In-Line Quality Control with Terahertz Scanners for High-throughput Production of Low Temperature Fuel Cells and Electrolyzer MEAs

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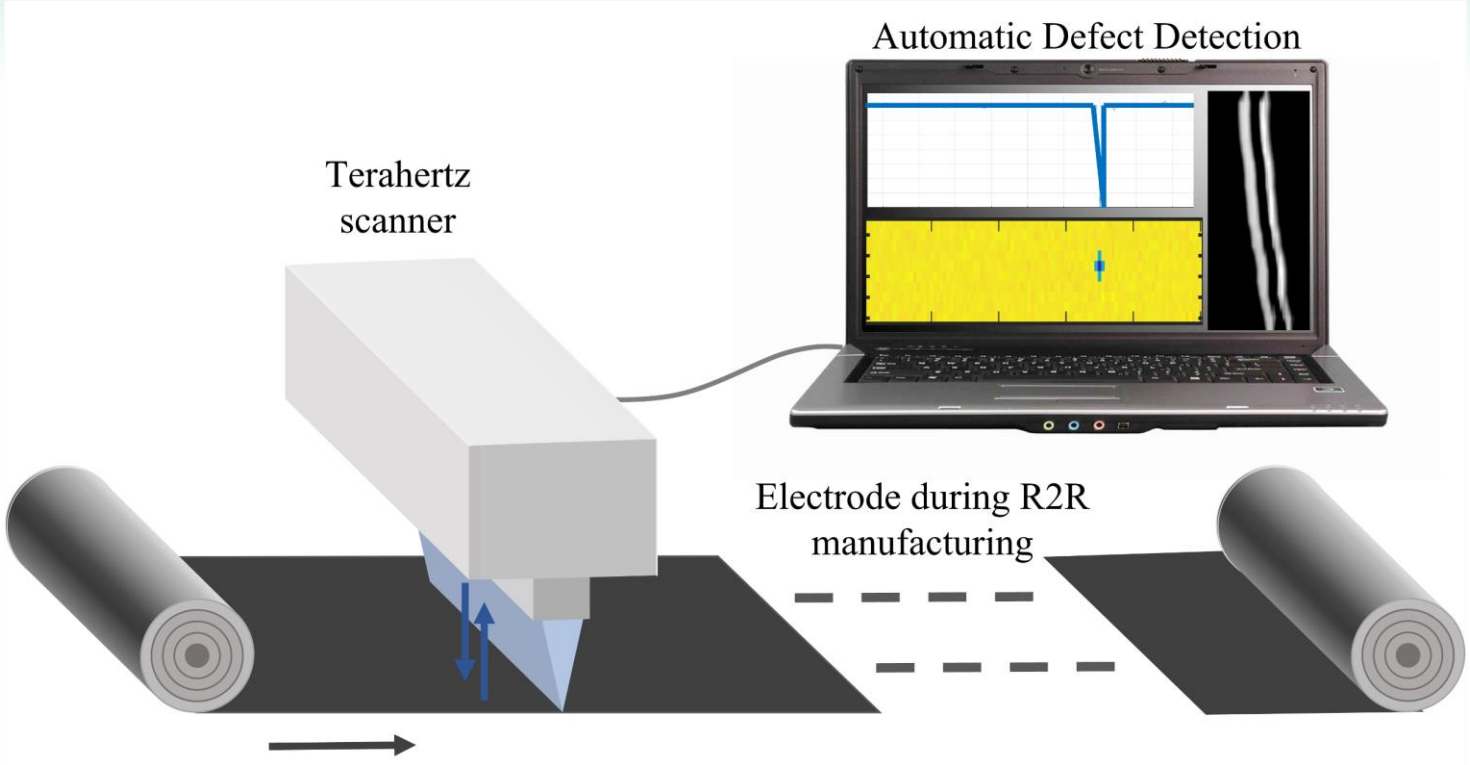
AMR Project ID #
MNF-BIL012

Project Goal

- Develop and assess a high-throughput terahertz scanner that can be used by manufacturers and researchers for in-line QC of PEM fuel cells and electrolyzers.



