ADVANCED NATURAL GAS PIPELINE MATERIALS

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL's Natural Gas Infrastructure Program strengthens the reliability, public safety, operational efficiency, and flexibility of the nation's aging natural gas infrastructure pipelines by developing effective mitigation technologies, including the development of advanced materials for natural gas pipelines.

The Laboratory works on ways to improve midstream operations – systems that actively connect production fields with local distribution systems. Natural gas transmission pipelines require a long lifespan, but population growth can encroach on the lines over time, worsening the consequence of gas line failure. One of the sources of catastrophic failure is internal corrosion of the pipeline principally due to the presence of incidental water and CO_2. Internal corrosion resulted in 10.8% of the total incidents. The total reported cost for the internal corrosion incidents was $190 million. While the gas is nominally dried prior to introduction to the pipeline, water can accumulate in low areas of the line. CO_2, as a natural gas impurity, is a significant issue because it will dissolve in residual water to form corrosive carbonic acid. This situation can be further exacerbated by the high partial pressure of CO_2 in the pipeline. Presently, internal corrosion is assessed through regular inspection during pipeline pigging. However, preventive maintenance is costly and may require the venting of natural gas prior to inspection. Natural gas leaks

caused by corrosion can be prevented by applying protective coatings and liners to pipelines. This can be accomplished by developing advanced materials that block the permeation of corrosive species to pipelines substrates.

Key focus areas of the program's research are:

- Polymer-Metal-Polymer Composite Barrier Liners
- Metallic Coatings
- Multilayer Barrier Coatings with High Chemical Stability
- Joining Methodologies for Composite Liners

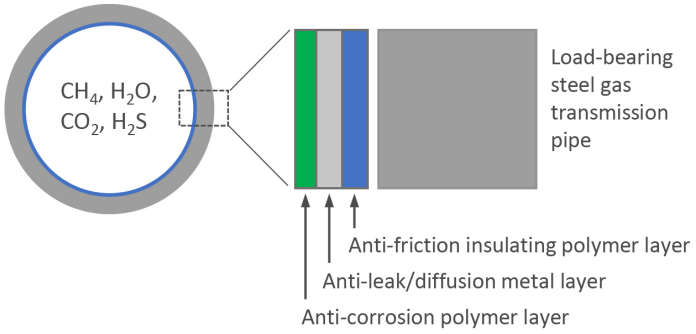
POLYMER-METAL-POLYMER COMPOSITE BARRIER LINERS

Water and CO_2 react to form carbonic acid that can corrode the inside of steel pipes. NETL is developing composite liners to investigate the use of impermeable barriers to reduce or eliminate carbonic acid corrosion of steel. Successful commercialization of the technology can save money and lives by reducing the rate of pipeline failure due to internal corrosion.

Polymer-metal-polymer composite barrier films have been shown to be effective in preventing carbonic acid corrosion of steel in the laboratory; however, much work remains to be done to go from the lab bench to testing a prototype composite liner in the field.

NETL is also investigating the feasibility of using composite barrier liners in pipelines that carry gases other than natural gas (e.g., CO_2 and hydrogen). A liner that is resistant to wet CO_2 enables the use of existing pipelines to transport the gas for enhanced oil recovery or carbon sequestration. This project, which is ongoing, provides an avenue for pipeline transport of hydrogen through the existing natural gas infrastructure without embrittling the steel pipes.

NETL's High-Pressure Immersion and Reactive Transport Lab and Severe Environment Corrosion Erosion Research Facility enable the testing of gas permeation and corrosion under pure and mixed gas environments at pipeline relevant pressures and temperatures.

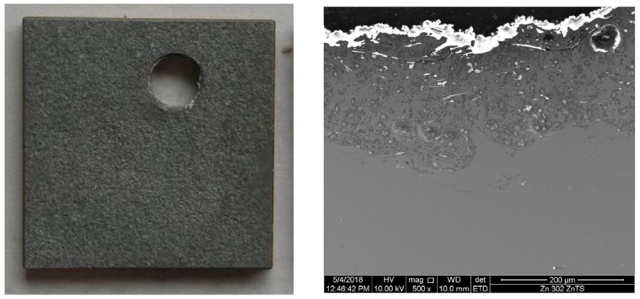


Gas permeation reduction with metal-composite barrier liners.

METALLIC COATINGS

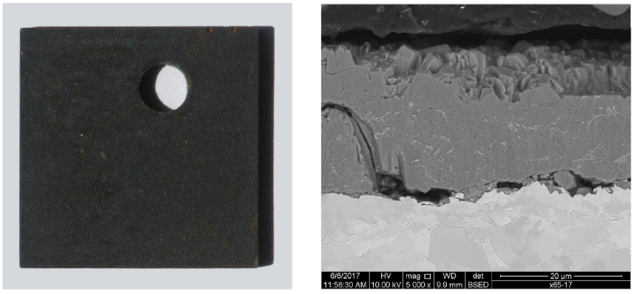
NETL is developing a metallic coating system to protect the interior of natural gas transmission pipelines from corrosion, thereby extending their safe operating lifespan by more than 100 years. After successful deposition and laboratory testing, at least two metallic coatings are to be tested in natural gas gathering lines, which tend to have shorter lifespans than transmission lines.

NETL has built an electrochemical reaction autoclave – a unique tool for studying corrosion in high-pressure conditions like a pipeline.



Surface view | Cross section view

Zn thermally sprayed surface after autoclave immersion testing for 168 h at 40 °C with 3 atm of CO_2 pressure.



Surface view | Cross section view

Bare steel surface after autoclave immersion testing for 168 h at 40 °C with 3 atm of CO_2 pressure.

