the ENERGY lab

PROJECT FACTS

Carbon Storage – ARRA - GSRA

Development of Protective Coatings for Co-Sequestration Processes and Pipelines

Background

The overall goal of the Department of Energy's (DOE) Carbon Storage Program is to develop and advance technologies that will significantly improve the effectiveness of geologic carbon storage, reduce the cost of implementation, and prepare for widespread commercial deployment between 2020 and 2030. Research conducted to develop these technologies will ensure safe and permanent storage of carbon dioxide (CO_2) to reduce greenhouse gas (GHG) emissions without adversely affecting energy use or hindering economic growth.

Geologic carbon storage involves the injection of CO_2 into underground formations that have the ability to securely contain the CO_2 permanently. Technologies being developed for geologic carbon storage are focused on five storage types: oil and gas reservoirs, saline formations, unmineable coal seams, basalts, and organic-rich shales. Technologies being developed will work towards meeting carbon storage programmatic goals of (1) estimating CO_2 storage capacity +/- 30 percent in geologic formations; (2) ensuring 99 percent storage permanence; (3) improving efficiency of storage operations; and (4) developing Best Practices Manuals. Developing and deploying these technologies on a large scale will require a significantly expanded workforce trained in various carbon capture and storage (CCS) technical and non-technical disciplines that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding that focus on conducting geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States. The training and projects can be categorized under one or more of the DOE Carbon Storage Program's five Technology Areas: (1) Geologic Storage and Simulation and Risk Assessment (GSRA), (2) Monitoring, Verification, Accounting (MVA) and Assessment, (3) CO_2 Use and Re-Use, (4) Regional Carbon Sequestration Partnerships (RCSP), and (5) Focus Area for Sequestration Science. This project analyzed protective coatings for pipelines and other infrastructure associated with the transport of CO_2 for carbon storage operations.

Project Description

NETL partnered with North Dakota State University (NDSU) to develop a coating to protect the interior of pipelines and process equipment used in the transport and final stages of the geologic storage process of post-combustion flue gases emitted from fossil fuel power plants from corrosion (Figure 1) and other potential stresses resulting from CO_2-SO_2-O_2-NO_X-H_2O mixtures. This mixture of gases can be referred to as dirty Supercritical Carbon Dioxide ($dSCCO_2$). Internal protective coating systems are expected to be more cost-effective than the overly expensive alloys currently required

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PARTNERS

None

PROJECT DURATION

Start Date
12/01/2009

End Date
11/30/2011

COST

Total Project Value
$298,949

DOE/Non-DOE Share
$298,949 / $0

PROJECT NUMBER

DE-FE0002054

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U.S. DEPARTMENT OF ENERGY

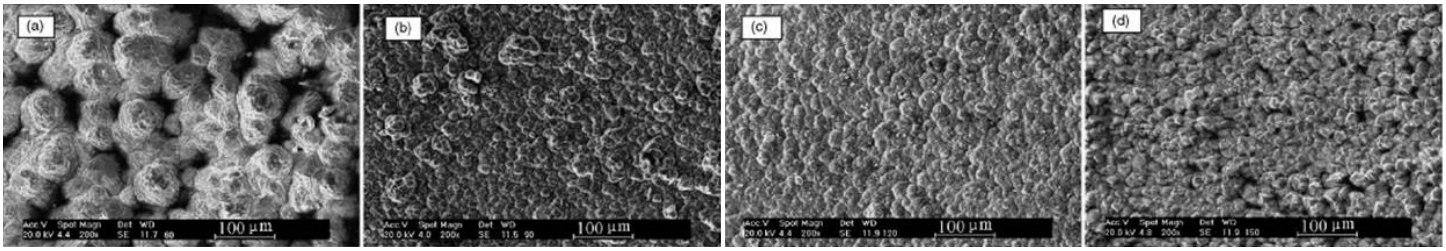

Figure 1. SEM (scanning electron microscope) images of corroded surface of J55 samples in static simulated production water saturated with $SCCO_2$ for 96 hours at different temperatures: (a) 60 °C; (b) 90 °C; (c) 120 °C; (d) 150 °C.

