2019 Planning Meeting

MATERIALS DATA SCIENCE
MDS RELY

Research Poster Presentations

September 11-12, 2019
Tinkham Veale University Center
Case Western Reserve University

Case Western Reserve University · NSF · University of Pittsburgh

MDS-Rely Posters

1. Wide Reach Classification
2. Passivating Metal Oxides for Improved Lifetime Performance
3. Comparative Connector Degradation Analysis of Al-BSF and Monofacial PERC Modules in Modified Damp Heat Exposure
4. IconIntent: Automatic Identification of Sensitive UI Widgets based on Icon Classification for Android Apps
5. Maintenance Optimization
6. PV Packaging Material Degradation under Damp Heat Exposure
7. Evaluation of Solar Plant Performance Loss Rate Calculation Methods
8. Studying Structural Dynamics Down to the Atomic Scale in Reactive Environments
9. Electroluminescence and Current-Voltage Correlation for Mechanistic and Electrical behavior of Photovoltaic Module using Computer Vision and Machine Learning Methods
10. Image Processing on Crystallization Growth of Rotating and Levitated Alloys
11. Printing of High Performance Microgrid for High Efficiency, Flexible Organic Light Emitting Diode
12. Network Modeling Applied to PV Systems
13. Assignment of Climate Zones for outdoor weatherability and degradation testing use 'kgc' R package
14. Bio Inspired, Mechanically Durable, Self-Healing, Anti Icing and Transparent Encapsulation Coatings
15. Real-world PV Module Degradation across Climate Zones Determined from Suns-Voc , Loss Factors and I-V Steps Analysis of Eight Years of Time-series Pmp , I-V Datastreams
16. Structural Equation Modeling (SEM) for Lifetime and Degradation Science (L&DS) using netSEM
17. Multi-Functional Optoelectronic Substrates
18. Mechanical Reliability of Metallic AM Parts
19. Advanced Manufacturing and Mechanical Reliability Center (AMMRC)
20. Fatigue and Fracture of Wires and Cables Used in Biomedical Applications
21. Understanding Kinetics of Carbon Transport across Length-Scales at Diamond-Transition Metal Interfaces

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RESEARCH PROJECT

Wide Reach Classification

Prof. Vincenzo Liberatore and Yiming Chen

Case Western Reserve University, Computer and Data Science

September 11, 2019

DEFINITION

Classification:

Machine Learning paradigm

Identify whether a new observation is positive or negative on the basis of a training set

Example: test a component and predict whether it will last *x* years

Performance metrics

Reach: number of true positives predicted as positives

Precision: true positives / predicted positives

Wide Reach Classification:

maximize reach

subject to precision large enough

PROJECT OBJECTIVES

Potential Applications

Choose machine components, as many as possible and almost certainly reliable

Search engine optimization (provide as many links as possible as long as almost all of them are useful) [2]

Project Objectives

Design, evaluate, and refine optimal and approximation algorithms for wide reach classification

Prove lower bounds and trade-offs (e.g., run-time vs approximation ratio)