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Project Goal EXAMPLES

- Develop efficient and durable high-temperature water splitting (HTWS) systems for production of hydrogen at a cost less than \$2/kg H_2, using proton conducting ceramic electrolytic cell (PCEC) technology at a temperature ≥500ºC.
- Develop PGM-free catalyst membrane electrode assemblies (MEAs) by engineering the ionomer/catalyst interfaces in cathodes for increased catalyst utilization and power density.

Project Overview

DOE SBIR Phase I Project (DE-FOA-0002903)

Timeline and Budget

- Project Start Date: 08/06/2023
- Project End Date: 03/31/2024

Budget

- Total Project Budget: $200,000

Barriers

- Lack of multi-purpose in-line QC equipment for fuel cell manufacturing.
- Limitations in terahertz imaging/scanning technologies.

Partners

- National Renewable Energy Laboratory (NREL)

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NATIONAL RENEWABLE ENERGY LABORATORY

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Potential Impact

DOE's Hydrogen Program Plan identifies the importance of QC to drive fuel cell and electrolyzer cost reductions and help bring about DOE's H2@Scale vision.

In-line QC solutions are more critical than ever as manufacturers scale up the manufacturing process by transitioning the fuel cell manufacturing to high-volume R2R facilities.

Lookin's terahertz scanners for in-line QC of fuel cell and electrolyzer MEAs can help manufacturers reduce their fabrication costs by reducing the scrap rates of electrodes while providing the highest performance, safety, reliability, and product availability.

The data provided by the terahertz scanner is also very valuable for fuel cell manufacturers and researchers to optimize their manufacturing processes further and identify the nature of the defects and their effect on the fuel cell and electrolyzer performance.

These help to strengthen U.S. manufacturing and to reduce greenhouse gas emissions, which are other DOE goal.

Approach

Development of a laboratory prototype terahertz scanner	*Develop a laboratory prototype multi-pixel terahertz scanner and evaluate its SNR, field-of-view, and scan rate to assess the feasibility of the proposed high-performance QC system.*
Assessment of fuel cell and electrolyzer samples using the developed scanner	*Test different subsets of fuel cell and electrolyzer MEA samples manufactured at NREL to determine image spatial/depth resolution and penetration depth and assess the feasibility of the proposed high-performance QC system.* *Acquire images of healthy and defective fuel cell and electrolyzer MEA samples manufactured at NREL under different settings to characterize the trade-offs between different image acquisition parameters such as scan rate, resolution, and penetration depth.*
Development and evaluation of advanced data analysis algorithms for processing the captured image data from MEA structures	*Develop and evaluate data processing algorithms for analyzing the captured image data from MEA structures to prove that the proposed system will be able to cope with the challenges associated with big data.*

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Approach: Safety Planning and Culture

Our project is not required to submit a safety plan to the Hydrogen Safety Panel.

