Several Technical Measures to Improve Ultra-High and Extreme-High Vacuum*

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UHV and XHV pressures are generally achieved by reducing the outgassing rate (hydrogen) of the stainless steel (ss) chamber walls and by providing large pumping speeds. Titanium nitride coatings were applied to ss walls to reduce the permeation rate of hydrogen but are not cost effective and so cannot be widely used. Copper and aluminum thin film coatings have been tried but the coating process itself introduces severe outgassing problem even though it has the potential of reducing the hydrogen permeation from the ss walls. Aluminum and Copper alloy (particularly beryllium copper, which is toxic) chambers have also been built since they have the lowest outgassing rate but have several disadvantages including the cost.

In this work, we investigated the use of inexpensive coatings of silica and titanium oxide on UHV/XHV chambers/components to reduce the adsorption/diffusion of water (which cracks into oxygen and hydrogen in the material and acts as the internal source of hydrogen) through the chamber walls thereby minimizing hydrogen outgassing. Further, we have also implemented backing of the turbo pump with an ion pump for reducing the vacuum chamber pumpdown times into UHV/XHV pressure range. The results of these investigations will be presented in this paper.

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In this work, we investigated the use of inexpensive coatings on UHV/XHV Components with silica and titanium oxide films to reduce the adsorption/diffusion of water which acts as the internal source of hydrogen through the chamber walls. Further, we implemented backing of the turbo pump with an ion pump for reducing the vacuum chamber pump down times.

*Ganapati Myneni - CEBAF Invention Disclosure: Low Cost Surface Diffusion Barrier for UHV/XHV Components and Chambers

Experiments
• Improve vacuum with various coatings on stainless steel chamber
  - Simple Ti compound, double sides thin/thick silica and outside silica coating
  - Comparison test with AFM silver coated BeCu chamber
• Vacuum performance with ion pump backed turbo system

Pumping of silica coating and AMF chambers

Silica and AMF chambers showed similar performance
- Ultimate pressure of the silica coated chamber is slightly lower

Turbo system operated successfully with ion pump backing
- Ultimate pressure ~ 2x10^-10 Torr obtained in a short period (4 hours)

Experiments from drag pump assisted turbo system

System performance is better without the drag pump backup
-- Pressure is ~ 45% lower without drag pump

Pumping performance improved after surface treatments
- Ultimate vacuum more than 65% lower with surface silica coatings
- Outside coated chamber presented lowest pressure: vacuum improved over 70%

Outgassing rates with various chamber treatments

<table>
<thead>
<tr>
<th>Material</th>
<th>Stainless steel</th>
<th>Ti compound coating</th>
<th>Silica thin coating</th>
<th>Silica thick coating</th>
<th>Silica outside coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outgassing rate, Torr l/s cm²</td>
<td>1.0 x 10^-12</td>
<td>~ 1.75 x 10^-12</td>
<td>~ 3.25 x 10^-12</td>
<td>~ 3.0 x 10^-12</td>
<td>~ 2.5 x 10^-12</td>
</tr>
</tbody>
</table>

Proposed pumping models for surface treatments

For partial pressure, like $H_2$

$P_{H_2} = \frac{(Q_{H_2}/S_{H_2})_{ext}}{1 + (Q_{H_2}/S_{H_2})_{int}} + P'_{H_2}/K_{H_2}$

$Q_{H_2}^{ext} = Q_{w-v} - Q_{V-W}$

$Q_{w-v}$ : outgassing and permeation
$Q_{V-W}$ : adsorption and permeation

$Q_{w-v}$ : leakage $H_2$

After system baking:

No coating: $Q_{w-v} > Q_{V-W}$
Both sides coating: $Q_{w-v} \approx Q_{V-W}$
Out coating: $Q_{w-v} < Q_{V-W}$

$P_{H_2}$: no coating > $P_{H_2}$: both coating > $P_{H_2}$: out coating

Summary
• Outside coated chamber presented best vacuum
• Silica coating better than AMF chamber
• Vacuum improved by a simple Ti compound coating
• Turbo system operated successfully with ion pump backing

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