Deliverables

Software implementation and documentation

RESEARCH METHODOLOGY

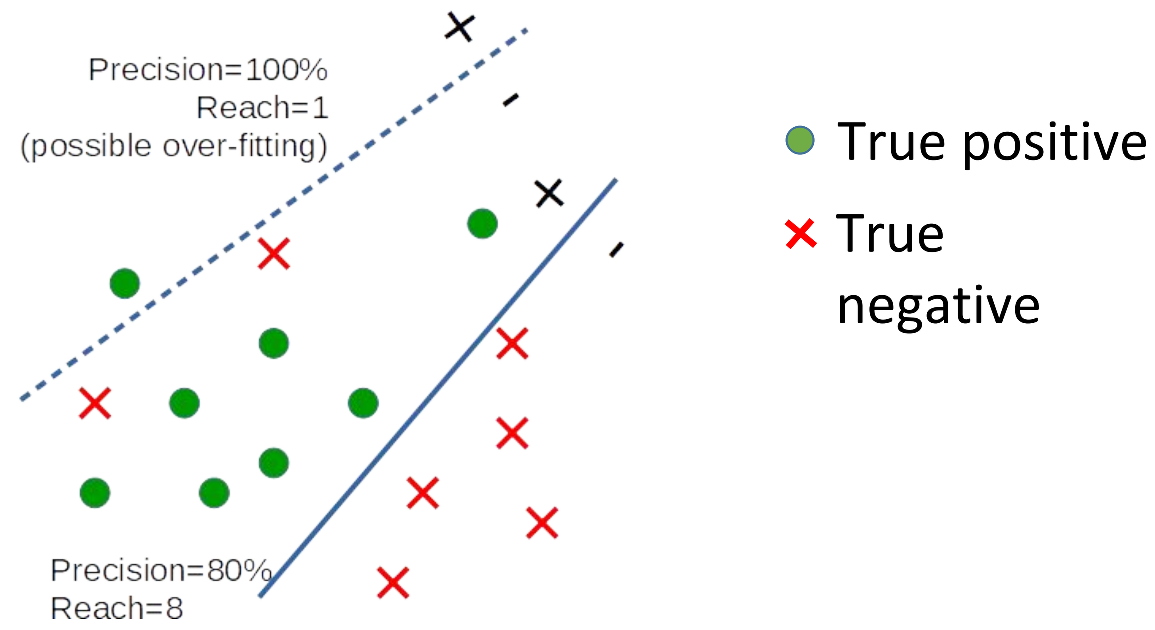
Previous Work

Known classifiers approach reach and precision indirectly. For example, SVM attempts to maximize geometric distance rather than reach [3]

Previous work attempted to learn which classifier works best [2]

Current Approach [1]

Formulate wide reach classification as an optimization problem and solve exactly or approximately



Currently Under Investigation

Formulation	Short description	Expected benefits	Potential drawbacks
ILP	Integer Linear Program	Optimal	Slow on high-dimensional data
Geometric	Computational Geometry Algorithms	Fast	Approximate solution Possibly complicated
QCQP, SDP	Quadratic and semi-definite programming	Fast, simple	Possibly low solution quality

PROJECT ORGANIZATION

Agile

Specification and data from, frequent meetings with project owner (for example, end-user)

Iterative approach, short cycles

Continuous delivery of research and software

Track record at CWRU

Estimated duration

6-36 months

References

[1] Y. Chen. Wide Reach Classification, M.S. Thesis, Case Western Reserve University, in progress.

[2] P. N. Bennett *et al*. Algorithms for Active Classified Selection: Maximizing Recall with Precision Constraints, *WSDM* 2017.

[3] C. Cortes *et al*. Support-vector networks, *Machine Learning*, **20**(3):273-297.

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RESEARCH PROJECT

Passivating Metal Oxides for Improved Lifetime Performance

Ina T. Martin, Roger H. French

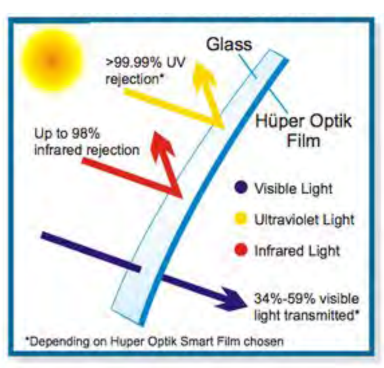
Case Western Reserve University, Department of Materials Science and Engineering

September 11, 2019

PROJECT DESCRIPTION

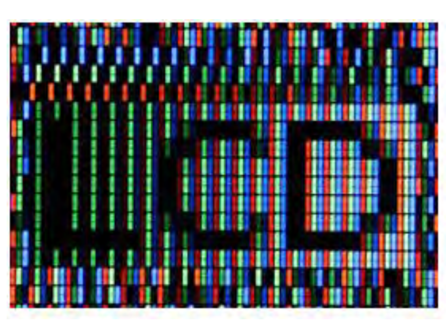
- Goals / objectives: demonstrate surface stabilization of metal-oxides via inexpensive, scalable chemical modification
- Relevance to industry: combining surface modification & accelerated aging to test new materials combinations
- Deliverables: improve lifetime by 4x

