Effects of Surface Treatments on the Outgassing of 3D-Printed 316L Stainless Steel.

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What Is Outgassing?

Outgassing occurs when surfaces release previously adsorbed molecules. Molecules attach to surfaces through bulk diffusion, permeation, vaporization, or—most commonly—adsorption. Adsorption is the physical bonding of ions or molecules onto a surface. Under vacuum, these surfaces continuously release molecules, so a perfect vacuum is impossible. Outgassing slows the pump-down process and makes reaching lower pressures more difficult.

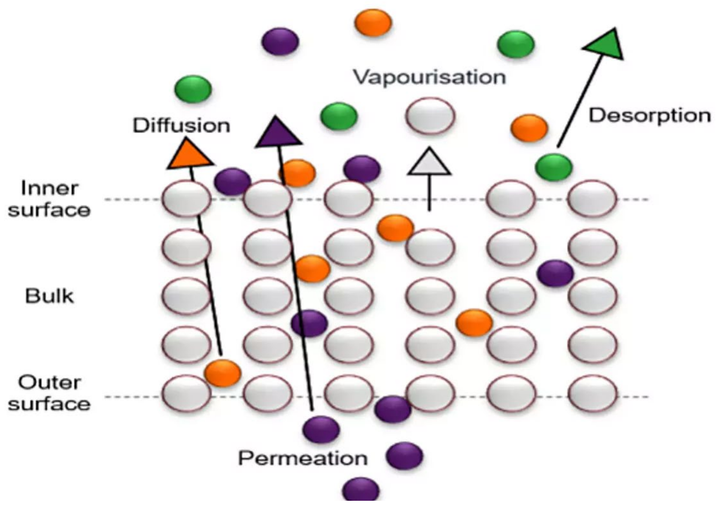

Figure 4: Mechanisms Contributing to Outgassing. [2]

Figure 1: Control reducer being tested for outgassing is untreated. Made of 3d printed 316 steel.

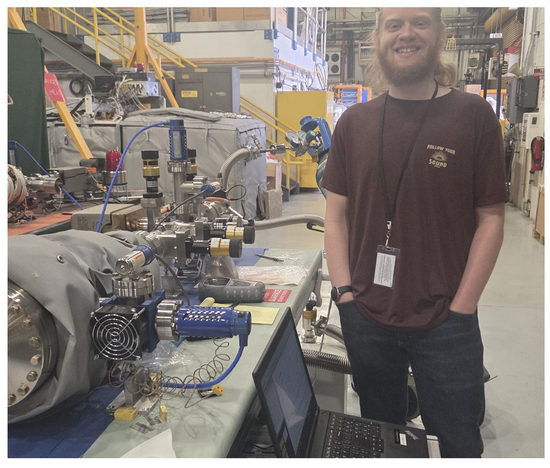

Figure 2: The vacuum setup used to test the rate of outgassing of the reducers.

Adsorption

Adsorption is the physical attachment or bonding of ions and molecules to a surface. There are two types: physical and chemical.

- *Physical adsorption* occurs when molecules (adsorbates) are held on the surface by weak Van der Waals forces. This is the primary source of outgassing and can often be removed through proper cleaning.
- *Chemical adsorption* occurs when a true chemical bond—ionic or covalent—forms between the adsorbate and the surface. It requires higher pressure and activation energy and is typically irreversible. [3]

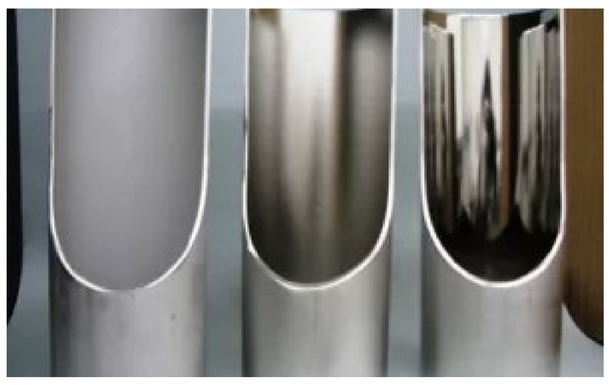

Figure 3: Example of the results of using electropolishing to polish parts. [1]

Surface Finish

The reducers, such as the one in Figure 1, have different surface finishes. Surface finish affects the effective surface area and outgassing. Rougher surfaces adsorb more gas, while smoother surfaces don't. By optimizing a combination of surface treatments, we aim to minimize outgassing and achieve the desired ultra-high vacuum.

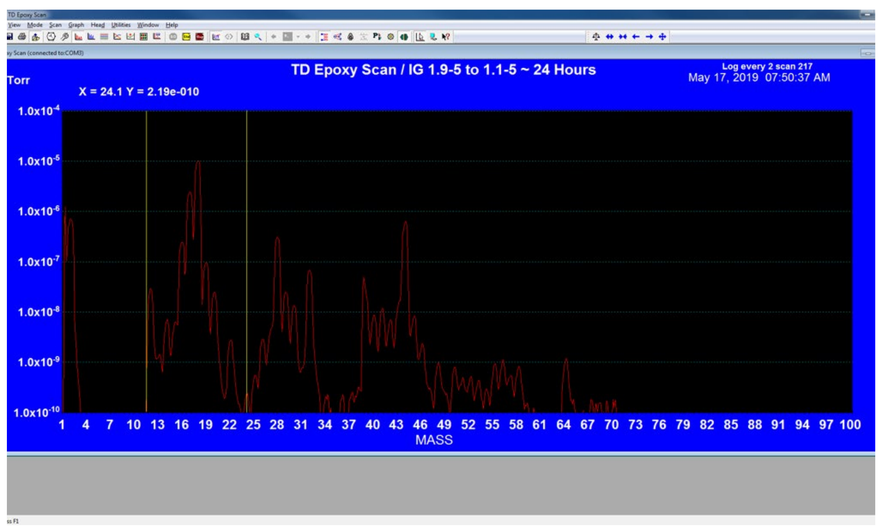

Figure 5: Example of a Residual Gas Analyzer (RGA). Y-axis is pressure in torr. X-axis is the mass of any particles picked up by the RGA.

Throughput Method

Throughput refers to the number of gas molecules being pumped out of the system—essentially, the vacuum pump's capacity. Using the throughput method, the following equation is applied: $q = (p_1 - p_2)C / A$, where C is the orifice conductance, A is the surface area of the test sample, and p represents pressure. Before testing a sample, the outgassing from the chamber walls must be measured first and then subtracted from the sample's measured results. The initial time is defined as the moment the pressure in the sample chamber reaches 7.5×10^{-3} torr.

Experiment

Table 1. Experimental Design Matrix for Evaluating the Effects of Sandblasting and Electropolishing on Outgassing Rates.

Sandblasting Pressure	Electropolishing Time	Specimen Count
Low (40-50 psi)	Short (5-10 minutes)	2
Low (40-50 psi)	Long (15-20 minutes)	2
High (70-80 psi)	Short (5-10 minutes)	2
High (70-80 psi)	Long (15-20 minutes)	2

References

[1] Apscon Industries LLP Website
[2] Leybold.com Introduction to Outgassing
[3] Basic Vacuum practice, Varian Associates Inc.