Fundamental Mechanochemistry-based Detection of Early Stage Corrosion Degradation of Pipeline Steels

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

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Main Objective

This project was awarded to Iowa State University in order to provide a model guided development of advanced detection methods to quantify the physical and mechanical changes associated with early stage stress corrosion cracking in high strength pipeline steel. This will render a systematic framework to monitor changes in parameters germane to corrosion prevention, while mitigating the corrosion impact on the pipeline infrastructure.

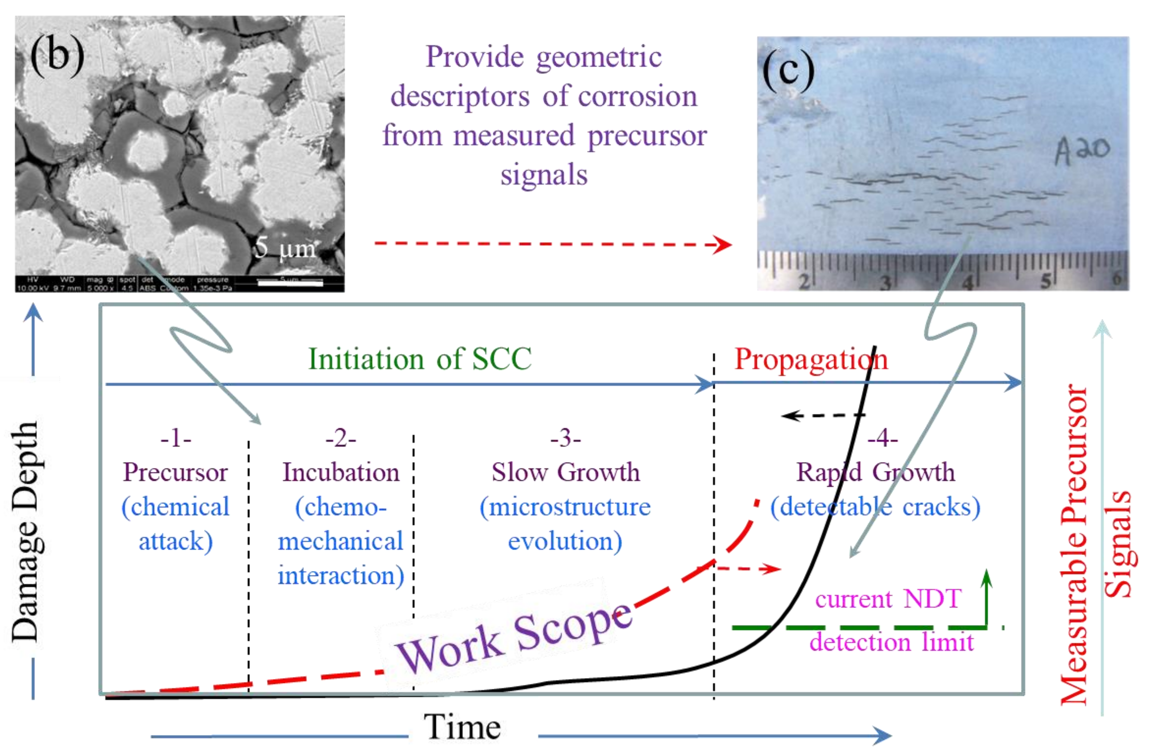

Figure 1. Scope of the proposed work to quantify measurable precursor signals during SCC initiation (b) Early damage percolation. (c) Colonies of SCC (detectable macro-cracks).