Smart windows



http://www.efficiencyfirst.org

LCDs

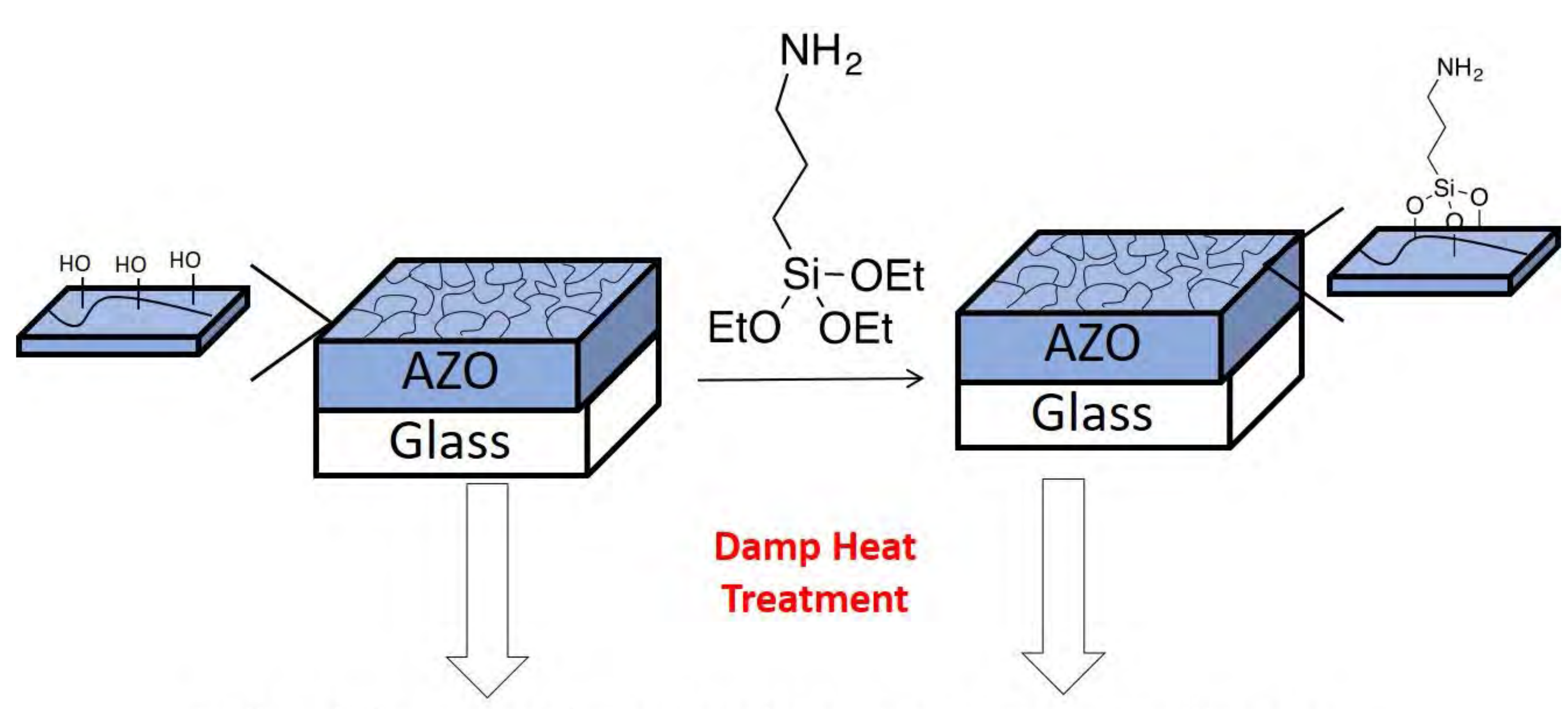


https://www.elprocus.com

LEDs

http://www.edisontechcenter.org/LED.html

Research Methodology



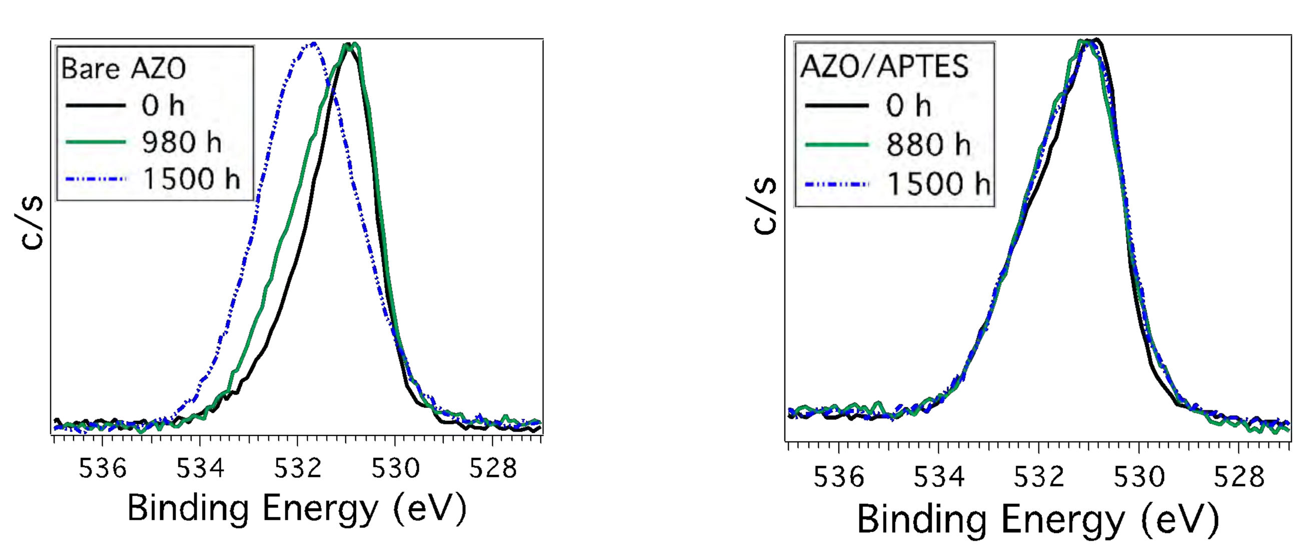
Hall mobility, resistivity, carrier density, transmission, yellowness, haze, surface roughness, and elemental composition

R. Matthews; E. Glasser; S. C. Sprawls; R. H. French; T. J. Peshek; E. Pentzer; I. T. Martin "Organofunctional silanes for stabilization of aluminum-doped zinc oxide surfaces" *ACS Appl. Mater. Interfaces*, **9** (2017) 17620-17628.

H. M. Merlitz; K. A. Peterson; I. T. Martin; R. H. French; "Degradation of Transparent Conductive Oxides: Interfacial Engineering and Mechanistic Insights" *Sol. Energ. Mat. Sol. C*, **143** (2015) 529-538.

PROJECT DESCRIPTION

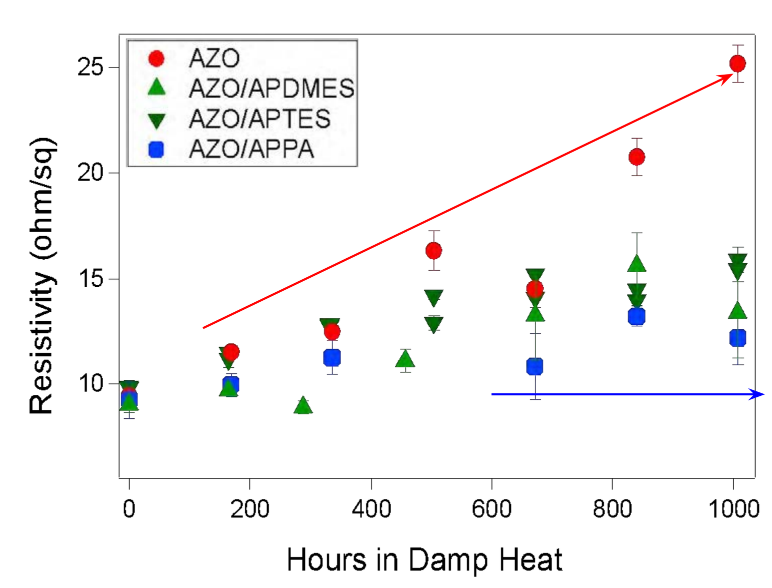
Nanometer coatings impart bulk stability

