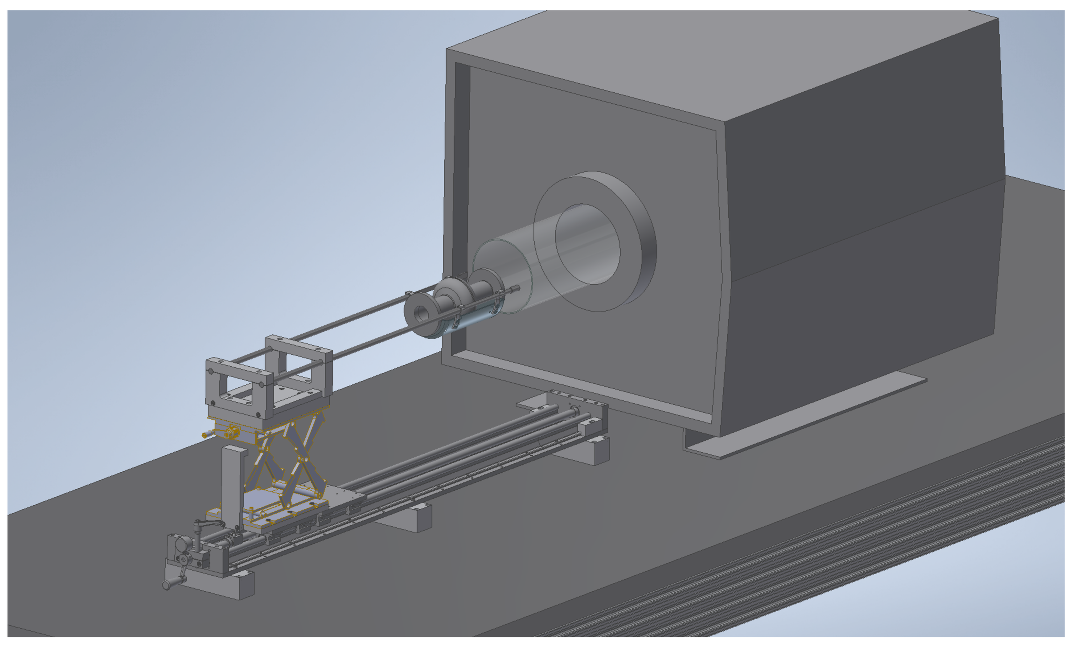
Gas and precursor delivery, safety and interlock



CVD precursor and gas delivery diagram



Samples on cutout cavity



Loading system

- A gas and chemical precursor delivery schematic was developed and is under assembly.
- The **plasma generator** and related UV and RF protection were installed.
- An analogue interlock has been planned to ensure safe operation for the system. An exhaust system has been installed to dilute and monitor exhausted **corrosive gases** and a chemical trap has been added for reducing the amount of corrosive gas that arrives at the pump.
- An **alumina screen** tube and a robust **loading system** are important in preventing **Si contamination**
- We can deposit a Nb_3Sn film by **first depositing Sn** using a Sn precursor and then annealing at high temperatures (>950C), or by using Sn and Nb precursors simultaneously and **depositing Nb_3Sn layer by layer**.
- Some examples of precursors we could use and their reactions:

$$SnCl_2 + H_2 \rightarrow Sn + 2HCl \qquad SnCl_4 + 2H_2 \rightarrow Sn + 4HCl \qquad ((C_2H_5)_4Sn)$$

Next steps and Future plans

- Assemble and test the gas delivery part of the system, ensure **no humidity and no leaks** are present.
- Install the loading system and an alumina tube inside the quartz tube if necessary to **prevent Si contamination.**
- Deposit **Sn on Nb** coupons and anneal at high temperatures. Uniformity, low impurity levels, and ideal stoichiometry are important.
- After obtaining good results on coupons, use a cutout **dummy 2.6GHz cavity with coupons** to determine the uniformity of the coating on the complex shape of a cavity.

Abstract

Next-generation, thin-film surfaces employing Nb3Sn, NbN, NbTiN, or other compound superconductors are essential for reaching enhanced RF performance levels in SRF cavities. However, optimized, advanced deposition processes are required to enable high-quality films of such materials on large and complex-shaped cavities. For this purpose, Cornell University is developing a plasma-enhanced chemical vapor deposition (CVD) system that facilitates coating on complicated geometries with a high deposition rate. This system, based on a high-temperature tube furnace with a high-vacuum, gas, and precursor delivery system, and uses plasma to significantly reduce the required processing temperature and promote precursor decomposition. Here we present an update on the development of this system, including final system design, safety considerations, assembly, and commissioning.

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