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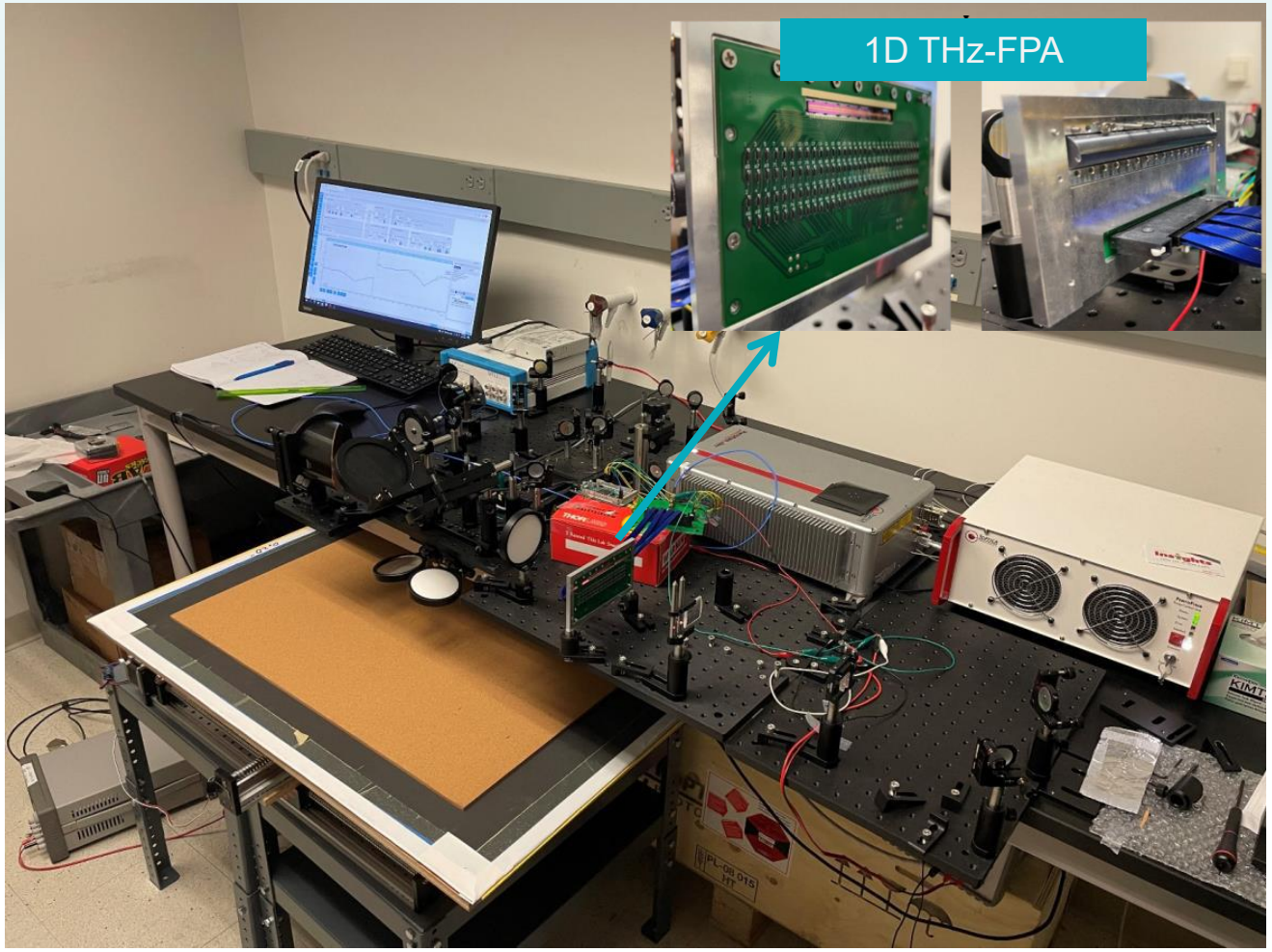
Accomplishments

Lookin developed a terahertz scanner prototype that offers high-throughput and high-sensitivity operation.



The terahertz scanner contains a one-dimensional, 64-pixel terahertz focal-plane array which offers the world's first multipixel terahertz time-domain imaging platform.

The field of view of the scanner is 5 cm x 1 mm.