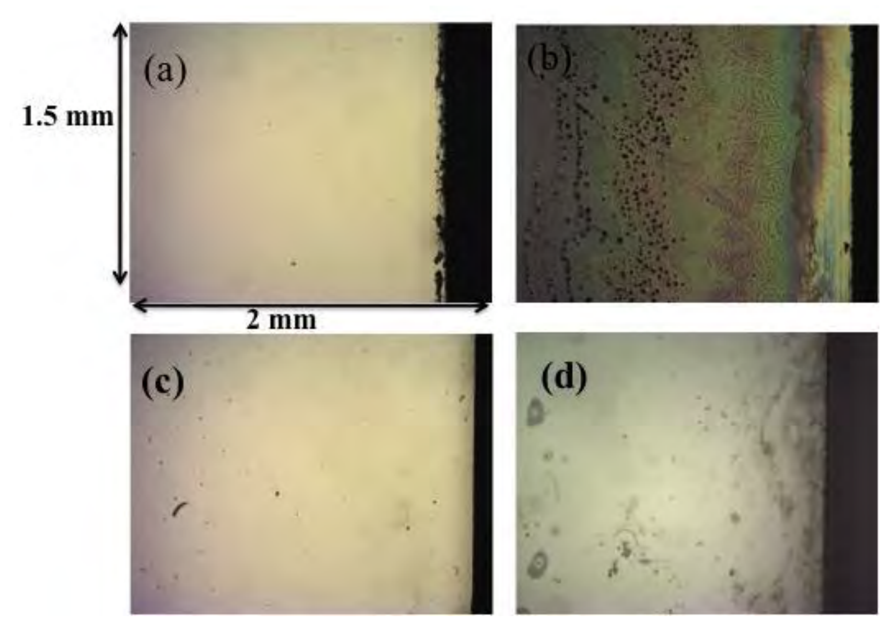


X-ray photoelectron spectroscopy spectra (~10 nm of material surface)

- O 1s envelope broadens and shifts to a higher binding energy w DH exposure
- @1500, cannot be fit with the method established for AZO
- Decrease in intensity at lower binding energy values is consistent with loss of components attributed to wurtzite structure
- AZO/APTES: O 1s is stable up to 1500 h DH exposure

PROJECT DESCRIPTION



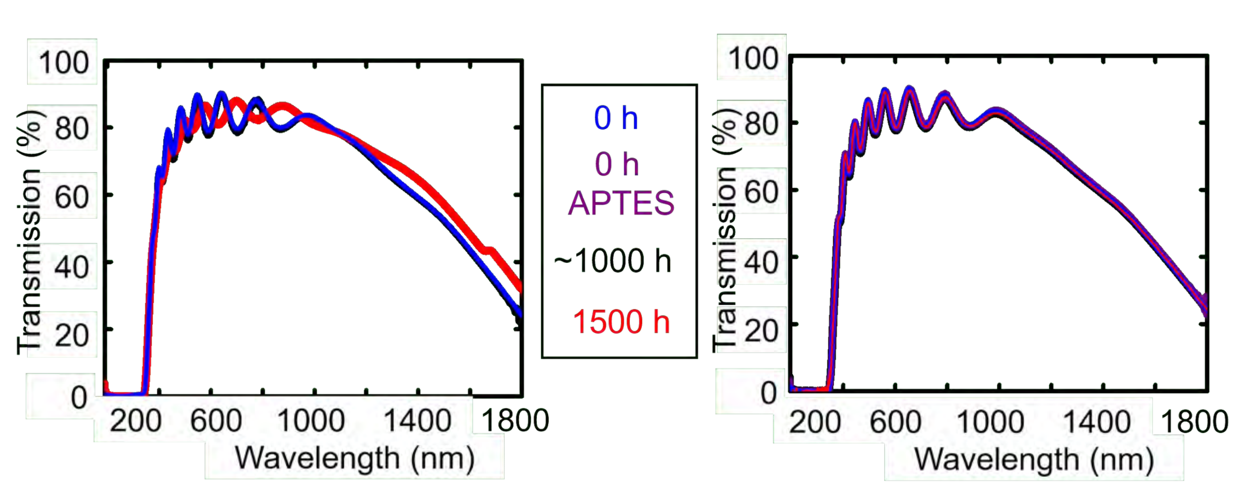


- 1-5 nm of covalently bound modifers mitigate damp-heat induced degradation of the electrical properties of AZO

PROJECT MILESTONES

Transmittance of UV, Visible, and IR regions

Bare AZO AZO/APTES



Major research activities	Q1	Q2	Q3	Q4
Task 1.1: Accelerated and outdoor exposure of replicate samples				
Task 1.2: Periodic removal and sample characterization				
Task 1.3: Data analysis and correlations				
Task 1.4: Evaluation of methods, alteration as needed				

