Coatings Trends & Technologies

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Design and Characterization of Functional Nanoengineered Epoxy-Resin Coatings for Pipeline Corrosion Control

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PHMSA
Pipeline and Hazardous Materials Safety Administration

North Dakota LEGENDARY

NDSU NORTH DAKOTA STATE UNIVERSITY

Acknowledgement

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ND DOC Venture I

- **Group members**

Graduate students: Xingyu Wang, Mingli Li, Matthew Pearson, Zi Zhang, Muhammad Naveed, Yiming Bu

Undergraduate students: Devin Neubeck, Wyatt Schirrick

High school students: Over eight high students from different schools in North Dakota State through past years

Outline

- **Background**
- **Experimental Program**
- **Results and Discussion**
- **Further Discussion**
- **Summary**

1. Background

Pipeline spill and pollutions

http://www.occupy.com/article/20000-barrels-spilled-north-dakota-pipeline-rupture?qt-article_tabs=2

Fig. 1 Pipeline accidents in the United State

(Photos from http://projects.propublica.org/pipelines/)

1. Background

Fig. 2 Internal corrosion: a) localized pits[1], b) fouling[2] and c) wear/erosion[3]

Table 1. Pipeline accidents in recent years at North Dakota (Pan et al., 2017[4]).

Accident	Location	Year	Loss
Pipeline spill	Tioga	2014	One gas pipeline exploded and burned
Pipeline spill	Tioga	2013	**865,000 gallons (one of the largest to happen onshore in U.S. history)**
Pipeline spill	Sargent County	2011	Spilling 400 barrels of crude oil
Pipeline spill	Neche	2010	Releasing 3,784 barrels of crude oil
Pipeline spill	Mantador	2004	Residents were evacuated, and a rail line was shut down
Pipeline spill	Barnes County	2003	Releasing 9,000 barrels of propane
Pipeline ruptured	Bottineau	2001	1.1 million US gallons (4,200 m^3) of gasoline burned
Pipeline spill	Harwood	2001	Spilling 40 barrels of fuel oil

[1]. Photos from http://www.flickriver.com/photos/59127492@N07/5416927808/
[2]. Photos from http://www.icorr.org/news/180/index.phtml
[3]. Photos from https://sites.google.com/site/metropolitanforensics/root-causes-andcontributing-factors-of-gas-and-liquid-pipeline-failures
[4]. Pan, H.; Ge, R.; Xingyu, W.; Jinhui, W.; Na, G.; Zhibin, L. Embedded Wireless Passive Sensor Networks for Health Monitoring of Welded Joints in Onshore Metallic Pipelines. In *ASCE 2017 Pipelines*; 2017.

1. Background

Challenges: The conventional coating systems have one or more weaknesses/limitations, incapability of resisting combined effects: corrosion, fouling and wear/erosion.

Solutions: To propose new nanomodified high-performance composite coatings that may be possible to mitigate corrosion, as well as high abrasion resistance.

Objectives: To conduct the in-depth investigation on critical parameters, including mechanical abrasion resistance, tensile strength and ultimate strain, corrosion resistance, and contact angles.

2. Experimental Program

Fabrication and characterization of the composite coating:

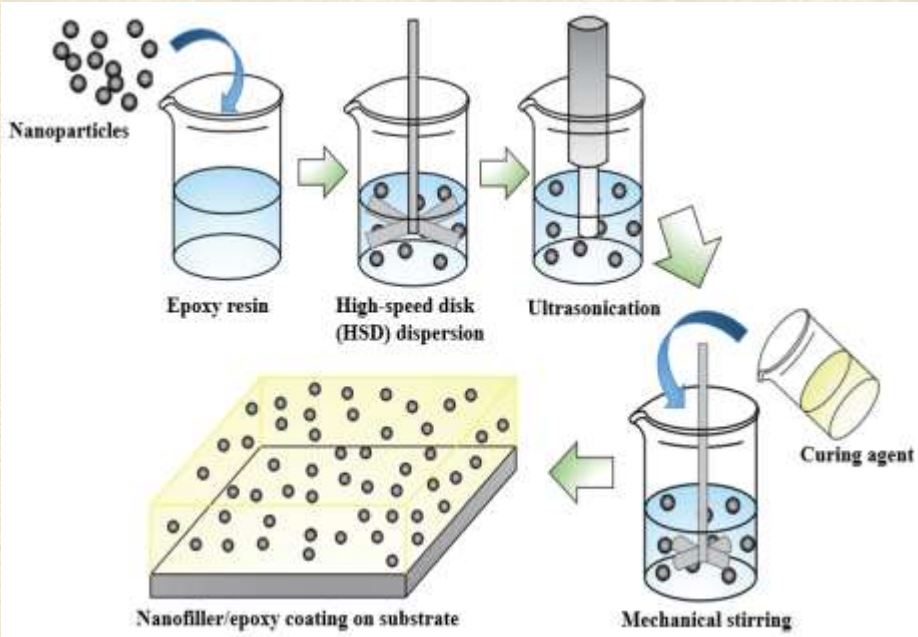


Fig. 3 Schematic of the fabrication process

Fig. 4 GNP/epoxy composite with and without dispersion procedure

Graphene contents varied from 0.1% to 3.0 wt.%

2. Experimental Program

Fabrication and characterization of the composite coating:

2.1 Test Matrix:

Graphene contents varied from 0.1% to 3.0 wt.%, and we selected the neat epoxy samples as the controlling reference.