for piping. This project work began with design considerations for polymers, hybrid coatings, and possible metal/inorganic coatings that are resistant to geologic storage fluid under piping delivery conditions. This project utilized past studies of $dSCCO_2$ resistant polymer coatings as well as new developments in coating science (organic, hybrid, inorganic, or metallic). Preliminary systems design began with characterization studies of pipeline materials for contact with $dSCCO_2$. Tradeoffs between corrosion mitigation by pipeline material choice alone vs. coatings on less resistant but economically more attractive pipeline materials were examined as the project proceeded. This coating study provides a basis for economic optimization of the coatings process for use with future CCS projects.

NDSU conducted a literature review regarding corrosion/coating quality sensors for use on both external and internal pipeline surfaces. This research was concurrent with studies that seek to develop potential coatings for these surfaces. Instrumental readings from such a pipeline system could potentially provide a database of safety verification information to address any regulatory and safety concerns that may be raised by permitting and regulatory agencies responsible for monitoring the CO_2 geologic storage pipelines. This technology may also be applied to external pipeline surface corrosion control where sensors can be employed to monitor the health of these systems as well. Further, the pipeline may require insulation to ensure that the temperature necessary to maintain $dSCCO_2$ in its supercritical state is maintained during transport to the carbon storage site. It is well known that insulated pipelines exacerbate tendencies toward external corrosion.

Goals/Objectives

This research effort sought to evaluate materials that can be used as protective coatings in CO_2 pipelines in order to improve the efficiency of CO_2 storage operations. The specific goals of this project include:

- Identifying and screening coating candidates for possible use as internal pipeline linings.
- Developing protocols for evaluating coatings, both internally and externally.
- Evaluating lining, cathodic protection, and external insulation for impact on corrosion.
- Engaging and training students in the multiple facets of the project.

Accomplishments

- By the completion of the project, five students had accumulated 4,821 training-related hours under the program.
- Performed literature reviews on polymers resistive to $dSCCO_2$ and pipeline steel corrosion under $dSCCO_2$ conditions. Several commercial coatings and an organic coating were chosen for the preliminary investigation. The commercial coatings were identified for further study based on the findings from literature review and consultation with technical service personnel at the respective companies from which they were procured. The organic coating was designed by the research team at NDSU.
- Prepared samples by applying the coatings to steel panels. The samples were exposed to different conditions of $dSCCO_2$ at different temperatures and different pressures across varying duration periods. After the exposure, the samples were characterized based on weight and thickness and visually inspected with regard to blisters and pores on the surface. Electrochemical impedance spectroscopy was also used to test possible sample failures under the exposure. With the combination of these characterization methods, the $dSCCO_2$ resistance ability of the coatings was obtained.
- The project results indicate that one commercial coating (3M Scotchkote™ 345) and the organic designed coating (Polyoil™ 130-based) display good performance and have the potential to act as internal pipeline coatings to transport $dSCCO_2$, if applied at a thickness greater than 50 micrometers. These two coatings could extend the service life of pipelines for $dSCCO_2$ transportation which could reduce maintenance and overall costs. The project results indicate that interior protection is viable for pipelines but field exposure and/or expanded lab exposure is still needed to verify the results under actual pipeline conditions.
- A final report has been completed and is now available.

Benefits

The benefits of this research are the development of design criteria for prototype protective coatings for $dSCCO_2$ handling in process equipment and pipelines, as well as a set of tests which can be used to qualify such coatings for use, and an initial list of the substrates for which these coatings are effective. Ultimately, these coatings may ensure the health and safety of pipelines employed in storage of $dSCCO_2$ without the use of costly specialty alloys, thus improving the efficiency of carbon storage operations and developing industry best practices. In addition, this project offered students the opportunity to develop vital skills, like the development, improvement, and implementation of CO_2 delivery and storage infrastructure, in order to deploy CCS technologies on a commercial-scale.