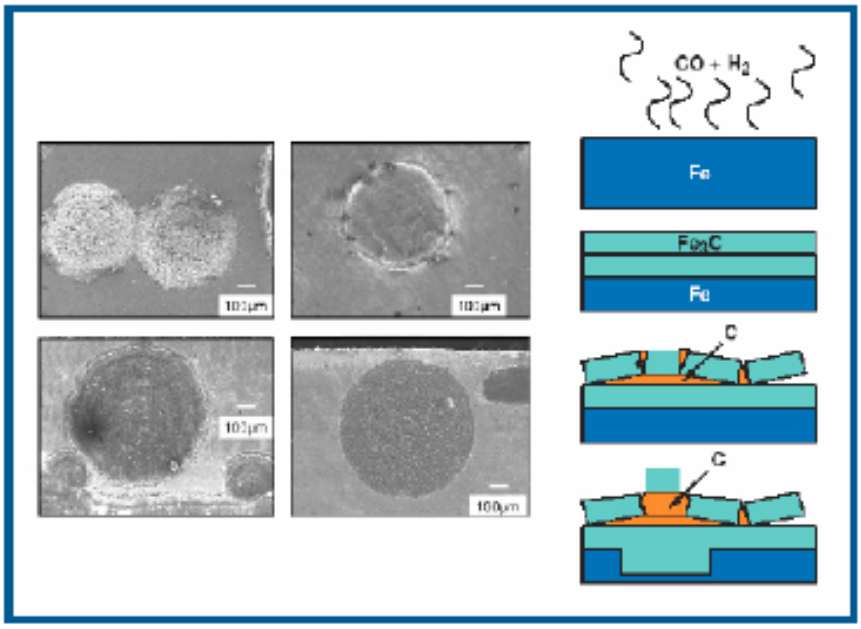
Development of Materials Resistant to Metal Dusting Degradation

New Metal Dusting–Resistant Materials Will Lead to more Energy- and Cost-effective Chemical Processes

Degradation of metallic structural components by metal dusting is a major issue in plants such as those involved in hydrogen production, ammonia synthesis, methanol reforming, and syngas (H2/CO2) mixtures production. Metal dusting is also experienced at high temperatures in the oxidizing-carburizing environments that are prevalent in the heat-treating industry and in processes that involve direct reduction in the production of iron. While experiments have proved that metal dusting does occur, industries did not develop an approach to combat this problem because of a lack of understanding of the mechanisms that lead to metal dusting.

The problems due to metal dusting had been mitigated in the past by designing processes to avoid conditions under which this phenomenon occurred. Such approaches, however, incurred significant penalties in terms of lower energy efficiency, wastage of materials, and decrease in product yield. Recently, work performed at Argonne National Laboratory clearly established the mechanisms that can lead to the initiation and propagation of metal dusting in iron, and nickel-based alloys. This knowledge base was used to develop alternate structural alloys with improved resistance to metal dusting.



Typical metal dusting degradation and damage mechanism

Benefits for Our Nation and Our Industry

The materials developed in this work possessed better resistance to metal dusting degradation, and their use results in more efficient recovery of heat from effluent gas in various processes due to higher gas temperatures, extended life of reforming systems, and increased productivity due to decreased downtime.

Applications in Our Nation's Industry

Improved alloys which are more resistant to metal dusting find applications in equipment used in various industries, including chemicals, petroleum, and steel. These processes include methanol reforming, syngas production, hydrogen production, and catalyst regeneration units in the chemicals/petroleum industry, and heat treating equipment, equipment used for the direct reduction of iron ores, and blast furnaces in the steel and heat treating industries.

Project Description

The goals of this project were to develop new high-strength alloys that are resistant to metal dusting attack in various process-industry sectors at temperatures up to 800°C; and to engineer the surfaces of currently available metallic structural Ni-based alloys to provide adequate mechanical properties at temperatures of interest to metal dusting degradation.

Barriers

Barriers addressed:

- The inability to accurately simulate industrial process conditions that accelerate metal dusting degradation;
- Lack of information on the resistance of Ni-based alloys to metal dusting degradation;
- Lack of knowledge on the performance of surface-modified alloys; and
- Nonavailability of commercial alloys with sufficient strength at 800°C to resist metal dusting degradation.

Pathways

The objectives of this project were achieved through (1) understanding the relationship between alloy chemistry and metal dusting characteristics in Ni-based alloys and identifying candidate alloys; (2) developing, through computational thermodynamic analyses, Ni-based alloys which are more resistant to metal dusting; (3) developing Ni-based alloys surface-engineered with alumina, chromia, and/or silica surface layers that form barriers to dissolution and diffusion of carbon; (4) testing candidate materials under simulated exposure conditions at temperatures up to 700°C and pressures of 600 psi; and (5) exposing and evaluating the behavior in laboratory-scale, pilot, and/or production units.

Results

- Developed metal dusting rate data for current Ni-based alloys and correlate results with alloy chemistry
- Evaluated the pit progression kinetics as a function of gas chemistry, alloy chemistry, and system pressure
- Developed and characterized the microstructures of newly developed nickel-based alloys
- Developed surface-engineered materials based on candidate Ni-based alloys
- Exposed modified alloys and surface-engineered materials in pilot or production units
- Completed evaluation of newly developed Ni-based alloys and weldments after metal dusting exposure

Commercialization

The project team included research and development organizations, chemical processing companies, and materials suppliers. Materials Technology Institute coordinated with its more than 50 member companies in the petroleum and chemicals industry and with user companies who were project partners to test the newly developed materials in typical industrial process environments. The participation of materials suppliers ensured the availability of the new materials for incorporation into process equipment.

Further commercialization efforts included updating a worldwide literature search on metal dusting, completing the scale up of alloys to semi-commercial level, developing 50-100 lb. heats of alloys for industrial testing, and using X-ray nano-beam technology to characterize alloys and establishing pitting kinetics.

Project Partners

Argonne National Laboratory
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Air Products and Chemicals Inc.
Allentown, PA

ConocoPhillips Inc.
Ponca City, OK

ExxonMobil Chemical Company
Baytown, TX

Haldor Topsøe A/S
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Haynes International
Kokomo, IN

Materials Technology Institute
St. Louis, MO

Special Metals
Huntington, WV

ThyssenKrupp VDM USA Inc.
Houston, TX

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Ending FY07
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