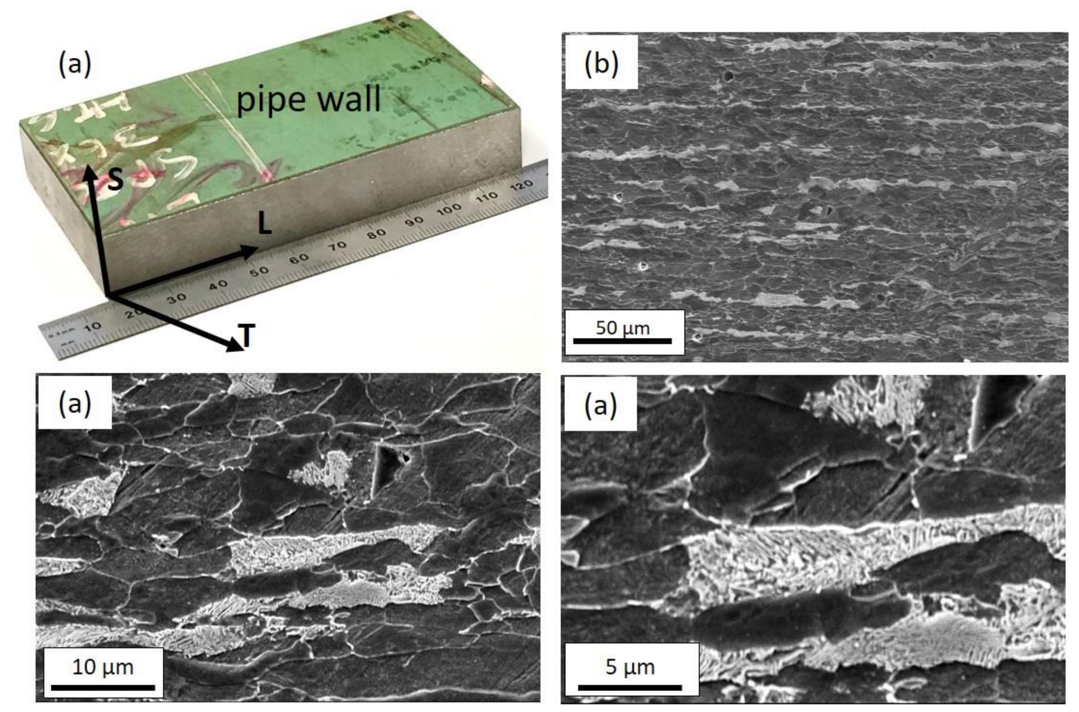

Figure 2. Microstructure of API 5L X70 Pipeline steel.

Project Approach/Scope

(1) Develop the mechanochemistry modeling framework for early stage SCC.

(2) Quantify the physical and mechanical changes during the early stage of SCC by Electrochemical Impedance Spectroscopy (EIS) and 4-Point Probe Electrical Resistance (4-PB).

(3) Assist future development of mathematical models.

