Tantalum Surface Alloying of Parts for Corrosive Hydrogen Production Process

Dean Gambale
Americas for Tantaline Inc.
Waltham, Massachusetts

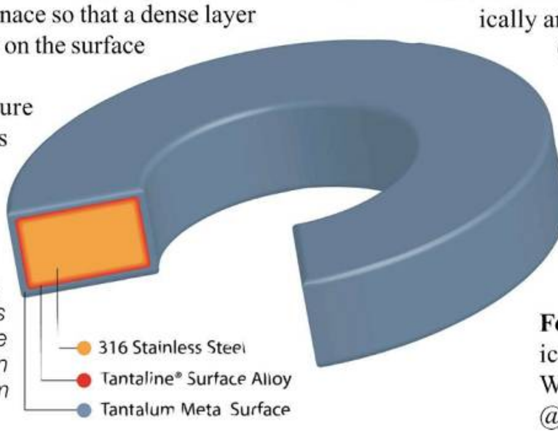
With increasing demand for energy and environmental concerns on the rise, there is a tremendous focus to develop the next generation of energy. Advanced processes for coal, natural gas, and especially hydrogen are being explored as possible alternatives to oil to serve the world's ever-increasing needs. However, in many cases, there is one critical factor limiting the success of these next generation processes – corrosion. The wide range of process temperatures, pressures, and chemical concentrations required pushes beyond the engineering limits of standard materials. As a result, new revolutionary materials have been developed, which not only enable energy research to continue, but also open up the prospect of an abundant, affordable infrastructure to support and deliver a clean energy supply.

Tantaline, based in Waltham, Mass., is a recent newcomer to the growing market for new materials for energy applications. The company's surface alloying process produces what is claimed to be the most highly corrosion resistant material commercially available and is especially suited for projects that work with hot acids or highly corrosive chemicals. With this process, engineers have higher performance at less cost than specialty metals like nickel, titanium, and zirconium base alloys – a significant benefit in any economic environment.

Surface Alloying with Tantalum

The tantalum vapor surface alloying technology takes advantage of the superior corrosion resistance properties of tantalum, and can be applied to almost any OEM standard or stainless steel part. Common parts selected for treatment include valves, fittings, instrumentation, etc.

In a furnace heated to 700-900 °C, the tantalum metal is chemically reacted and vaporized. The gaseous tantalum diffuses into the substrate, typically stainless steel, creating a surface alloy approximately 50 μm thick. The gaseous tantalum atmosphere is maintained in the furnace so that a dense layer of pure tantalum grows on the surface of the part over the diffusion layer. The pure tantalum surface layer is also about 50 μm thick. The treated part has the original OEM part size and shape, but now has the same chemical properties and corrosion resistance as pure tantalum metal. The figure shows how the layers develop when a washer made of 316 stainless steel is subjected to the treatment.



Schematic cross section of a treated 316 stainless steel washer showing the surface alloy diffusion zone and pure tantalum metal surface.

Case Study – Hydrogen Production

Hydrogen fuel is an attractive alternative for the world's energy problem. However, hydrogen currently is produced from fossil fuels, and, therefore, does not yet contribute to energy independence. General Atomics, a high-technology systems development company, turned to Tantaline as part of a demonstration to supply hydrogen for a hydrogen-based economy from a sulfur-iodine thermochemical process. The sulfur-iodine process involves hydrogen production by thermochemically decomposing water into hydrogen and oxygen without using fossil fuels (see sidebar). Heat and water are the only inputs while oxygen and hydrogen are the only outputs, resulting in no emissions.

> The sulfur-iodine thermochemical process is a leading candidate for hydrogen production. It consists of three chemical reactions that lead to the dissociation of water:
>
> 1: $H_2SO_4 \rightarrow SO_2 + H_2O + \frac{1}{2}O_2$
> 2: $I_2 + SO_2 + 2H_2O \rightarrow 2HI + H_2SO_4$
> 3: $2HI \rightarrow I_2 + H_2$
>
> Section I: Recycle and acid (HI and H_2SO_4) generation.
> Section II: Sulfuric acid concentration and decomposition.
> Section III: Hydrogen iodide concentration and decomposition.

A key challenge General Atomics faced was the exceedingly corrosive nature of the process. The sulfur-iodine thermochemical reactions are aggressive mechanically and chemically, requiring materials that can handle high temperatures and pressures along with concentrated, corrosive acids and chemicals. The combination of a severe operating environment and highly corrosive chemicals limits materials choices; even specialty materials like Hastelloy (Haynes International Inc.) struggled to survive a few days. General Atomics found that the tantalum surface alloy was the only material that could effectively resist the corrosive environment and make the process economically and technically feasible.

General Atomics has installed more than 1,500 parts that have been treated by Tantaline in the form of Swagelok (Solon, Ohio) fittings, valves, and instrumentation. The tantalum surface alloys enabled General Atomics to continue the project, demonstrating that the sulfur-iodine thermochemical process can be a viable commercial alternative for future hydrogen energy production. iTSSe

For more information: Dean Gambale, CEO, Americas for Tantaline; 1050 Winter St., Suite 1000, Waltham, MA 02451; tel.: 1-888/268-2586; dgambale @tantaline.com; www.tantaline.com.