Zn coatings deposition of protective Zn carbonate.

MULTILAYER BARRIER COATINGS WITH HIGH CHEMICAL STABILITY

Natural gas leaks were estimated to cost U.S. consumers $20 billion between 2000 and 2010 and caused an average of 17 fatalities and $133 million in property damage annually. A significant portion of these leaks are related to the internal corrosion of steel pipelines caused by salt water and gaseous impurities contacting bare steel. Adding a protective coating to the inner pipe surface should mitigate the corrosion, but commonly used protective coatings based on epoxy and polyethylene are unsuitable for this application because of their low gas and water vapor barriers. In contrast, existing layer-by-layer (LbL) assemblies are known for their high gas and water vapor barriers, but they tend to decompose in CO_2-saturated salt water. By fine-tuning the composition, molecular interaction, and structure of LbL assemblies, NETL is developing multilayer barrier coatings that can remain chemically stable in CO_2-saturated salt water.

An LbL assembly uses complementary interactions, such as ionic, hydrogen, or covalent bonding, between components to deposit materials one layer at a time. Researchers can design the structure of these multilayer coatings with nanometer precision to achieve a high oxygen barrier and a reasonable water vapor barrier. NETL is depositing multilayer coatings produced through LbL assembly on the inner surfaces of steel pipelines. Their barrier and corrosion resistance are being characterized and then used to interpret anti-corrosion properties.

NETL has world class in-house test facilities to measure the pure gas, mixed gas or water vapor permeance of multilayer coatings as well as an advanced electrochemical impedance spectroscopy for estimating the rate of electrochemical corrosion and a suite of advanced materials laboratories for the fabrication and characterization of polymer/clay multilayer coatings.

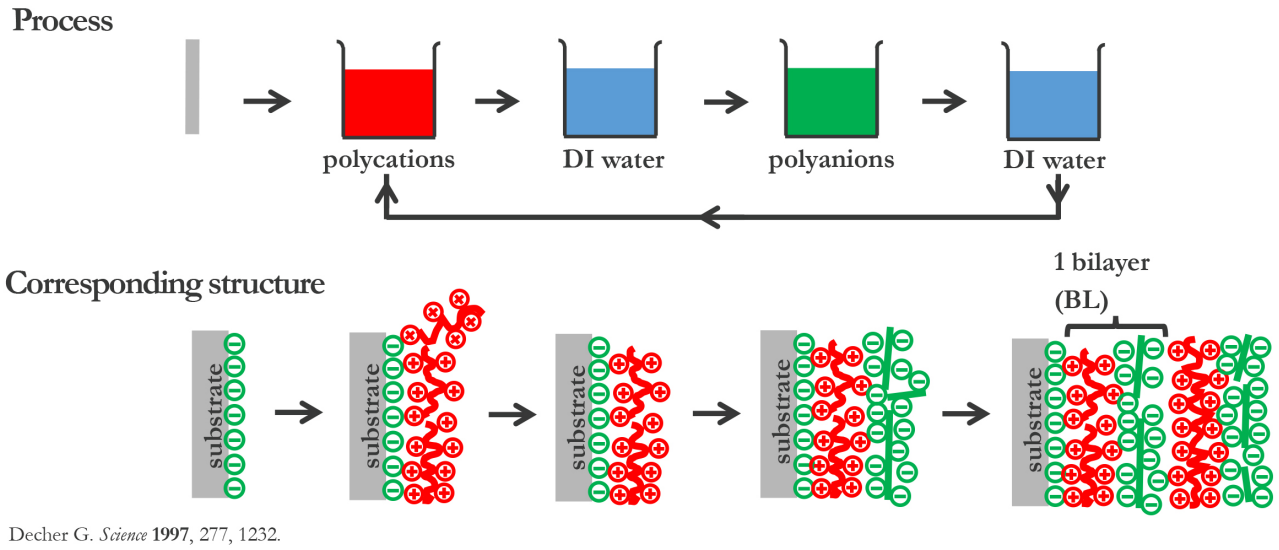
JOINING METHODOLOGIES FOR COMPOSITE LINERS

A barrier impermeable to water and methane, lining the interior of the pipeline walls, can prevent emissions and corrosion resulting in improved reliability for natural gas pipelines.

A metal foil liner coated with polymer on both sides will be impermeable to both water and methane molecules. Polymer coating on the metal foil will increase the robustness of the liner, which is especially needed during the installation and pigging processes. NETL is working to identify and demonstrate a viable joining technology for a metal thin foil layer of composite liners for natural gas pipelines. This technology is required to join metal thin foils in a defect-free and continuous manner.

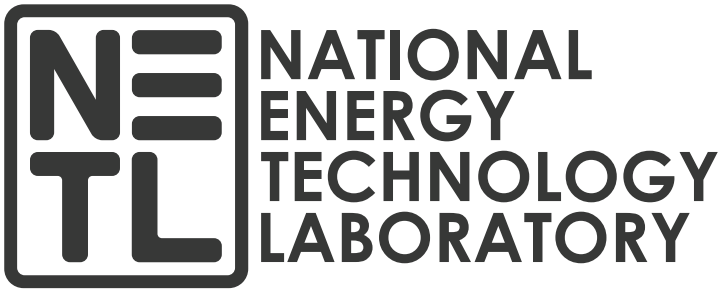
NETL maintains mechanical testing facilities and microstructural characterization laboratories for joining microstructure characterization.

LbL Assembly



Decher G. *Science* **1997**, 277, 1232.

In a typical layer-by-layer (LbL) assembly process, positively and negatively charged components are alternately deposited to produce layered composite membranes.



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