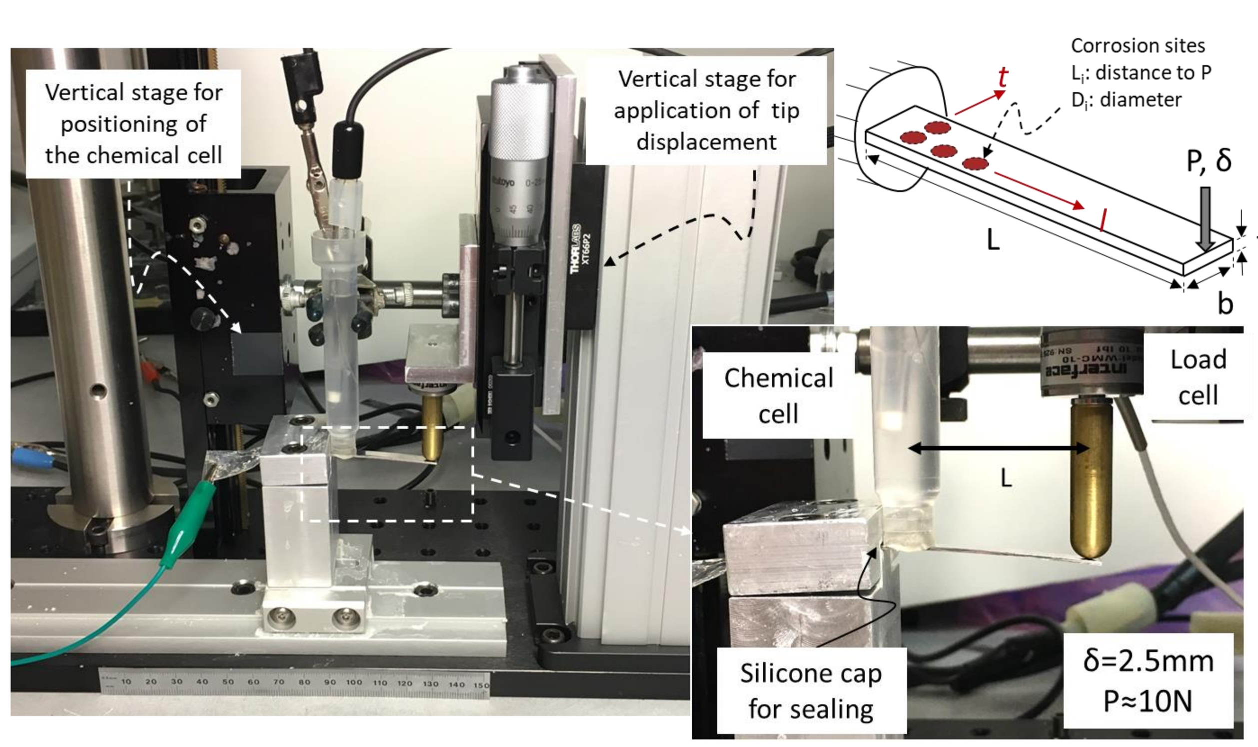

Figure 3. Experimental setup to produce SCC conditions.

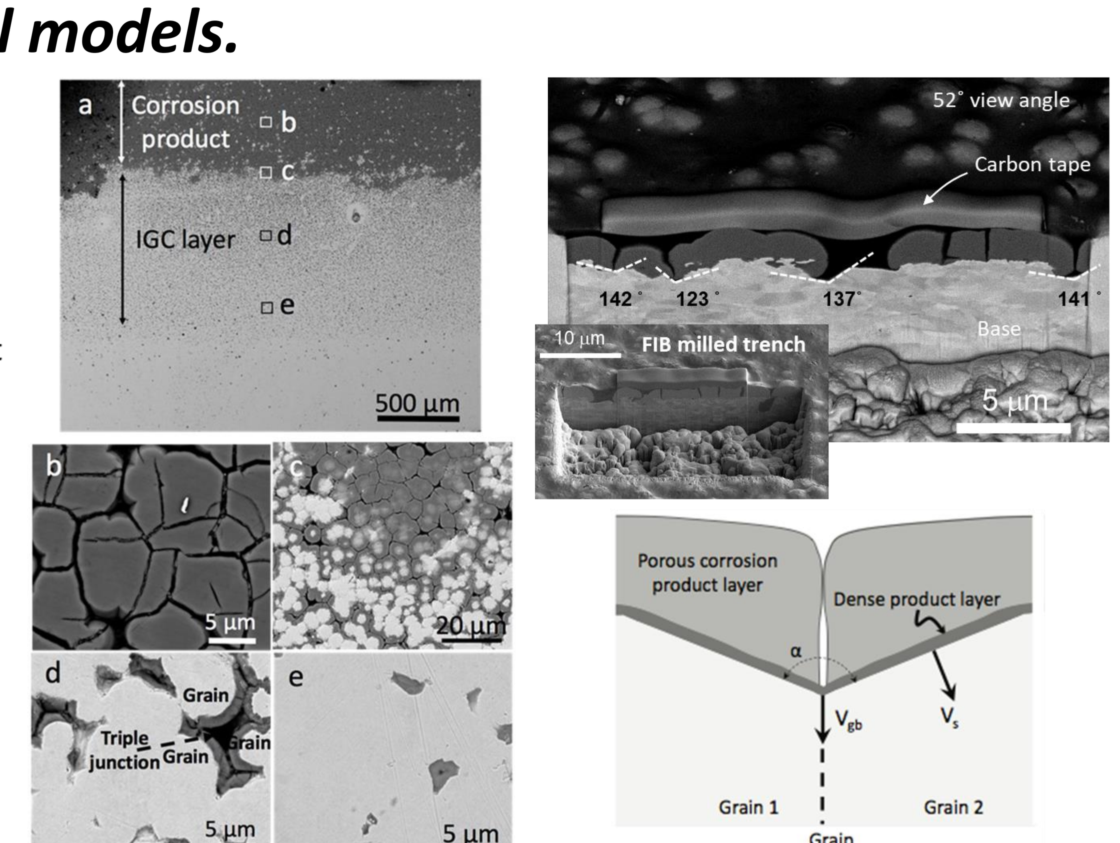

Figure 4. Characterization of early-stage morphology of intergranular corrosion.