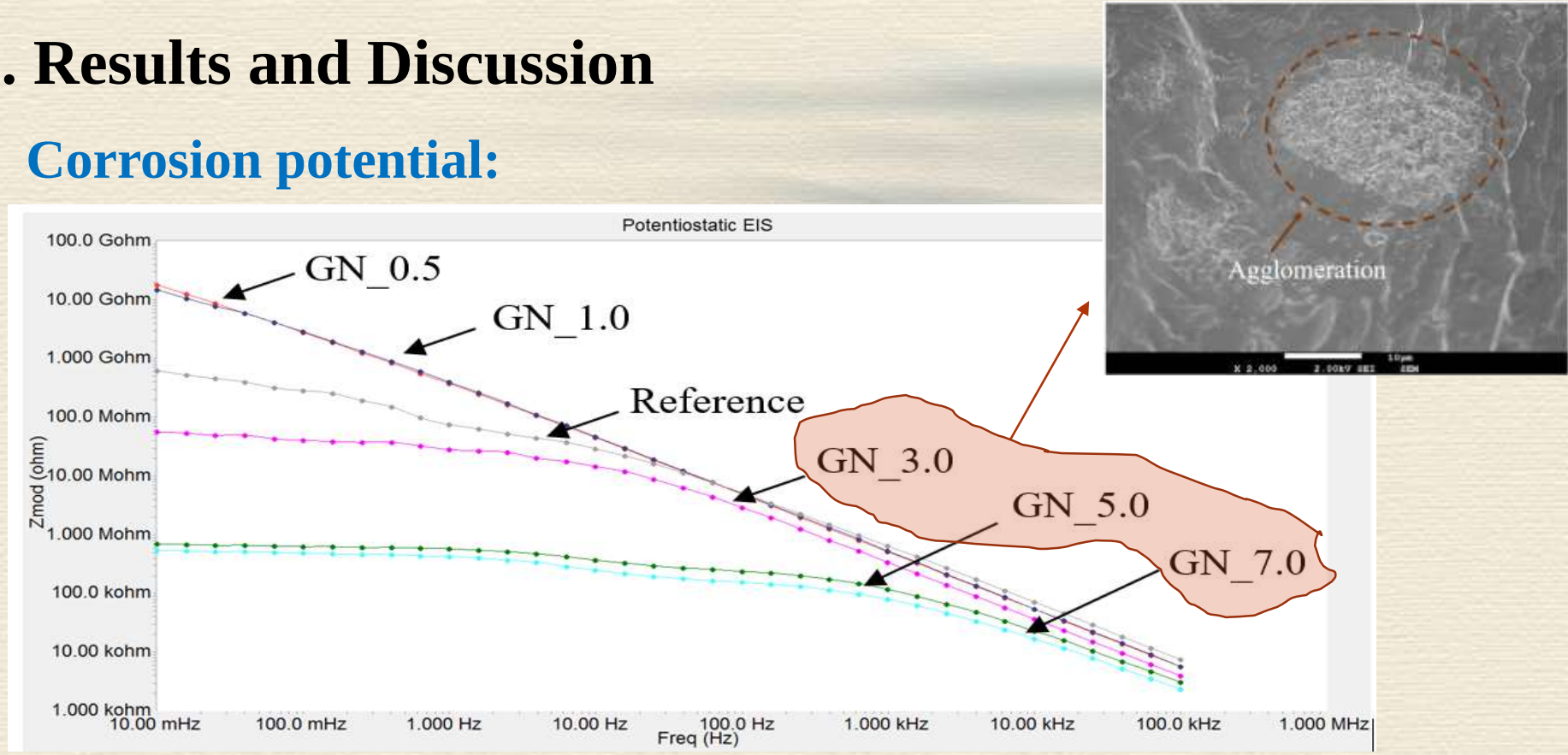
2.2 Test Setup:

(a) EIS (b) Taber abraser (c) Coupon tensile (d) Contact angle

Fig. 5 Schematic of test setup

3. Results and Discussion

Corrosion potential:

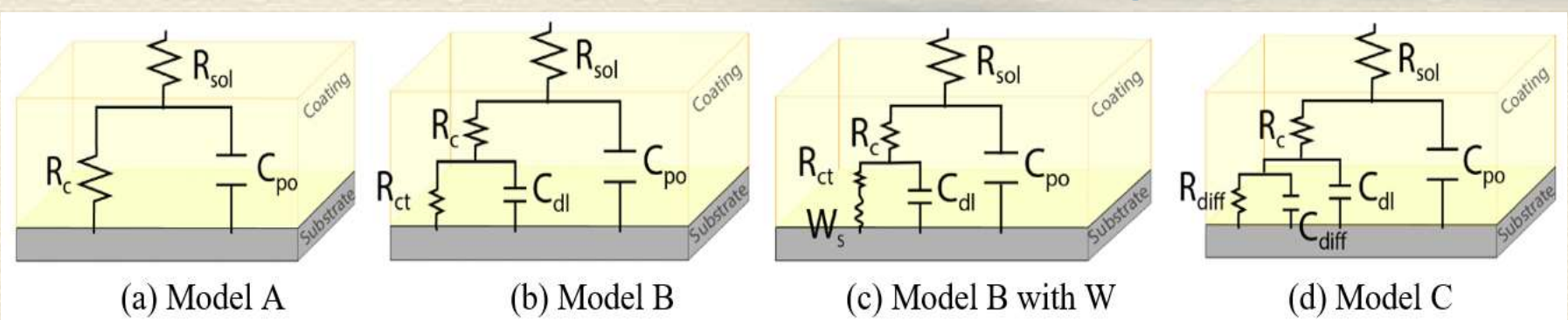


Accelerated corrosion tests:

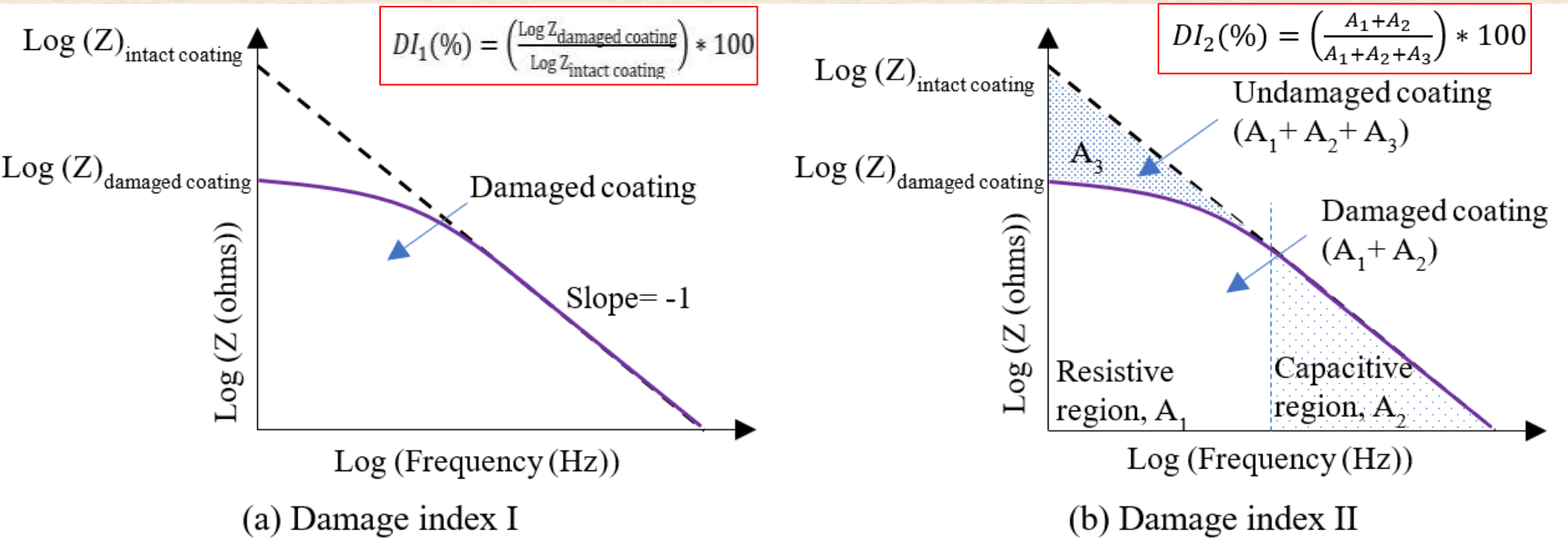
Scribing coated samples and salt fog chamber with tested samples

3. Results and Discussion

Evaluation of corrosion resistance in short-/long-runs



Equivalent electrical circuit models at four stages: (a)-(d)



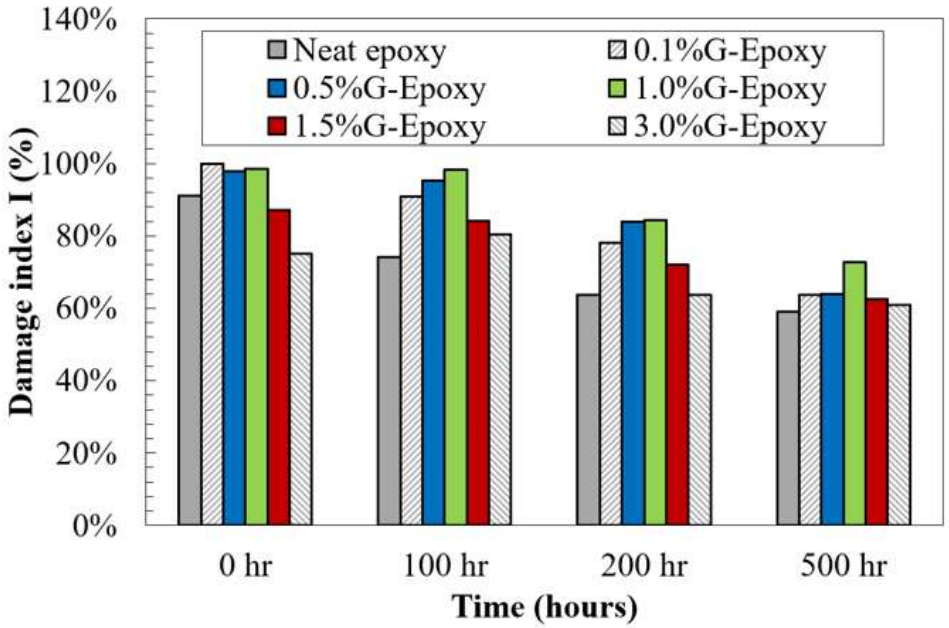
Damage indices for the coating degradation assessment: (a)-(b)

3. Results and Discussion

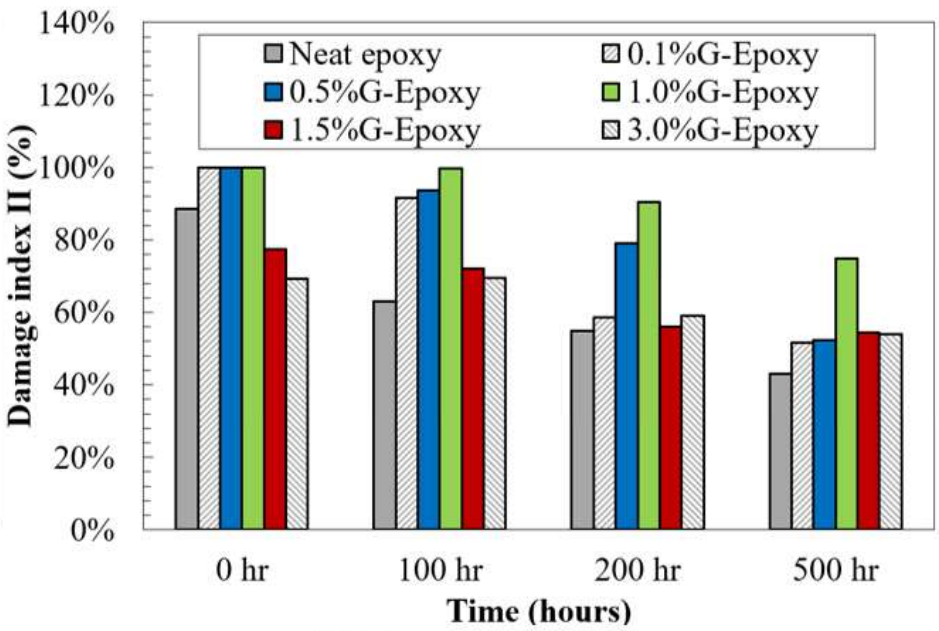
Evaluation of corrosion resistance in short-/long-runs