LEVERAGED TECHNOLOGIES

Instrumentation:

- Accelerated aging: CSZ ZPH8 environmental chamber
- Characterization tools from the centers listed below
- **Robust and material agnostic**

CWRU core facilities and research centers

- The SDLE Research Center (Ohio Third Frontier, Wright Project Program Award tech award 12-004)
- The Materials for Opto/electronics Research and Education (MORE) Center (Ohio Third Frontier grant TECH 09-021)
- The Swagelok Center for Surface Analysis of Materials (SCSAM) through the CWRU School of Engineering

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RESEARCH PROJECT

Comparative Connector Degradation Analysis of Al-BSF and Monofacial PERC Modules in Modified Damp Heat Exposure

Carolina M. Whitaker, Alan J. Curran, Jennifer L. Braid, Roger H. French

Case Western Reserve University, Department of Materials Science & Engineering

Introduction

Background

- With the ability to turn solar power to electrical energy, photovoltaic (PV) modules are a crucial tool in the field of renewable energy. However, due to constant exposure to outdoor conditions, PV modules will degrade. Multiple types of solar modules have been constructed in hopes of finding the highest performing cells even after extreme degradation.

Objectives

There are multiple objectives in this study:

- Understand how connector replacement affects power output
- Identify how cell type relates to power recovery through connector replacement
- Plan future focus based on a preliminary round of degradation

Experimental Procedures

Accelerated Degradation

- 19 modules are put through modified damp heat

1. Perform accelerated degradation
2. Take IV curves and attain measurements
3. Replace old connectors on all modules
4. Take IV Curves and attain measurements
5. Analyze data using R

Conclusion & Future Outlook

Conclusion

- At full module level, PERC Gen1 cells with a KPX backsheet performed best with a power % diff of **9.96** and a R_S % diff of **-22.39**
- At single cell level, Al-BSF cells with a PPF (295B) backsheet performed best with a power % diff **14.36** and an R_S % diff of **-13.96**
- Backsheet or cell type weren't expected to make a significant impact

Future Plans

- Repeat the accelerated degradation step for a total of 3500 hours, each with connector replacements
- Find ways to prevent connector corrosion
- Continue to see if there is still a difference between the performance based on backsheet or cell type

Dataset Description: Mini Modules

General Description

- Each mini module is made up four individual cells
- Cells are connected in series with one another
- Cells have connectors which carry the energy produced

Figure 1. Male (left) vs. Female (right) connectors

Cell Type

- Aluminum Back Surface Field (Al-BSF) cells are standard in the solar industry
- Passive Emitter and Rear Contact (PERC) cells have a more stable back surface
- 3 unique polymer backsheets: *KPF, KPX,* and *PPF (295B)*

