the ENERGY lab

PROJECT FACTS

Carbon Storage – ARRA MVA

Passive Wireless Acoustic Wave Sensors for Monitoring CO_2 Emissions for Geological Sequestration Sites

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 conducted a comprehensive study to develop/evaluate low-cost, efficient CO_2 leakage monitoring technologies for geologic carbon storage sites.

Project Description

The University of Pittsburgh developed a knowledge base for the successful development of novel sensors and sensor systems for CO_2 emission monitoring. This project has developed a CO_2 sensor and instrument for measuring and monitoring CO_2 emissions for geological carbon storage sites in a continuous mode, while providing training opportunities for graduate students in the areas of acoustic wave sensors, nanomaterials, and the geologic storage of CO_2. A passive wireless CO_2 sensing system based on surface acoustic wave (SAW) technology and carbon nanotube (CNT)

CONTACTS

Traci Rodosta
Carbon Storage Technology Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507
304-285-1345
traci.rodosta@netl.doe.gov

Robert Noll
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236
412-386-7597
robert.noll@netl.doe.gov

Qing-Ming Wang
Principal Investigator
University of Pittsburgh
647 Benedum Hall
Pittsburgh, PA 15260-6830
412-624-4885
qwang@pitt.edu

PARTNERS

None

PROJECT DURATION

Start Date 12/01/2009

End Date 11/30/2012

COST

Total Project Value
$366,900

DOE/Non-DOE Share
$300,000/$66,900

PROJECT NUMBER

DE-FE0002138

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

nanocomposite was developed by the research team. A SAW device was studied to determine the optimum parameters for CO_2 detection and deployment in the subsurface. The wireless CO2 sensor can respond to CO_2 concentration changes in the air in a timely manner and communicate wirelessly with a control center regarding the detection results.

Potential impacts of the project include:

- Significantly advanced sensor technology for detecting very low levels of CO_2 emissions for applications at CO_2 sequestration projects.
- Novel application of nanomaterials and devices, specifically for in situ and real-time monitoring of CO_2 emissions from geological sequestration sites.
- An in-depth understanding of material properties and microfabrication technology, as well as device development based on acoustic wave sensors and polymer nanocomposite thin films.
- Acquisition of key data to assess physical and geochemical subsurface processes associated with CO_2 emplacement.

Goals/Objectives

The overall goal of the proposed project was to fabricate SAW sensor with wireless component, use CNT nanocomposite as sensing element, and explore the application of SAW sensor and CNT nanocomposites for deployment at carbon storage sites. Toward that end, the following specific project objectives were performed in response to the above goal:

- Fabricate the SAW sensor and characterize the impact of different parameters on SAW performance.
- Fabricate the CNT nanocomposite and characterize the impact of different parameters (particularly temperature, humidity, and other gases) on nanocomposite response.
- Evaluate the CNT nanocomposite gas response and characterize SAW sensor gas response.
- Develop a novel CNT nanocomposite SAW sensor with wireless function.

Accomplishments

By the completion of the project, four students had accumulated 6,500 training-related hours under the program.

- SAW characteristics were studied during the construction of SAW flow sensor. The impact of the piezoelectric material properties on sensor performance, and the effect of strain on sensor performance were all assessed. The results show a linear relationship between the SAW delay time and flow rate, as predicted by simulation and theoretical calculation.
- The percolation threshold was studied. Polyimide (PI) was first chosen in nanocomposite fabrication because of its resistance to harsh environment, especially high temperature, thus extending the sensor application range. Due to the nature of nanocomposite, the thin film is very sensitive to temperature change. Better understanding of the temperature sensitivity on nanocomposite response is an important feature given possibly harsh conditions in a carbon storage environment.
- Parylene was found to be a suitable sensor packaging material as it enhances resistance to humidity while preserving the gas sensitivity and the detection limit. Humidity test results for the SAW sensor with packaging shows a lower frequency of detection for saturated water vapor, while maintaining the same detection frequency for pure CO_2. Sensor packaging material is a key factor in developing a ruggedized CO_2 sensor, capable of being deployed at an active carbon storage site.
- Different wireless modules were studied and a separated antenna was chosen based on cost effectiveness. Due to the fabrication limit of the sensor, the planar antenna was excluded and a tunable capacitor with a coil structure was chosen instead. Test results show a large difference between parallel and series orientation of the coil, thus suggesting the existence of an optimum coil orientation. With current configuration, the wireless module is expected to work at a distance of over one foot. The development of a wireless component for this monitoring technology will increase the robustness of the sensor network and the data it collects.

A final report has been completed and is now available.

Benefits

The overall project will make a vital contribution to the scientific, technical, and institutional knowledge base necessary to establish frameworks for the development of commercial-scale CCS. This research will lay down a solid foundation for the development of commercially viable advanced sensor technology to detect very low levels of CO_2 emissions for in situ real-time monitoring of CO_2 emissions at the geological sequestration sites. This, in turn, will provide sufficient and precise data for further evaluation of the coupled subsurface processes—including hydrological, mechanical, and geochemical—to ensure that CO_2 will be stored permanently. Additionally, the project will offer graduate student research opportunities that will help cultivate a workforce trained in the skills and competencies required to implement CCS technologies on a commercial-scale.

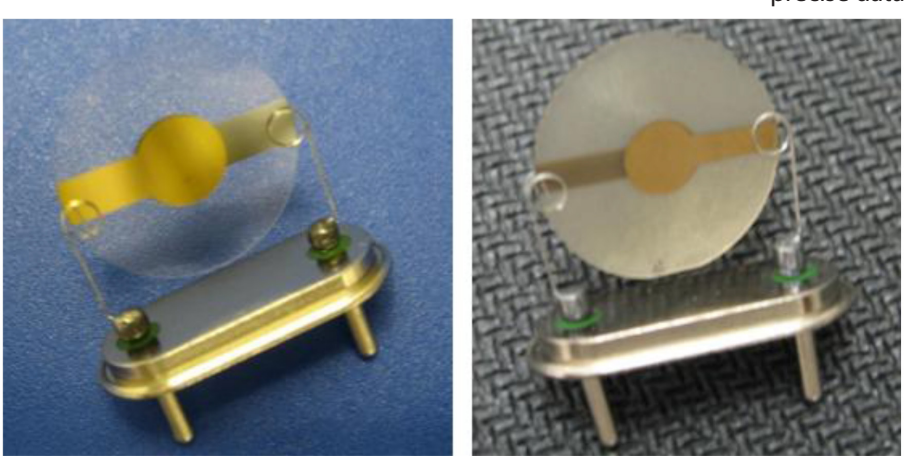

Figure 1. Quartz (left) and langasite (right) SAW resonators. The langasite resonators developed under this project are capable of achieving a high electromechanical coupling and possess a high phase transformation temperature up to 1,470 °C.