APPLICATION NOTE

FOUR WAYS TO REDUCE OUTGASSING IN VACUUM SYSTEMS

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There are four main ways you can reduce outgassing in your vacuum system. These are: cleaning and handling (bakeout), surface treatment, passivation, and purging and backfilling. In this Application note, we will take a closer look at each of these methods.

1. CLEANING AND HANDLING

These techniques include relatively simple methods which take a short amount of time and are mostly performed on individual parts ex-situ. They're effective against gross and fine surface contamination and can reduce outgassing rates by anything from 50% to five orders of magnitude. Proper material preparation is vital to achieve low outgassing rates and reach UHV.

Generally, the cleaning process will involve the following steps:

1 Remove gross contaminants such as rust, grease or paint

2 Remove fine contaminants such as oils, cutting lubricants and adsorbed species such as water

3 Remove hydrogen from the materials bulk (most metals)

This cleaning should be followed by bakeout for reduced outgassing rates. It's important that items are handled carefully once material preparation has begun. This prevents contamination, as a set of fingerprints (for example) can take several days to desorb. The length of time in which there's exposure to moisture should be limited wherever possible.

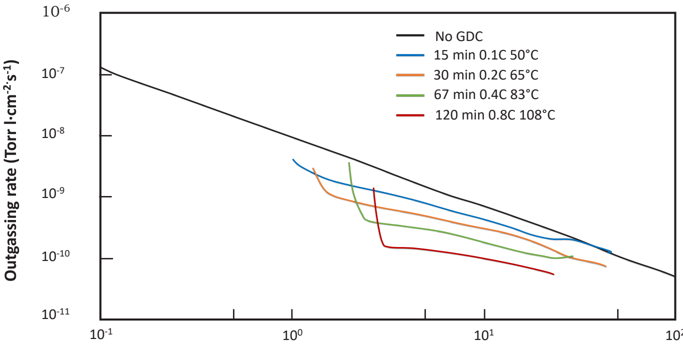

Diagram 1: An example of cleaning; Glow Discharge Cleaning[1]

2. SURFACE TREATMENT

Surface treatments reduce the net surface area by reducing roughness; the most common techniques are mechanical polishing and electropolishing.

Mechanical polishing is often one of the first material treatments used to remove gross contaminants, while electropolishing replaces an amorphous surface layer with an ordered oxide layer. Electropolishing is particularly effective against hydrogen/hydrocarbons. The net effect of reducing surface roughness is shown below in diagram two.

For example, for stainless steel with a typical outgassing rate of ~2e-7 mbar.l/s/cm^2 electropolishing reduces outgassing by a factor of 30. Meanwhile, mechanical polishing reduces outgassing by a factor of 50 and a 30-hour bakeout at 250°C by a factor of over 70,000.

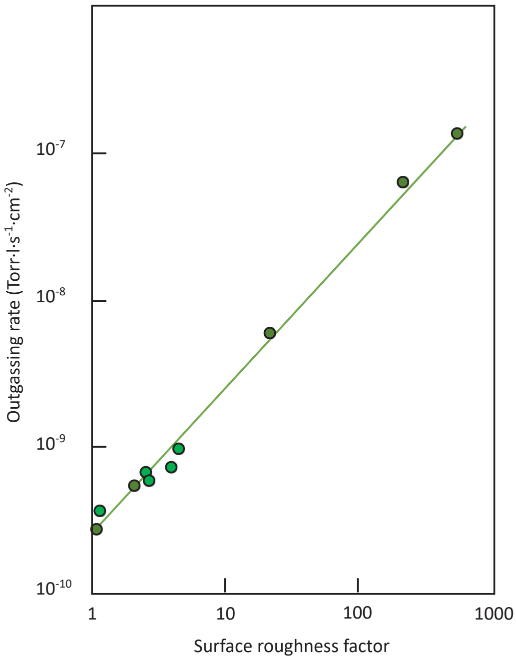

Diagram 2: Effect of surface roughness on outgassing[2]

3. PASSIVATION

Passivation via coatings creates a barrier layer against contaminant adsorption and permeation. Coatings are usually applied via CVD, PVD or sputter coating at raised temperature (200-500°C) and can be:

- Passive — a simple barrier
- Active — pumping gases (H_2, CO, H_2O, O_2 and N_2) from the chamber and trapping them. These (Non-Evaporable Getter) coatings require periodic activation by heat to keep surface sites free

As mentioned, bakeout is one of the most commonly used and reliable passivation techniques. The gas load qAB after bakeout to a maximum temperature of T_{Bmax} for stainless steel was found empirically to be: $\text{Log}(q_{AB})=-1.87\log T_{Bmax}-4.51$

A temperature from 100–500°C is required to remove water vapour; higher temperatures up to 1000°C are required for hydrogen removal from the material's bulk.