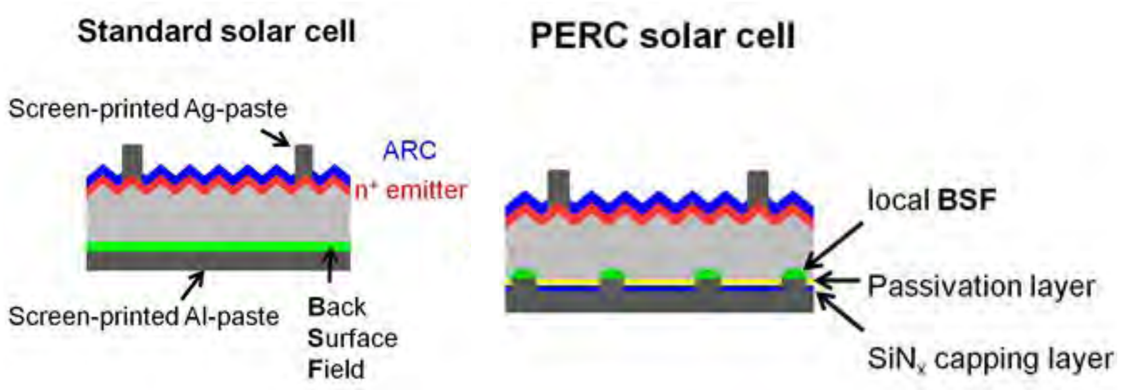
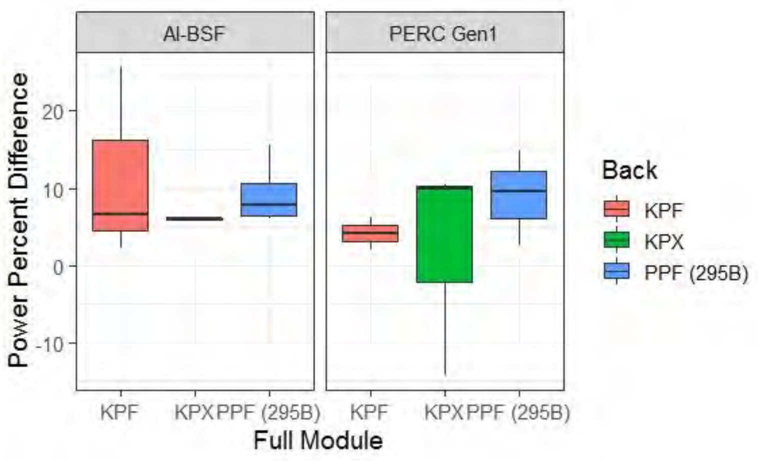
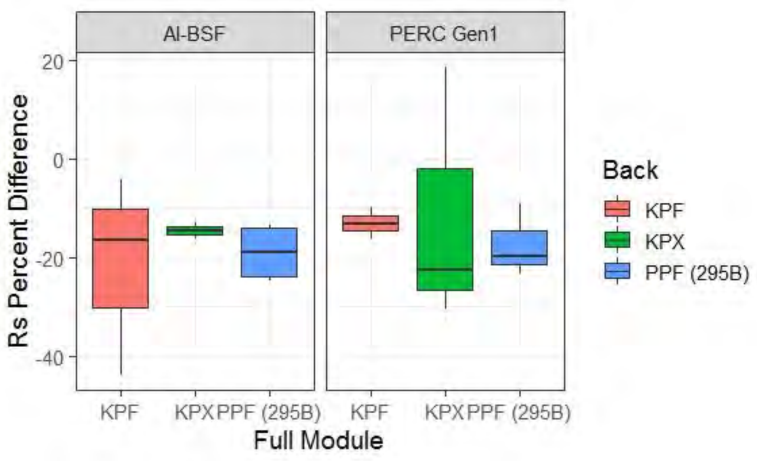


Figure 2. Al-BSF cell (left) vs. PERC cell (right)

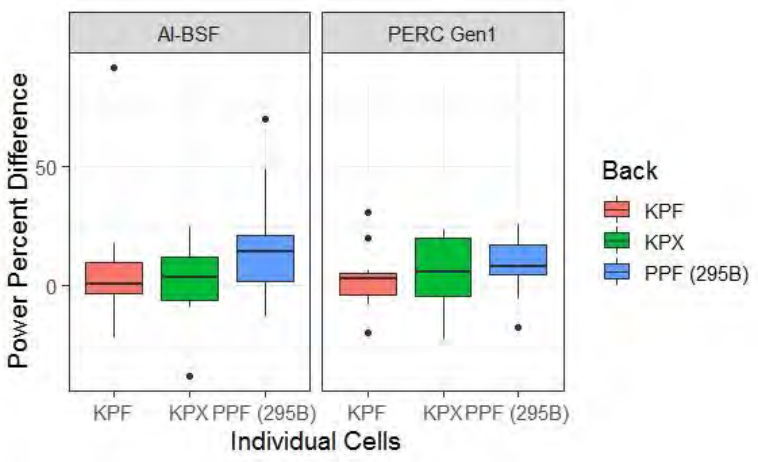
Preliminary Results



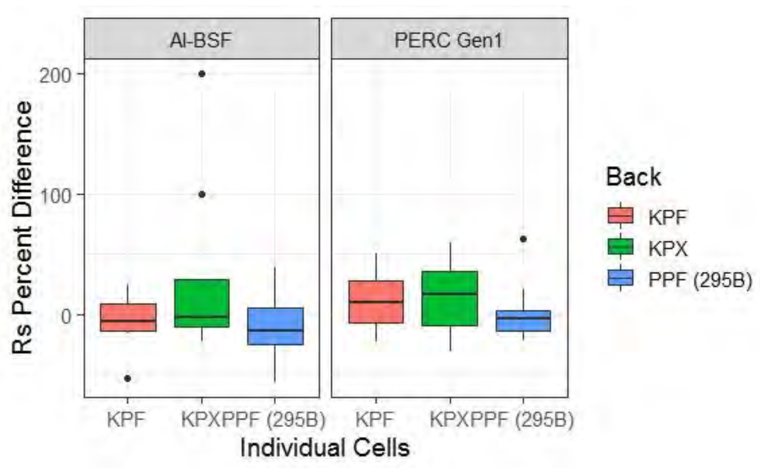
Graph 1. *P_{MP} percent difference of full module*



