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CHROMLOK™ OXIDE OVERLAY COATINGS FOR THE HIGH TEMPERATURE PROTECTION OF METALLIC COMPONENTS

ABSTRACT:

Nexceris has developed the *ChromLok™* family of oxide based protective coatings to improve the high temperature stability of metallic components in harsh process environments. The microstructure and performance of the oxide coatings have been optimized through careful engineering of the process, from the starting raw material oxide powder through the formulation of the oxide-based coating suspension and the subsequent deposition and heat treatment of the applied coating.

The *ChromLok™* compositions can be tailored to achieve a range of electrical properties, from conducting to highly insulating, at the operating temperature. Further, the coatings can be tailored to accommodate bonding to common aluminosilicate and borosilicate glasses. *ChromLok™* coatings can be selectively applied to as-received metal surfaces, allowing patterning of electrical and chemical features.

INTRODUCTION:

Steel alloys offer excellent formability, strength and damage resistance in high temperature atmospheres, and can offer extended life in harsh environments, if properly protected. However, operation in harsh service environments exposes metals to oxygen, steam, and a variety of even more corrosive species that compromise alloy properties. Corrosion at high temperature can be particularly challenging, as the kinetics of metal corrosion and oxidation are increased, and polymeric-based coatings can degrade or decompose. Glass coatings offer options for some applications, but the relatively limited thermal expansion range of these materials and their potential to create new corrosion products through interaction with the underlying metal limit their application.

Nexceris has developed the *ChromLok*^{TM} family of oxide based protective coatings to improve the high temperature stability of metallic components in harsh process environments. These crystalline oxide coatings are unique in that they achieve excellent adhesion and chemical compatibility with common stainless steels through a simple manufacturing process.

Nexceris offers multiple proprietary formulations in the *ChromLok*^{TM} family to meet your needs. Leveraging world-class capabilities, we produce unique ceramic oxide powders to tailor the process and properties of each coating. Through careful design of the oxide coating suspension, the microstructure and performance of the resultant coating can be optimized. The coating (or multiple functional coatings) can also be applied in localized areas on complex geometries to create high value solutions.

ChromLok^{TM} coatings are typically applied by aerosol-spray deposition, using Nexceris' dedicated coating production space (Figure 1a). This high performance platform utilizes a nozzle-less ultrasonic spray head technology which makes it amenable to coat a wide-range of oxide based coating suspensions. A precise coating application produces very high material transfer (low overspray) and fine control of coating thickness. For non-planar components, alternative deposition techniques more suited to the complex non-line-of-sight geometries, including dip-coating and slip coating, have been utilized. An example of *ChromLok*^{TM} coated products, showing the ability to coat surface features and selectively coat regions, is shown in Figure 1b.

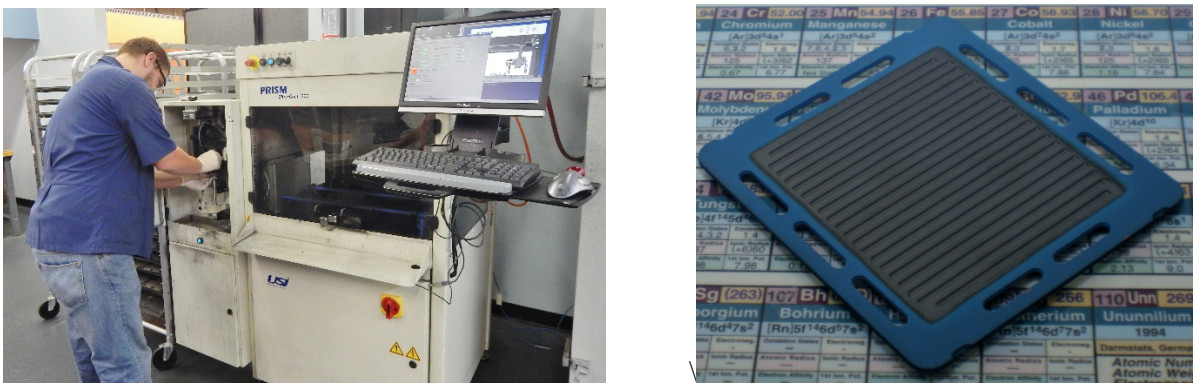

Figure 1. *ChromLok*^{TM} coating process: (a) Nexceris facility for coating deposition (left); and (b) multi-compositional coating demonstrating spatial resolution and conformal coating of features (right).

After deposition, careful heat treatment of the green coated part is performed to achieve an adherent, dense and protective oxide coating. To achieve the required densification, high sintering temperatures are required for air firings, which can lead to detrimental oxidation of the metallic substrate. Nexceris has therefore developed modified controlled atmosphere firings where the pO_2 level is controlled to densify the coating at lower temperatures, limiting oxidation of the metal substrate.