Longer and repeat baking leads to lower outgassing rates, as shown in the graph below.

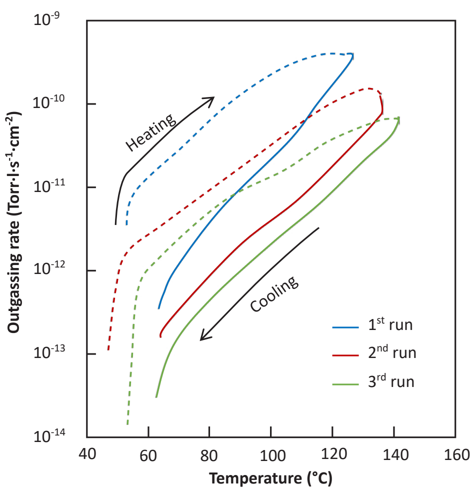

Diagram 3: Bakeout cycling

4. PURGING AND BACKFILLING

A constant flow of a dry gas through the chamber can remove contamination and reduce water vapour concentration. Even a short purge is effective at reducing outgassing. After a purge flow stops, humidity can rise to over 30% within a few hours. You can see these effects represented in the graph.

Backfilling, or venting, with N_2 can also reduce water vapour for systems regularly let up to the atmosphere — as shown in diagram 4. A relatively new technique of bakeout/purge uses inert gas pumping/purging cycles during bakeout and gives a faster bakeout as shown in diagram 5.

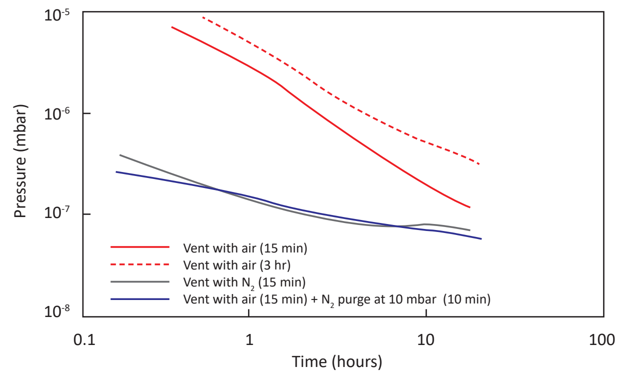

Diagram 4: Vent/purge cycling effect on outgassing

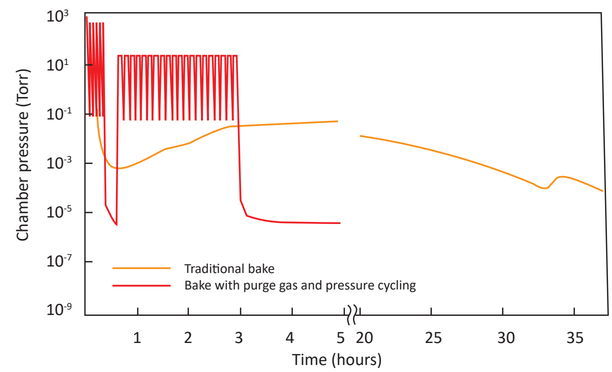

Diagram 5: Bake with purge gas and pressure cycling[3]

SUMMARY

Outgassing can limit the achievable vacuum in a system and is often the most important gas source in HV and UHV. There are several techniques to reduce outgassing as much as possible. These include actions to be taken ex-situ such as surface cleaning and treatments and vent-purge cycling and system bake-out.

This note is based on the article in Applied Science and Convergence Technology 26 (5): 95-109 (2017) R Grinham and A Chew.

REFERENCES

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