Table 2 EIS data associated with different stages of the equivalent electrical circuit models

Label	Content of graphene (wt.%)	Exposure to accelerated environmental stresses			
		Onset	100-hr	200-hr	500-hr
Neat epoxy	/	Model B with W	Model B with W	Model B with W	Model C
0.1% G-Epoxy	0.1	Model A	Model B	Model B with W	Model B with W
0.5% G-Epoxy	0.5	Model A	Model B	Model B	Model B with W
1.0% G-Epoxy	1.0	Model A	Model B	Model B	Model B with W
1.5% G-Epoxy	1.5	Model B with W	Model B with W	Model B with W	Model C
3.0% G-Epoxy	3.0	Model B with W	Model B with W	Model B with W	Model C



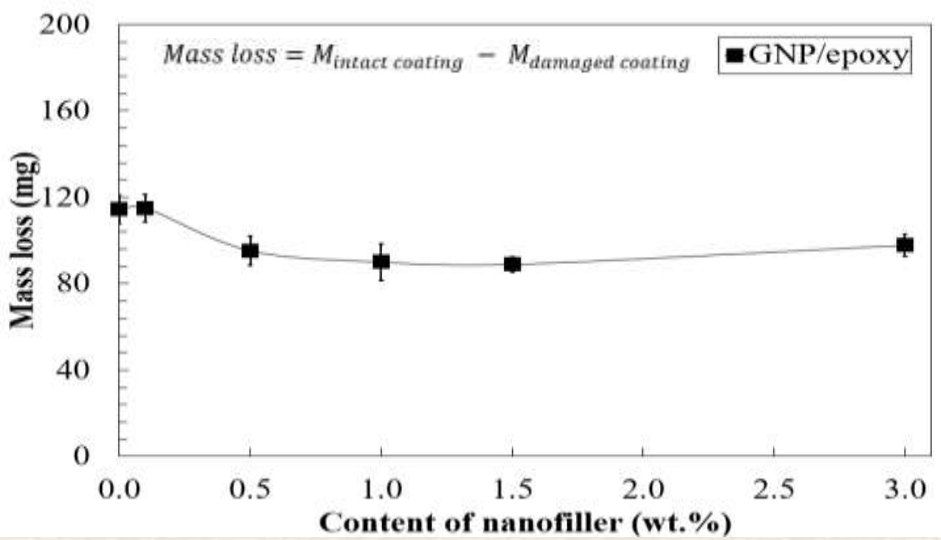
(a) Damage index I



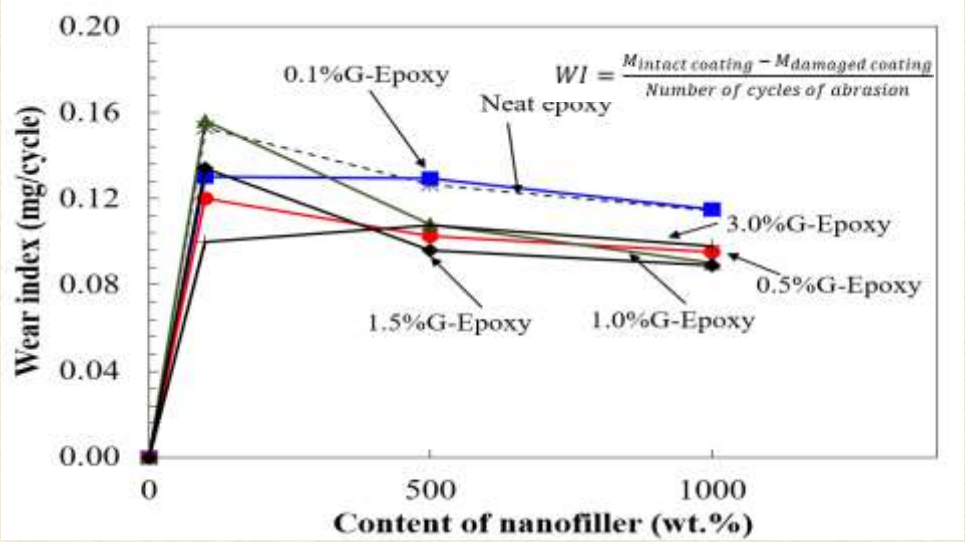
(b) Damage index II

3. Results and Discussion

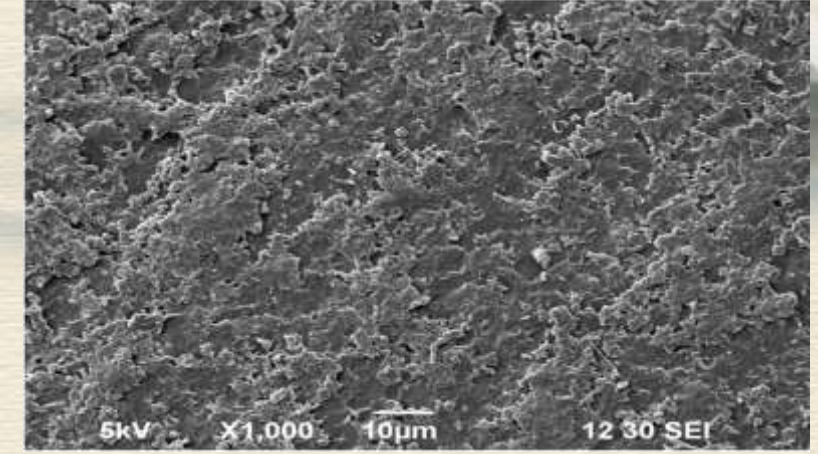
Abrasion resistance:

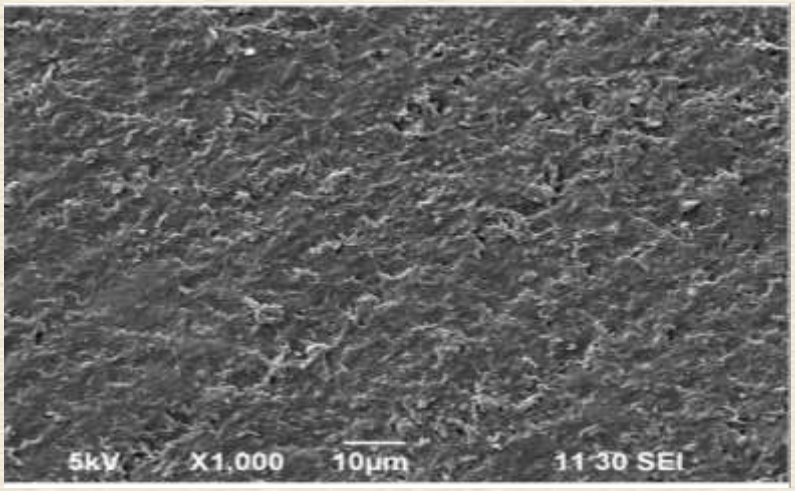


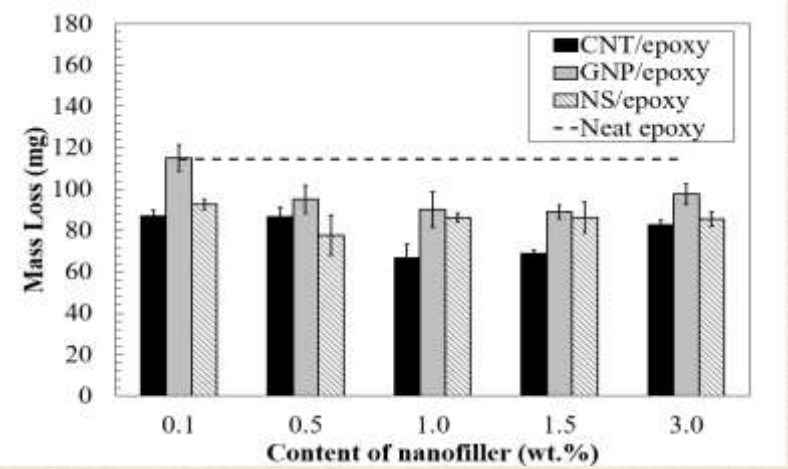
Mass loss of the test samples



Wear index of the test samples

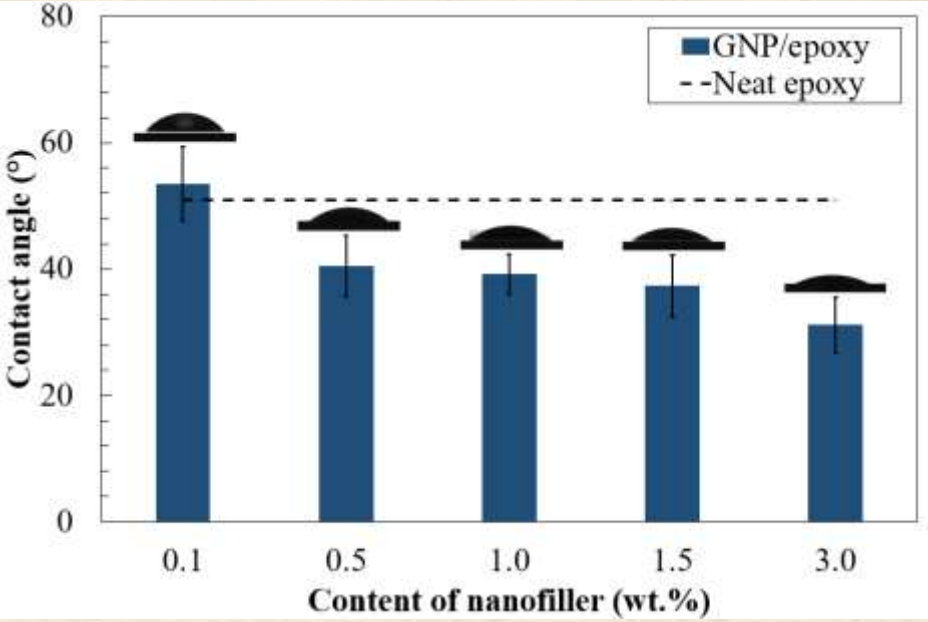


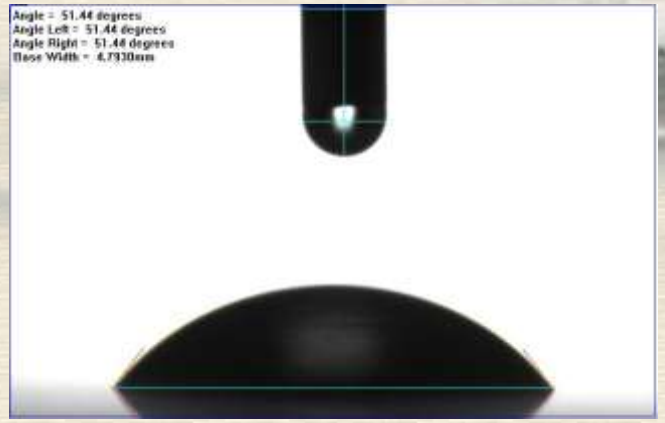


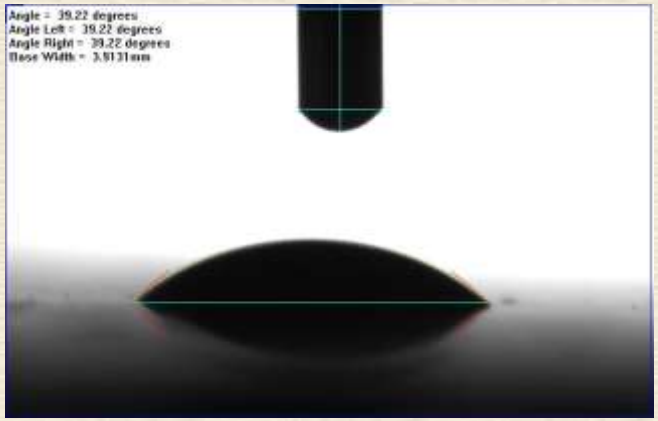


3. Results and Discussion

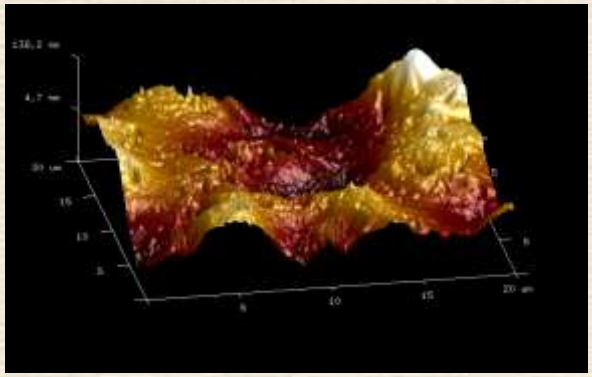
Contact angle:

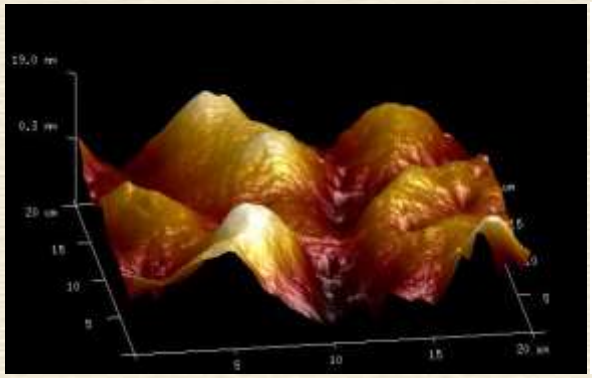


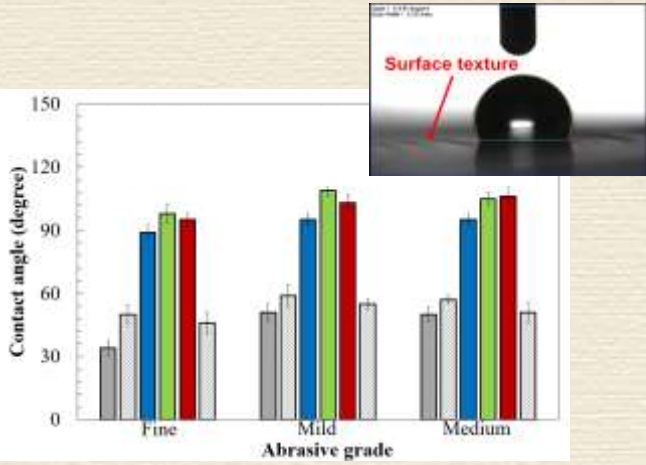




Water contact angle of the samples



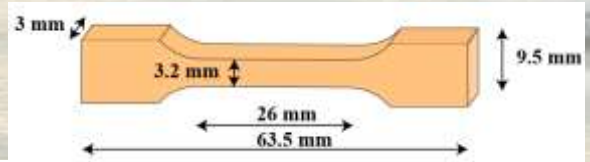


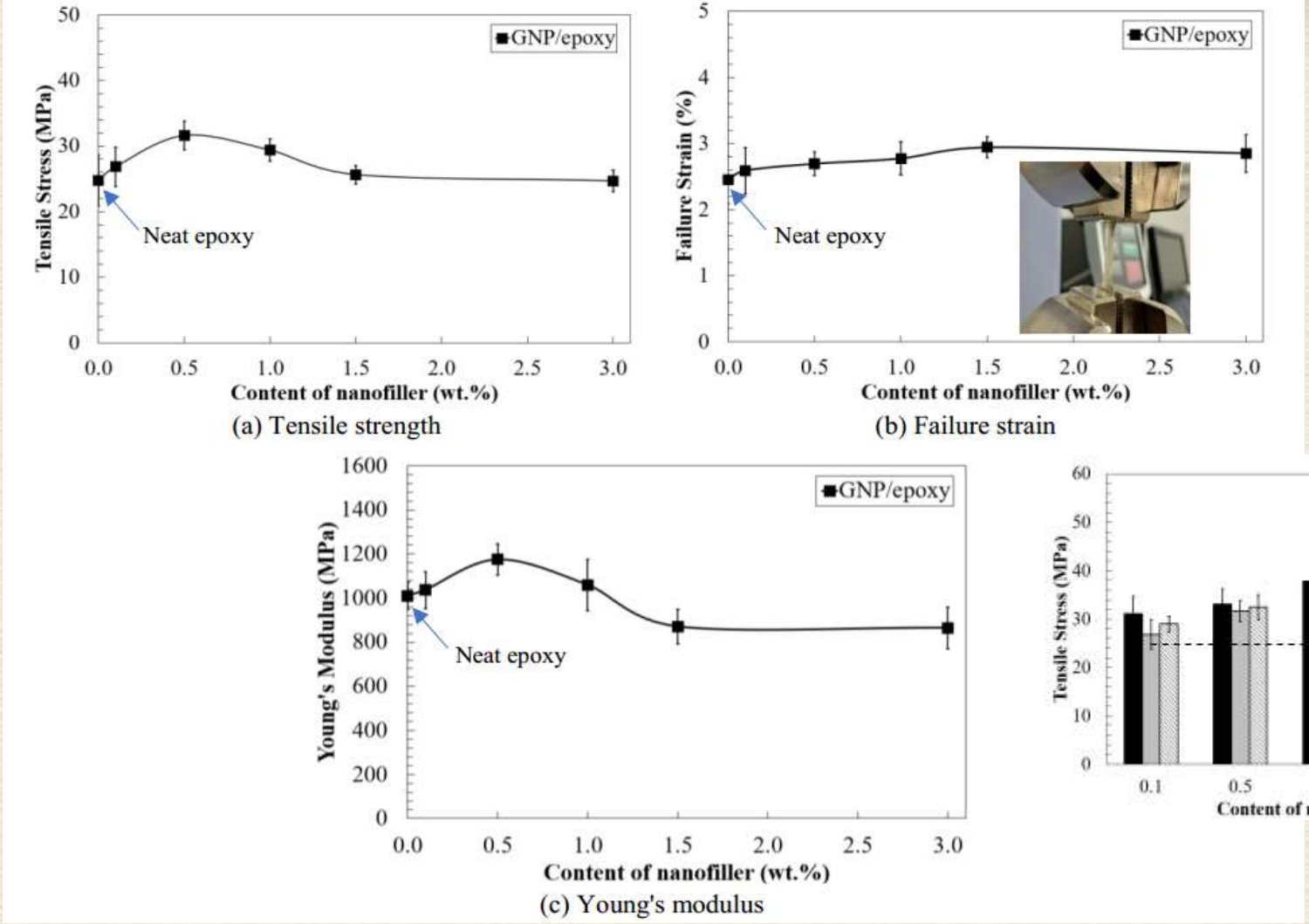


Reference Surfaced modified After abrasion

3. Results and Discussion

Mechanical Properties:





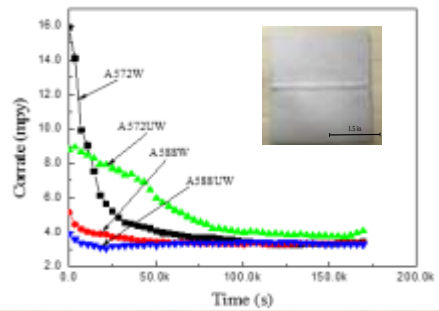
Tensile behavior of the dog-bone samples

4. Further Discussion

Framework of High-Performance System

Failure Mechanism