ChromLok™ COATING PERFORMANCE:

Nexceris has developed carefully controlled sintering processes to achieve high density oxide coatings on metal substrates. Figure 2 shows the top-down and cross-section microstructure of a *ChromLok*™ manganese cobaltite $(Mn,Co)_3O_4$ mixed spinel oxide coating on a ferritic stainless steel (441) substrate. The manganese cobaltite (MCO) coating was deposited on the stainless steel substrate through an aerosol-spray deposition (ASD) process, followed by heat treatment to develop a dense protective coating.

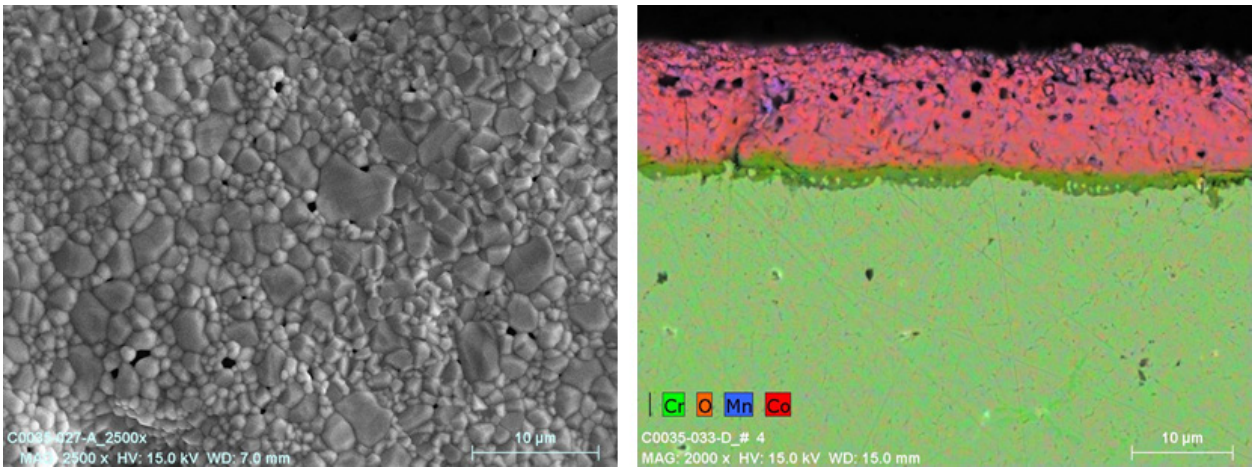

Figure 2. SEM images of MCO coating, applied using Nexceris' coating process: (a) top-down image (left); and cross-section image with superimposed EDS compositional analysis (right).

Nexceris' oxide coatings demonstrated excellent long-term stability at elevated temperatures. Figure 3 shows the oxidation resistance of a 18 wt. % Cr ferritic stainless steel substrate with and without an MCO protective coating at 800 °C and 900 °C. The *ChromLok*™ surface serves as an adherent oxygen diffusion resistance layer, limiting the growth of the inherent alloy oxidation products at the surface, and preventing loss of Cr.

