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The differences that good coatings can make

Hardide CVD coating as a replacement to hard chrome plating for the flow control industry

Hard chromium electroplating has long been a trusted industry solution used to extend the life of valves that control the flow of abrasive, erosive and corrosive fluids and gases. However, it is an environmentally unfriendly process using hexavalent Chromium salts – a known carcinogen which represents a health and safety hazard. Hard Chrome plating (HCP) is subject to increasing legislative restrictions in Europe (first of all with the introduction of the REACH regulations) and the United States (OSHA), which are reducing the availability and increasing the cost of hard chrome.

By Dr Yuri Zhuk, Technical Director, Hardide Coatings

Over the last decade an extensive search for the replacement for Hard Chrome plating was launched, led by aerospace producers, which identified and tested several alternatives. Thermal spray coatings were generally acknowledged as the best available replacement for HCP, but these coatings can only be applied to external surfaces and simple geometries which can be ground post-coating. No alternatives were able to replace Hard Cr on internal surfaces and complex shaped items which could match key characteristics of HCP such as hardness, adhesion and corrosion-resistance.

To fill this gap, Hardide-A has been developed and proven as an attractive replacement for HCP, especially suitable for internal surfaces and complex shapes. Hardide-A matches the standard thickness (50-100 microns) and hardness (800-1200 Hv) of hard chrome which simplifies the switch from Hard Chrome to Hardide as no dimensional changes or drawing re-design is necessary. Moreover, Hardide-A outperforms HCP in several key properties including enhanced protection against corrosion, wear and chemically aggressive media, enhanced fatigue life and a non-porous structure.

Hardide coatings are applied by chemical vapour deposition (CVD), where the coating is crystallised from the gas phase atom-by-atom. This enables the uniform coating of internal surfaces and complex shapes where other coatings such as HVOF, D-gun and PVD cannot be used. No grinding or other expensive finishing operations are required to achieve a good finish of 0.3-0.2 μm Ra due to the smooth and uniform 'as coated' surface. Hardide coatings can be applied to a wide range of metals including various grades of stainless steel, tool and alloy steels, nickel, cobalt and copper-based alloys and titanium.

HCP typically has a network of micro-cracks, which provide a path for the corrosive and chemically aggressive fluids and gases to attack the substrate. Hardide CVD coatings are free from porosity and micro-crack so effectively protect the substrate from corrosive and chemically aggressive media. In comparative salt spray corrosion testing, a Hardide-coated mild steel plate showed no signs of corrosion after 480 hours, while both HCP and HVOF thermal spray coated plates showed heavy rust stains and some coating delamination.

The coating provides especially effective protection against acidic media and has successfully passed the NACE Sulfide Stress Cracking test. In this test, specifically designed to replicate high H_2S sour oil and gas conditions, a batch of pre-stressed coated and uncoated steel samples were immersed for 30 days in a corrosive solution of salt and acetic acid saturated with H_2S. After this test the surface of the control uncoated 17-4 stainless steel sample changed colour to black and showed extensive micro-cracking induced by H_2S. One of the cracks went through the full sample width. In contrast, Hardide-coated samples showed no change at all, both visual and metallographic examination confirmed that the media had not affected the Hardide coating and that the coating completely isolated the substrate from attack. This demonstrated that the Hardide coating can help extend the life of the valves controlling sour oil and gas in both upstream and downstream applications.

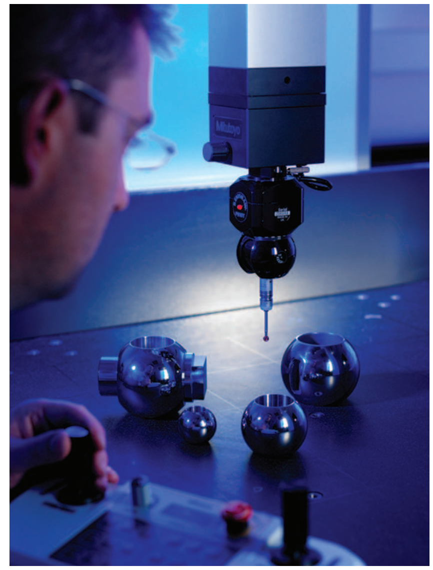
A coating that lasts

The Hardide-A coating also has enhanced toughness and ductility. Valves used in the oil and gas industry may experience impact or shock loads in operation. Some of the valve components can be deformed under load, these actions causing fracture, or chipping of hard materials, which can lead to catastrophic equipment failure. Even in normal operation, in erosive or abrasive environments, brittle, hard material will suffer from microcracking and fatigue erosion, which can lead to premature failure. Therefore, toughness and ductility are very important in practical applications of hard materials. In reality, hardness and toughness are often incompatible characteristics. Most traditional materials can be described as either hard (but brittle, like glass) or tough and ductile (but soft, like copper). Hardide coatings are nanostructured materials consisting of a metallic tungsten matrix with dispersed nanoparticles of tungsten carbide typically between 1 and 10 nm in size. Nanostructured materials can have a combination of properties (like hardness and toughness) that are not common in macro or microstructured materials. The coatings provide a good illustration, combining extremely high micro-hardness with unique toughness, and crack and impact resistance. This combination helps achieve exceptional resistance to wear and erosion.