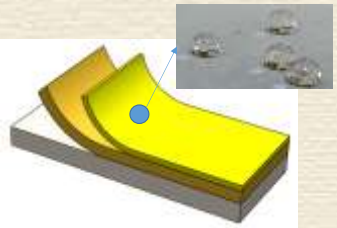
Soil, welds, metallic types



High performance underground structures

Mitigation and Protection

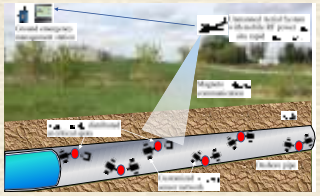
New coatings



Monitoring and Diagnosis

Wireless sensor networks

Rapid damage detection



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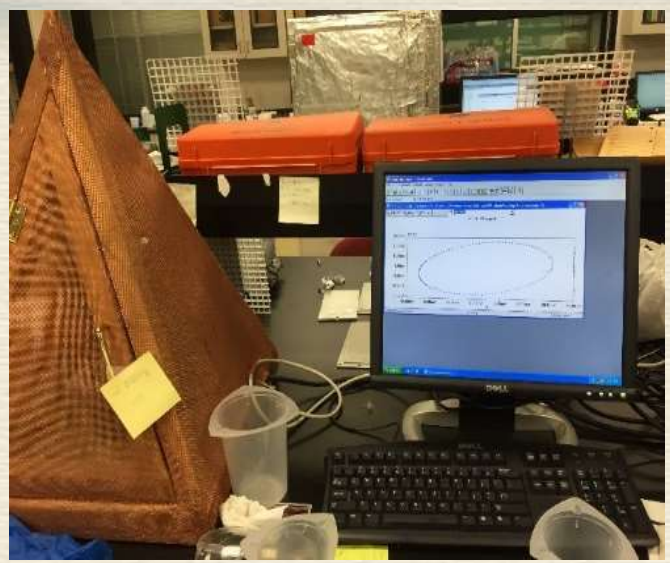
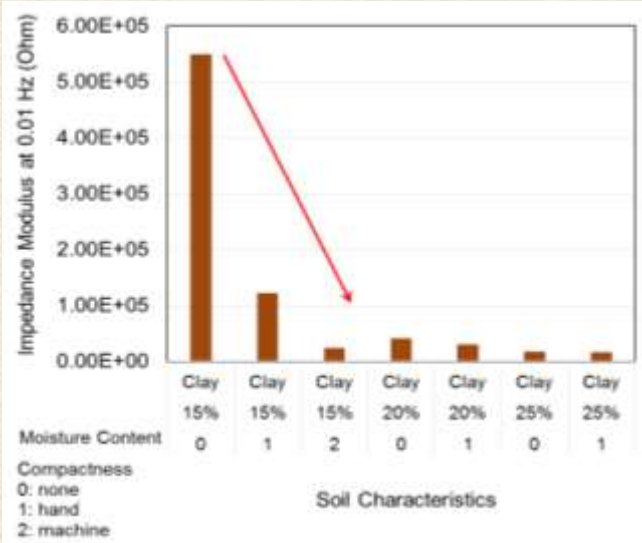
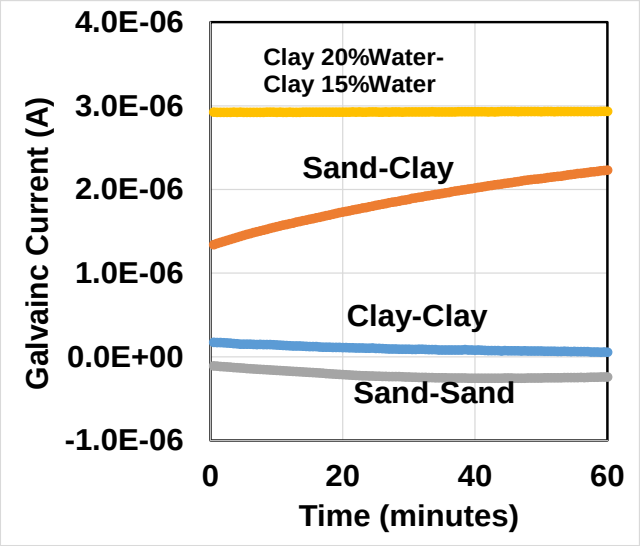
Framework of High-Performance System