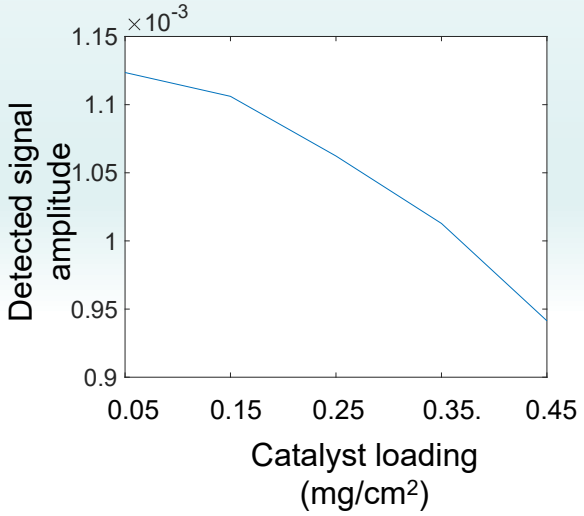
The scan rate is 10 Hz.

The system is designed to move the sample in one direction with a mechanical stage to mimic roll-to-roll manufacturing

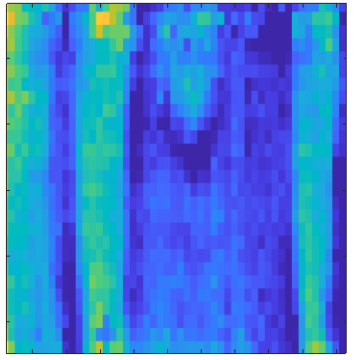
Accomplishments

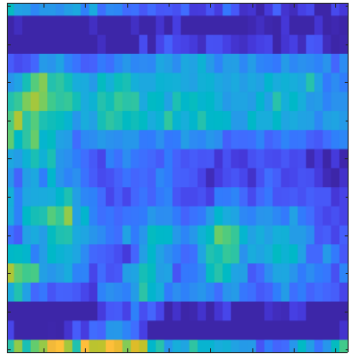
Lookin's terahertz technology was found to be a very useful instrument for non-contact determination of defects, such as load variations in catalysts, delamination at layer interfaces, pinholes on membrane or catalyst, thickness variations on membranes.

- *Lookin tested variety of healthy and defective fuel cell parts, from nafion membrane, to catalyst coated membranes (CCMs), gas diffusion electrodes (GDEs) to gas diffusion layers (GDLs), and full assemblies.*
- *We found that Lookin's scanners can be used to measure membrane thickness with micrometer-level accuracy.*
- *We found that Lookin's scanners can penetrate through catalyst and membrane layers to see any lamination problems on GDEs and CCMs.*
- *We found that Lookin's scanners can be very useful for non-contact point-by-point load determination of catalyst layers.*



Terahertz images of GDEs with catalyst layers having varying load:





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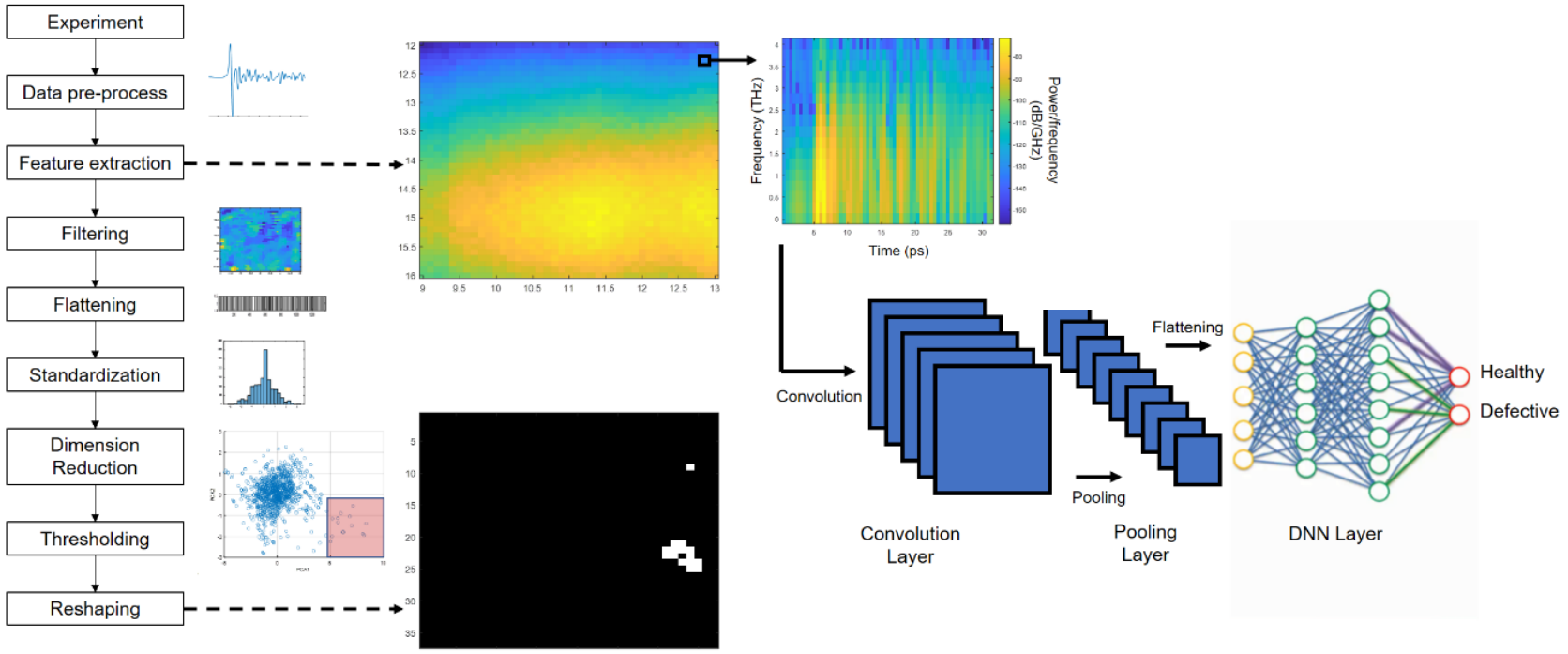
Accomplishments

Lookin continues working on the big data acquired from the measurements.

Lookin is developing an innovative data analysis framework based on deep learning that can push the resolution and sensitivity levels of terahertz imaging.



Accomplishments

The project was awarded in August 2023, and was not reviewed last year.

Collaboration and Coordination

In this DOE-funded SBIR Phase I project, Lookin works with NREL.

NREL group prepares healthy and defective fuel cell and electrolyzer samples and characterize them with other QC techniques.

Lookin and NREL PIs have regular meetings to discuss the progress in the project and future steps.

NREL researchers also visited Lookin's site to offer further support in the development of the product.

NREL
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Proposed Future Work

Lookin's investigation on electrolyzer MEAs showed that terahertz waves cannot pass through the materials used for electrolyzers. However, the team also found the effect of some defects can be seen from the surface profile of MEAs.

Lookin worked on various machine-learning algorithms and applied on the measurement results fuel cell samples. The team faced overfitting problems in early measurements. However, the team found solutions after taking more measurements on more samples under different conditions.

Lookin's technology is evaluated in the laboratory environment. The challenges in real-world conditions should be evaluated carefully.

Proposed Future Work

Lookin continues working on electrolyzer MEAs. By using the terahertz scanner, the team captures the surface topology of MEAs to detect any defect reflected on the surface.

Lookin continues working on the development of data analysis algorithm. Lookin acquired enough data from healthy and defective samples to train and test the measurement results for automatic defect detection.

Lookin's technology is evaluated in the laboratory environment. Lookin will work on field studies in future programs.

Summary

In a DOE-funded SBIR Phase I Program, Lookin, in collaboration with NREL, develops a high-throughput and high-sensitivity terahertz scanner to use for in-line QC of fuel cell and electrolyzer MEAs.

Lookin developed a laboratory prototype of the terahertz scanner, tested various fuel cell parts and assemblies, and developed a data analysis algorithm to detect defects on membranes, CCMs, and GDEs.

Lookin pursues opportunities to evaluate terahertz scanner in field.