**Getter Materials**

**By Dan Herring**

Experience has shown us that sensitive materials in the presence of even minute quantities of gases can destroy the integrity and shorten the life expectancy of components. Therefore, what can be done to further protect the work in a vacuum environment? Reducing the chamber pressure to as low as is economically feasible is not enough. This reduces the gas contaminants. Thus, a getter material must also play a role in the reduction of gas contaminants.

A getter is simply a reactive material that is deliberately placed inside a vacuum system to increase the efficiency of that vacuum by scavenging unwanted contaminates. Essentially, when gas molecules enter the evacuated space, they combine with it chemically or by adsorption so as to be removed from the environment. A getter material thus increases the vacuum efficiency by eliminating even minute amounts of unwanted gases from the evacuated space.

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**Getter Properties**

The action of a getter material depends on:

- Adsorption (i.e. accumulation of gas molecules at the surface)
- Absorption (i.e. diffusion of gas molecules in the solid);
- Chemical binding (i.e. reaction with the surface atoms).

A getter material is designed to react with the gas species present in the vacuum, creating a chemical reaction. Typical gases present in vacuum systems are carbon monoxide (CO), carbon dioxide (CO₂), nitrogen (N₂), hydrogen (H₂), and water vapor (H₂O). Most metal surfaces have a protective oxide on them, which under vacuum and at high temperatures will dissolve and diffuse into the getter material before it can escape. Thus a getter material must also have the ability to allow the diffusion of contaminating gases once they have been absorbed.

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Getters bind gases on their surfaces. Thus, the greater the surface area of the getter material, the greater its getter capacity. This is because the getter capacity is affected by temperature since diffusion rates of the surface-bound gas increase with temperature. This helps keep the getter surface active continuously.

The chemical reactions (in simplified form) are as follow (here GM represents the getter material):

1. 2GM + O₂ → 2GMO
2. 2GM + N₂ → 2GMN
3. 2GM + CO → GMC + GMO
4. 2GM + CO₂ → CO + 2GMO → GMC + GMO
5. GM + H₂O → H + GMO → GMO + H (bulk)
6. GM + H₂ → GMH + H (bulk)
7. GM + CₓHᵧ → GMC + H (bulk)
8. GM + Inert Gas (He, Ne, Ar, Kr, Xe) → No reaction

Table 1 [1] Getter Capacity of Common Materials

<table>
<thead>
<tr>
<th>Getter Material</th>
<th>Gas Species</th>
<th>Getter Capacity (Pa·l/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Oxygen (O₂)</td>
<td>1.00</td>
</tr>
<tr>
<td>Barium</td>
<td>Carbon Dioxide (CO₂)</td>
<td>6.69</td>
</tr>
<tr>
<td></td>
<td>Hydrogen (H₂)</td>
<td>11.50</td>
</tr>
<tr>
<td></td>
<td>Nitrogen (N₂)</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Oxygen (O₂)</td>
<td>1.00</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Oxygen (O₂)</td>
<td>1.70</td>
</tr>
<tr>
<td>Rare Earth Elements (cerium, lanthanum)</td>
<td>Carbon Dioxide (CO₂)</td>
<td>6.29</td>
</tr>
<tr>
<td></td>
<td>Hydrogen (H₂)</td>
<td>6.13</td>
</tr>
<tr>
<td></td>
<td>Nitrogen (N₂)</td>
<td>6.43</td>
</tr>
<tr>
<td></td>
<td>Oxygen (O₂)</td>
<td>1.80</td>
</tr>
<tr>
<td>Titanium</td>
<td>Hydrogen</td>
<td>27.00</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>6.85</td>
</tr>
<tr>
<td></td>
<td>Oxygen</td>
<td>4.40</td>
</tr>
</tbody>
</table>

10¹⁸ particles (i.e. 6.7 x 10¹⁸ hydrogen molecules or 1.34 x 10¹⁹ hydrogen atoms) so that each titanium atom in the getter corresponds to approximately 6.7 x 10¹⁸ titanium atoms.

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Getter capacity is affected by temperature since diffusion rates of the surface-bound gas increase with temperature. This helps keep the getter surface active continuously.

Titanium can be used as an effective getter material when running titanium parts in vacuum to keep surfaces clean (i.e. to avoid oxidation and discoloration) during annealing at a temperature of 1400°F (760°C) range, titanium scrap (often in the form of clean, dry machine turnings) is commonly used as a getter material.
Non-Evaporative Getters

Non-evaporable getters have become an integral part of many ultrahigh vacuum environments. Binary, ternary and multicomponent alloys from Group IV and Group V (vanadium, titanium and zirconium) are most often used. These generally consist of a film of a special alloy material which must form a passivation layer at room temperature. The alloy materials used have names of the form St (Stabil) followed by a number:

- St 707 - a 70% zirconium, 24.6% vanadium balance iron alloy
- St 787 - a 80.8% zirconium, 14.2% cobalt balance mischmetal alloy
- St 101 - a 84% zirconium and 16% aluminum

In tubes used in electronics, the getter material coats plates within the tube which are heated, while in semiconductor manufacturing, getters are used in more general vacuum systems, such as in separate pieces of equipment in the vacuum chamber, and turned on when needed.

Final Thoughts

For heat treaters, getters are often considered a last resort to help keep parts “bright and clean”. However, they play an important role in successful vacuum processing of many highly sophisticated products and processes. Dan Herring is president of THE HERRING GROUP Inc., which specializes in consulting services (metallurgy) and technical services (industrial education/training and process/equipment as technical support). He is an associate professor at the Illinois Institute of Technology/Thermal Processing Technology Center.

References