Results to Date

The first two phases of the project have been completed. The major findings can be listed as,

- **Geometry identification and description**: IGC creates triangular wedges of porous corrosion product centered at GB triple junctions, generating compressive stresses.
- **Species distribution and Exchange**: IGC induces local degradation of hardness at GBs due to vacancy generation and selective oxidation of Silicon.
- The next stage is to perform EIS and 4-PB surface resistance measurements and provide quantitative measure of the extent of the damage during early stage of SCC.

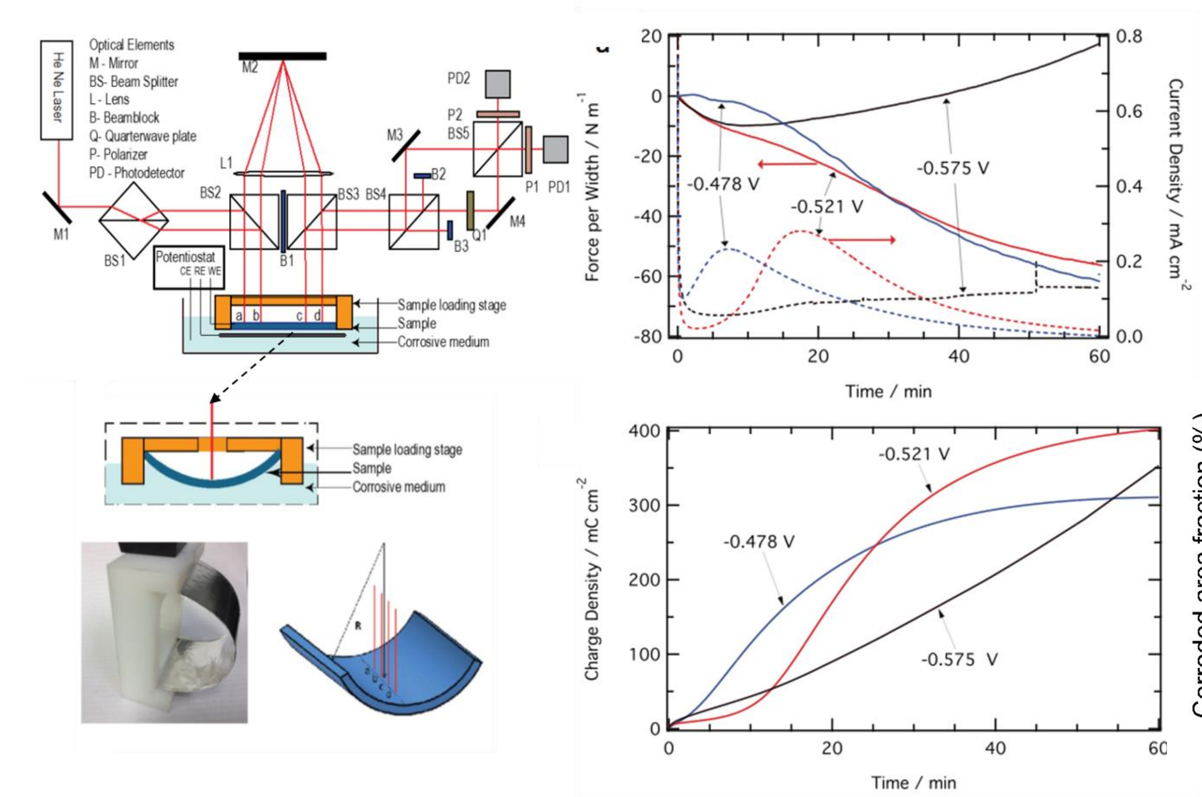

Figure 5. Schematic of the interferometry setup for in-situ curvature measurement through the electrochemical cell. Force per width, current density and charge density transients.