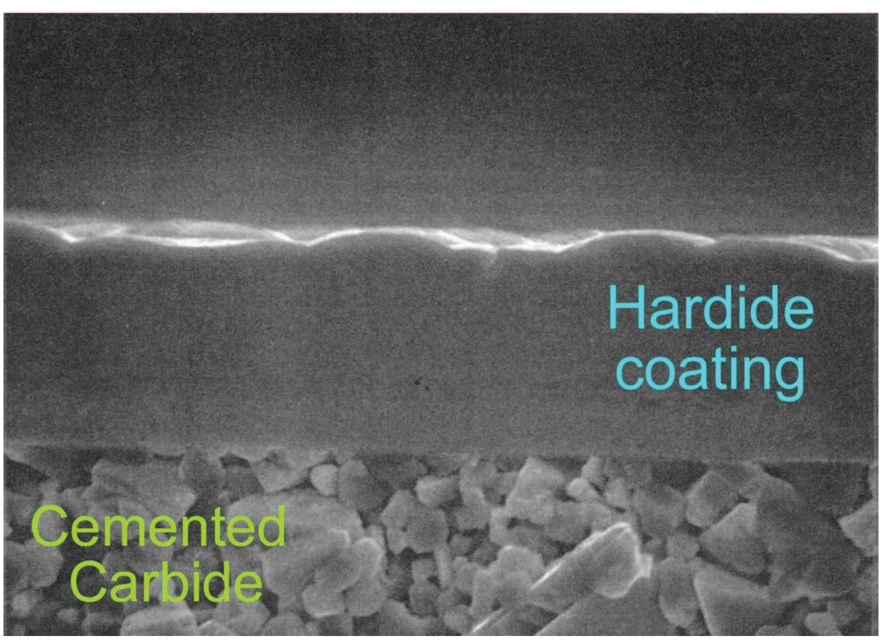
The coatings are used successfully in several advanced downhole tools, and typically extend the life of critical parts by factor of four. They have also proven successful in applications on metal-seated ball valves and pumps. Ball valves can suffer from abrasion by sand or stone chippings present in fluids and from erosion by accelerating flow when the valve is being closed/opened. The CVD coatings make the valve parts scratch-proof and capable of resisting abrasion and erosion. In one case, the coating was approved for use on a new line of balls and seats by Flowserve after successful slurry test results. The coating allows Flowserve to offer Type 316 stainless steel as the base metal for use in severe service applications that require metal-to-metal seating, including abrasive and slurry applications. In the Flowserve slurry tests, Hardide-coated 316 balls and seats remained operational after more than 70,000 cycles in slurry where a Co-Cr wear-resistant failed in 29,000 cycles. Testing is under way of several other applications of coatings on valves and pumps handling abrasive and chemically aggressive fluids.

To sum it up

In summary, Hardide CVD coatings offer a unique combination of protective properties including wear and erosion resistance and protection against aggressive chemicals and corrosion. The ability to coat internal surfaces and complex shapes unlocks new applications for hard coatings on critical



parts. Enhanced toughness and impact and crack resistance are essential in many critical industrial applications. As it is pore-free, the coating protects the substrate from attack by aggressive media. The use of these CVD coatings enables advanced valve design for valves operating in abrasive and corrosive environments and under shock loads. The coatings are a useful addition to the range of advanced materials and processes available for designers and engineers. Hardide-A is a technically comparable and better performing alternative to HCP. It is a clean and innovative technology that can offer a commercial solution to valve manufacturers and end users.



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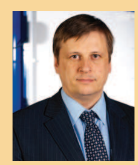

Dr Yuri Zhuk is a Founding Director of Hardide Plc, and is responsible for the company's technology, research & development, patenting and applications development programmes. Hardide was established in Oxford in 2001 to commercialise a unique nano-structured CVD coating. In 2005 Hardide Plc was floated on the London Stock Exchange (AIM) and currently is a leading producer of CVD hard coatings supplied to blue-chip customers in the UK, the US, Norway, EU countries. Dr Zhuk holds a PhD degree in Plasma Physics and Chemistry from the Moscow State University and an MBA from the Open University.