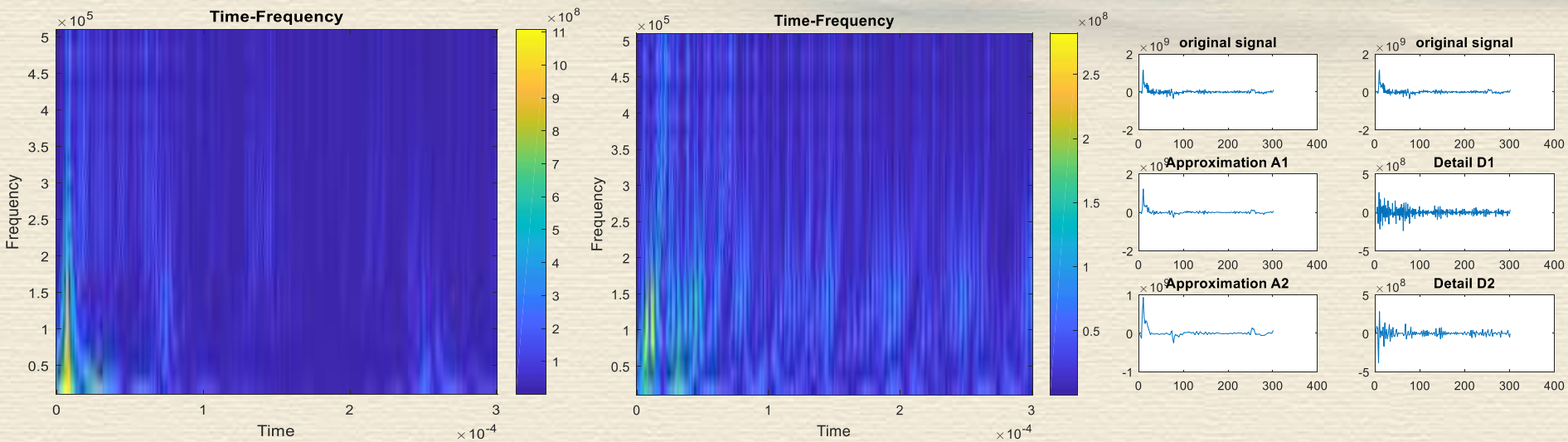
Photos from https://www.shawcor.com/media-center/4829644545/pipeline-coating-2017-in-vienna-austria-to-showcase-shawcor-technical-expertise



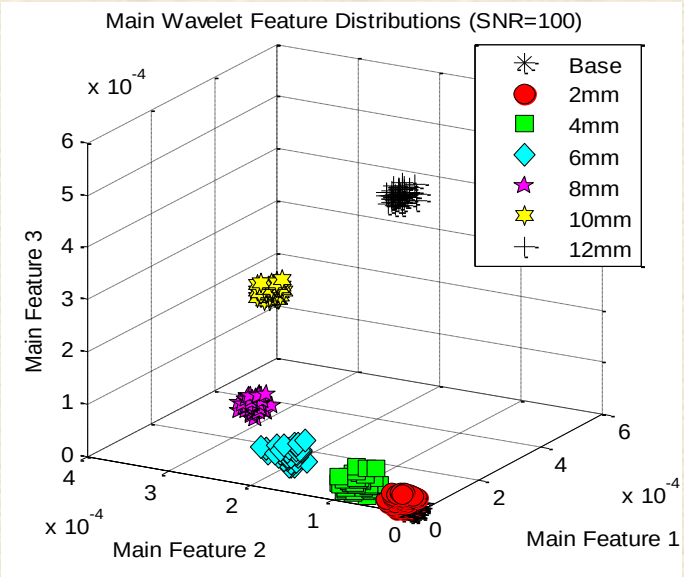


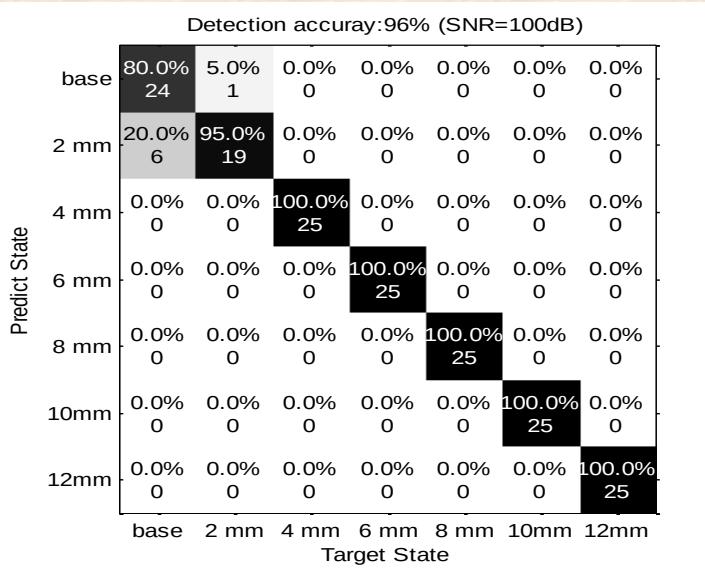
4. Further Discussion

Framework of High-Performance System



Signals in time-frequency or time domains





NDSU UAV System Lab

https://www.ndsu.edu/pubweb/~nagong/uav.html

Research, Industry, Outreach

Faculty Members

Na Gong

Assistant Professor

Jinhui Wang

Assistant Professor

Zhibin Lin

Assistant Professor

5. Summary

The inclusion of graphene in the polymeric coatings as potential for corrosion mitigation in the metallic structures, including oil and gas pipelines, and bridges.

The test results suggested the 0.5-1.0 wt. % of the graphene nanofiller led to the great improvements.

Great improvements in both mechanical and electrochemical properties for corrosion resistance for pipeline applications, while enhanced abrasion resistance and ductility also respond for the loading of the graphene particles.

Questions ?

Thank You!

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