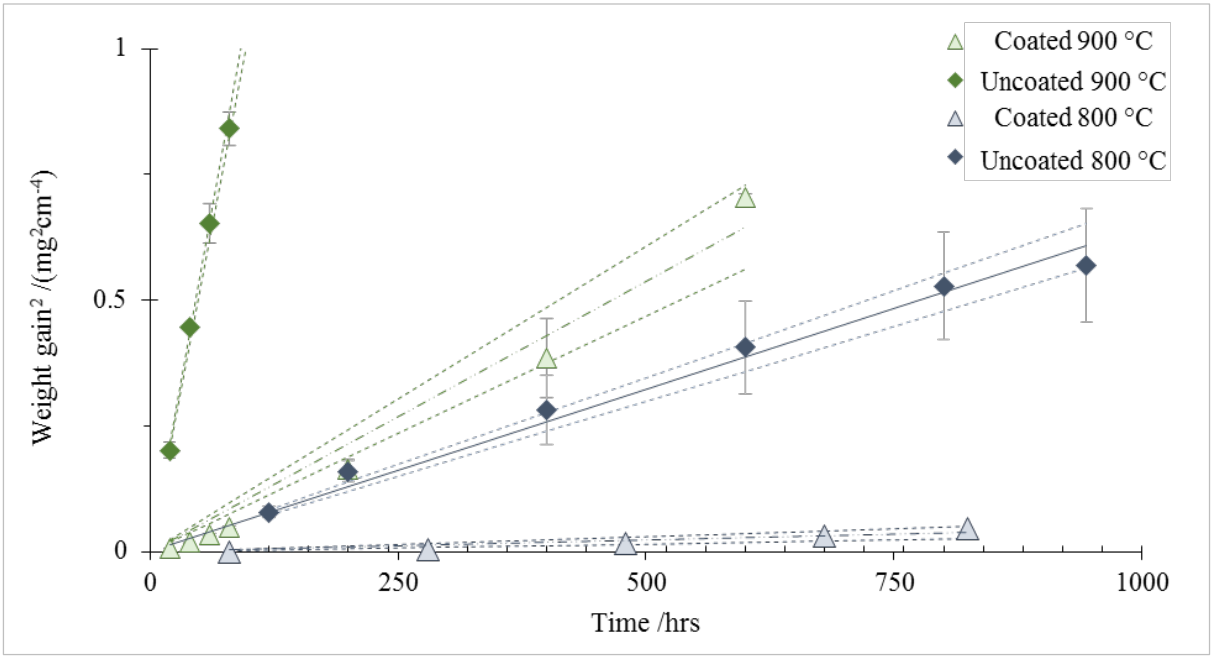

Figure 3. Oxidation resistance of *ChromLok*™ coated and uncoated 18 Cr ferritic stainless steel.

In addition to demonstrating excellent high temperature stability in both oxidizing and reducing environments, the MCO coating is electrically conductive. Figure 4 shows the long-term electrical resistance (ASR) of MCO coated stainless steel in humidified air at 800 °C. Even after 35,000 hours of service, the coating has maintained extremely low resistance.

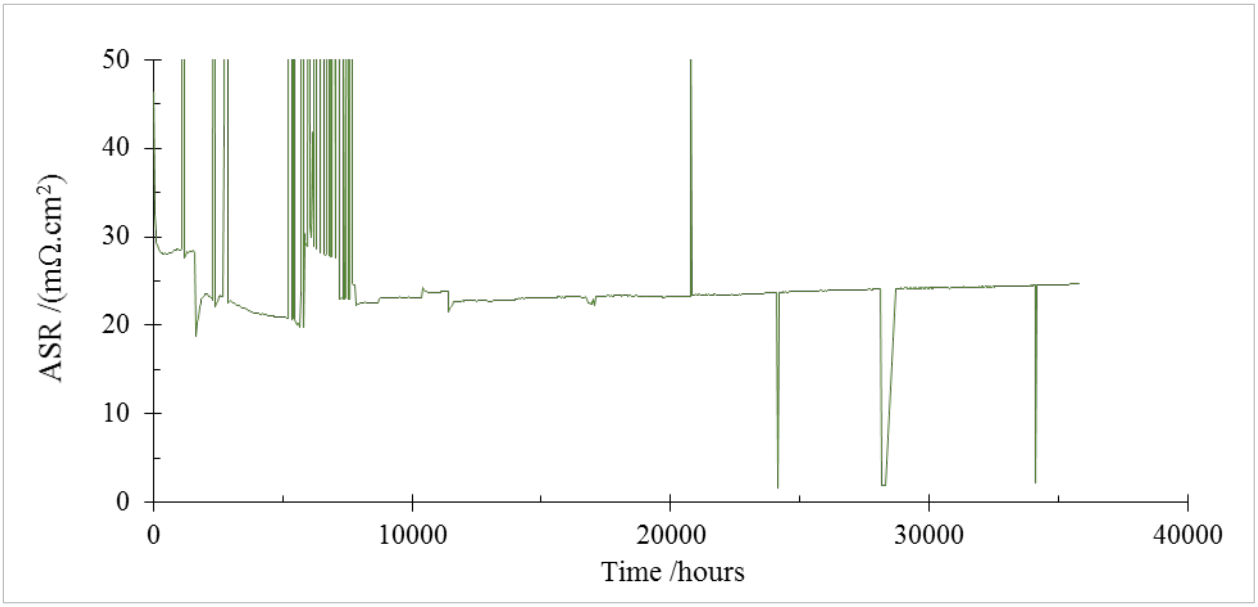

Figure 4. Electrical area-specific resistance (ASR) of *ChromLok*^{TM} coated ferritic stainless steel (800°C, humidified air).

CONCLUSIONS:

Nexceris has successfully demonstrated the versatility of its coating process to deposit a wide-range of oxide-based coatings, including both spinel and perovskite based oxides on metallic components. Through careful design of the starting oxide powder properties and the suspension composition, in combination with controlled coating application and tailored firings, highly dense and protective coating microstructures have been achieved.

Commercial applications of the coating are well-established for advanced energy applications where high conductivity is essential to technical success. Nexceris sees additional applications in other demanding service environments where maintaining conductivity and preventing corrosion could be enabling, such as combustion liners and burner materials as well as heat exchange applications.