Multi-Layer Al/Al2O3 Barrier Coating to Retrofit Natural Gas Transmission Pipelines to Safely Transport CO_2 or H_2

Gianluca Roscioli
Arculus Solutions

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Bulk transportation of CO_2 and H_2 is a crucial development in our efforts to reach net zero by 2050.

While using the extensive US 320,000-mile grid of natural gas transmission pipelines seems the simplest, fastest and most cost-effective solution, those pipes suffer (i) strong corrosion from carbonic acid in the case of CO_2, and (ii) hydrogen embrittlement leading to high leak rates and catastrophic failures when blending even small percentages of hydrogen with natural gas.

Dense oxide and nitride layers have an extremely low hydrogen diffusivity that can effectively delay hydrogen ingress into the steel substrate, yet they are not widely used because of their poor mechanical durability and their failure as long-term solution. Despite that, when alternated with metallic layers of the same base metal in metal-oxide multilayer composite structures (such as aluminum/aluminum oxide), three peculiar properties can be observed. (i) Formation of a physical barrier to hydrogen permeation thanks to the development of extended space-charge zones at the metal/oxide interface, which repel incoming positively charged hydrogen ions diffusing in the oxide. (ii) Improved adhesion to the substrate thanks to the metallic interlayer that provides physical and mechanical compatibility between the metallic substrate and the oxide layer, thus preventing delamination. (iii) Enhanced resistance to mechanical damage thanks to the strong micro-cracking resistance and the self-healing behavior of the multi-layer composite structure.

Arculus brings to market, partnering with N2 Solutions, a patent-pending, multi-layer Al/Al2O3 coating developed at MIT that is inert to carbonic acid and impermeable to hydrogen. In this study, we produced several coatings with different structures and demonstrated their hydrogen-barrier effect through hydrogen permeability testing using a Devanathan-Stachurski permeation cell, both in the as-deposited and in a damaged state. The results are compared to identify the best structure for field application. Last, we will show a novel application method we developed to apply the optimized coating structure onto the internal surface of pipelines using a smart pig.

KEYWORD(S) FOR SUBJECT AREA: Coatings, Coating inspection, Hydrogen, CO_2, Corrosion studies, Emerging technologies, ILI applications, Instrumentation, Manufacturing, Pipe, Repair, Rehabilitation, Robotics.

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