High Performance Corrosion Protection for Commercial Stainless Steels

Presented to:

Matthew M. Seabaugh, Ph.D
Director
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Overview of Presentation

• Nexceris Introduction
• Potential of Coating Technology
• Overlay Coatings
• Diffusion Coatings
• Emerging Technologies
COMPANY OVERVIEW
Corrosion Protection
Near Term Products
Assess Technology Fit to Existing Markets
Cutting Edge Materials Research
Power Generation
Natural Gas Appliances
Exhaust Cleanup
Natural Gas Compression
Catalysts

What We Do
How We Work with Customers

We Are Seeking:
• Partners to Develop New Products
• Partners to Reach Target Markets
• Collaborative Solution Development for Specific Markets or Customers

We Provide Unique and Proprietary:
• Coating Capability
• Coating Technology & Know-How
• Catalyst Designs
• Catalyst Formulation & Mfg.
Need for Coating Technologies

Coatings Allow Better Materials Design:

• Alloy Selection to Meet Application-Critical Criteria
  – Mechanical Strength
  – Electrical Conductivity
  – Thermal Conductivity
  – Cost

• Surfaces are Tailored to Create Additional Value:
  – Corrosion Resistance
  – Catalytic Function
  – Electrical Function
  – Appearance
Coating Technologies

We Divide High Temp Coatings into Two Categories:

• Overlay Coatings
  – Metal or Ceramic Coating on Top of Substrate
    • Examples: Catalytic Reactors, Electrical Components
  – Plasma Spray
  – Physical or Chemical Vapor Phase Growth
  – *Spray and Heat Treat*

• Diffusion Coatings
  – Metal or Ceramic Coating Evolves From Support Alloy
    • Examples Aluminides, Carbides, Nitride Coatings
  – Vapor Phase/Vacuum Treatments
  – Plating and Heat Treat in Controlled Atmosphere
  – *Atmospheric Spray and Heat Treat*
TECHNOLOGY OVERVIEW
Overlay Protective Coatings

Process Characteristics
- Designed for ferritic stainless steel
- Reduces Cr volatility
- Electrical conductivity can be tailored
- Coatings for oxidizing and reducing atmospheres
Overlay Coatings on Complex Metal Surfaces
Overlap and Integration with Heterogeneous Catalysis

- High Temperature Chemical Reactors

- VOC Oxidation for Stationary Industrial Systems and H₂ abatement systems for advanced Batteries

- Fuel Reforming and SMR Reactors
How Are Overlay Coatings Applied?

Non-Protective Coatings
- Dip Coating
- Wash Coating

Protective Coats
- Spray Deposition
- Screen Printing
Overlay Protective Coatings

Dual MCO/Aluminide Coated Metallic Interconnect

MCO active area coating

Aluminide seal area coating

Coated Balance of Plant Components

5 ft. long stainless steel SS316 pipes
Other Features of Aluminide Technology:

- Increased Thermal Conductivity
- Enhanced Emissivity
- Improved Wear Resistance
- Simple, Low Cost Application

Lower Cost Austenitic Alloys in

- Heat Transfer
- Corrosion Resistance
- Carburization Resistance
- Sulfidation Resistance
Diffusion Protective Coatings

- Ferritic (441, 446, Crofer 22APU)
- Austenitic (316, 347H)
- Inconel (600, 601, 617)
- Nickel Alloy 200
- Copper Alloys
Compositions Evaluated to Date
Cross-section SEM and Al compositional EDS map for Nexceris aluminide coating on Grade 304 stainless steel

Cross-section SEM of aluminide coating produced by CVD on Grade 304

Diffusion Coatings on Superalloys

Cross-section SEM for Nexceris aluminide coating on Inconel 617

Cross-section SEM of Si modified aluminide coating produced by pack cementation on IN-738 LC

Oxidation of Common Alloys

Aluminide coating successfully prevents spallation alloy scale during oxidation

- Stainless Steel 316
- Stainless Steel 430
- Stainless Steel 304

Substrate: Alloy 304, 316 and 430; Aluminide coating: 20 µm fired
Test Conditions: 900 °C, Humidified Air, Isothermal oxidation testing
Comparative Performance of Coated 430 vs Various Austenitic Steels

430 Alloy Achieving Corrosion Performance of 4X more expensive 310 Alloy
Propane Torch Stress Tests

Pass 1

Pass 7-10
Modifying Oxidation Behavior

- SS316 with Aluminide coating
- 500 hours in humidified air at 900 °C
NexTech’s coating process successfully reproduces the diffusion based surface microstructure produced by more conventional aluminization processes.

Vapor Phase Aluminization (VPA) Coating Microstructure on SS316

NexTech’s Aluminide Coating Microstructure on SS316
Oxidation resistance of coated 316 SS: effect of firing temperature

- Al_850C_Average
- Al_1000C_Average
- Uncoated
- VPA

Temperature: 900 °C
Atmosphere: Humidified air
Addressing Biomass Derived Contaminants
50h Exposure KCl containing air, 650 °C
How Does it Work?

Coat → Heat Treat → Form
Coating Application Methods

Also:
- Dip Coating
- Curtain Coating
- Brush Painting
- Transfer Printing
Post Coating Rolling Operation
(304 Stainless Steel)
SEM analysis (Rolled 304 Stainless Steel)

Rolling operation does not damage the aluminide coating

Rolled component: outside

Rolled component: inside

Flat component (no forming)
Stratalyst™ Product
Thermal Management and Catalyst Support

Expanded Metal Mesh:
Strand width: 0.008”, Length of diamond: 0.125”

Metallic Foam: Pore Size 3000 μm

Metallic Foam Pore Size 800 μm
Extending the Design Space

Single Dip Coating in Aluminum & Air Firing

Increased Corrosion Resistance
Increased Surface Area
Passivation to Chemical Interactions

- Creates New Catalyst Support Product Platform
- Creates Immediate Opportunities in Burner Markets
The product:
**Strata-Lyst** Nickel Aluminide Catalyst Supports

**Porous $\alpha$-$\text{Al}_2\text{O}_3$ Topcoat**
- Open, Interconnected Porosity for Infiltration
- Catalysts Infiltrated to Allow Lower Temp Combustion

**Aluminide diffusion coating**
- Oxidation resistance
- Enhanced IR Emssivity
- Good Thermal Conductivity

**Nickel Skeleton**
- Deformability
- Mechanical Robustness
- Lower Cost than Alloys (Mfg. Scale—NiMH Batteries)
Applications in Burners for Corrosion Resistant Foams
Conclusions

• Coatings can protect low-cost alloys in high temperature environments.

• Overlay coatings approaches offer broad chemical compositions and tailorable electrical and catalytic properties.

• Diffusion coatings offer excellent thermal stability, corrosion resistance and damage tolerance.

• Coatings can be applied by low-tech, easily scaled and adopted technologies with wide process tolerances.

• Technologies in development to create unique coated composites from a range of iron and nickel alloys.

• We are exploring other alloys for heat exchange applications.
For Further Information

Matthew M. Seabaugh, Ph.D.
Director
Nexceris
404 Enterprise Drive
Lewis Center, OH 43035
Phone: (614) 842-6606 extension 107
Email: matt@nexceris.com