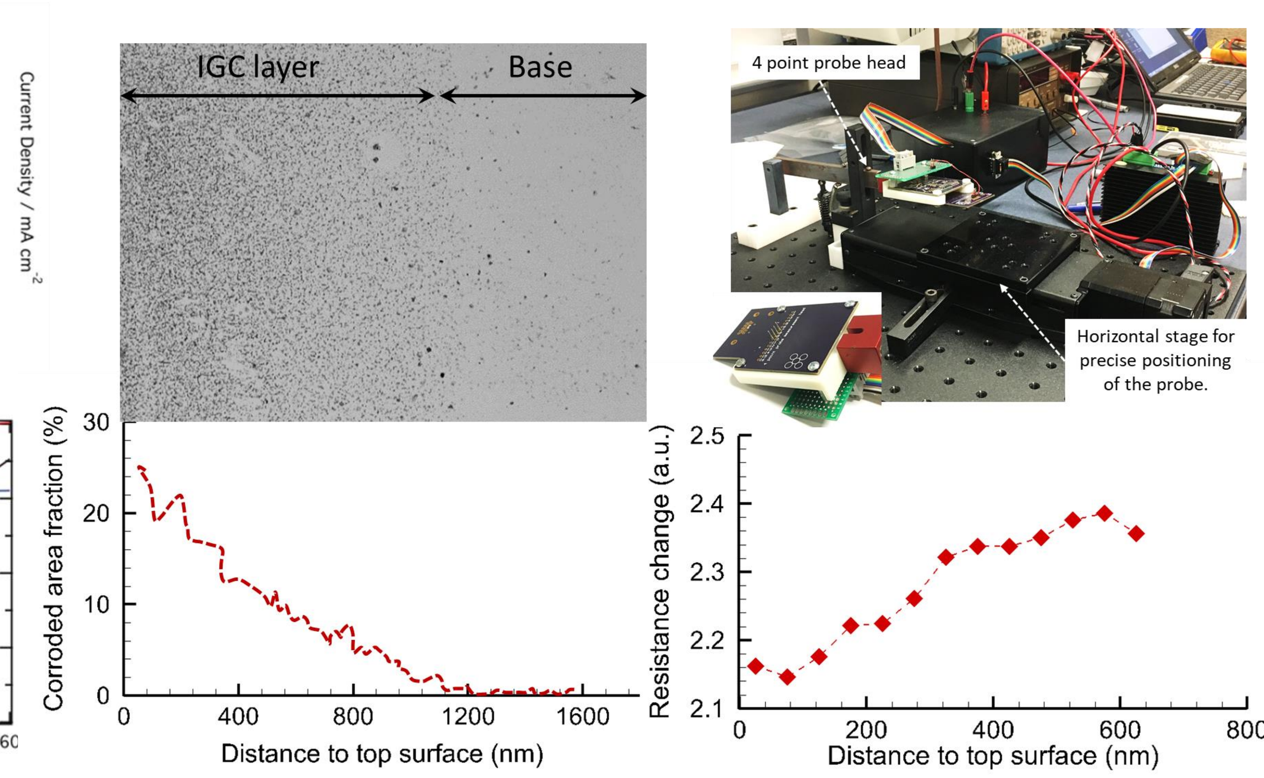

Figure 6. Preliminary measurements of geometric descriptors for IGC layer density and surface resistance variation within the IGC layer.

Project Products

1. D Yavas, P Mishra, A Alshehri, P Shrotriya, AF Bastawros, KR Hebert, "Morphology and stress evolution during the initial stages of intergranular corrosion of X70 steel," Electrochimica Acta, 2018.
2. D Yavas, P Mishra, A Alshehri, P Shrotriya, KR Hebert, AF Bastawros, "Nanoindentation study of corrosion-induced grain boundary degradation in a pipeline steel," Electrochemistry Communications 88:88-92, 2018.
3. D Yavas, P Mishra, AF Bastawros, KR Hebert, P Shrotriya, "Characterization of sub-surface damage during the early stage of stress corrosion cracking by nano indentation," Experimental and Applied Mechanics, 4:37-44, 2017.

Acknowledgments

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Public Project Page

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