Graph 2. *R_s percent difference of full module*



Graph 3. *P_{MP} percent difference of individual cells*



Graph 4. *R_s percent difference of individual cells*

Acknowledgements & References

Acknowledgements

- The authors would like to thank the SDLE lab, the Case Alumni Association, and Case Western's SOURCE program for funding the project.

References

- Xuan Ma, et al., "Data-driven I-V feature extraction for photovoltaic modules," IEEE Journal of Photovoltaics

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RESEARCH PROJECT

IconIntent: Automatic Identification of Sensitive UI Widgets based on Icon Classification for Android Apps

Xusheng Xiao, Hanlin Wang

Case Western Reserve University, CDS Department

09/11/2019

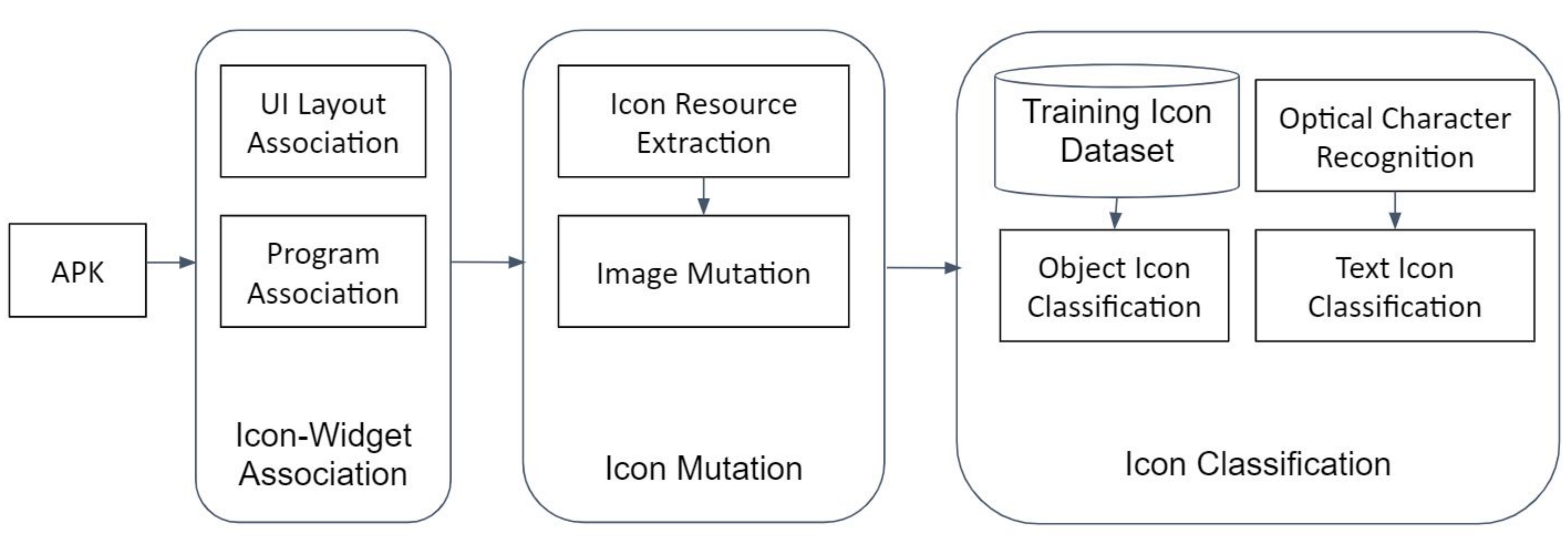
Introduction

Smartphone and mobile applications (apps) are playing a significant role in real life. Apps access users' data to provide customized services, but some apps may be aggressive in using users' data, even cause harms to users.

Prior work focuses on analyzing apps' code to detect data beaches and cannot analyze GUIs to detect privacy issues.

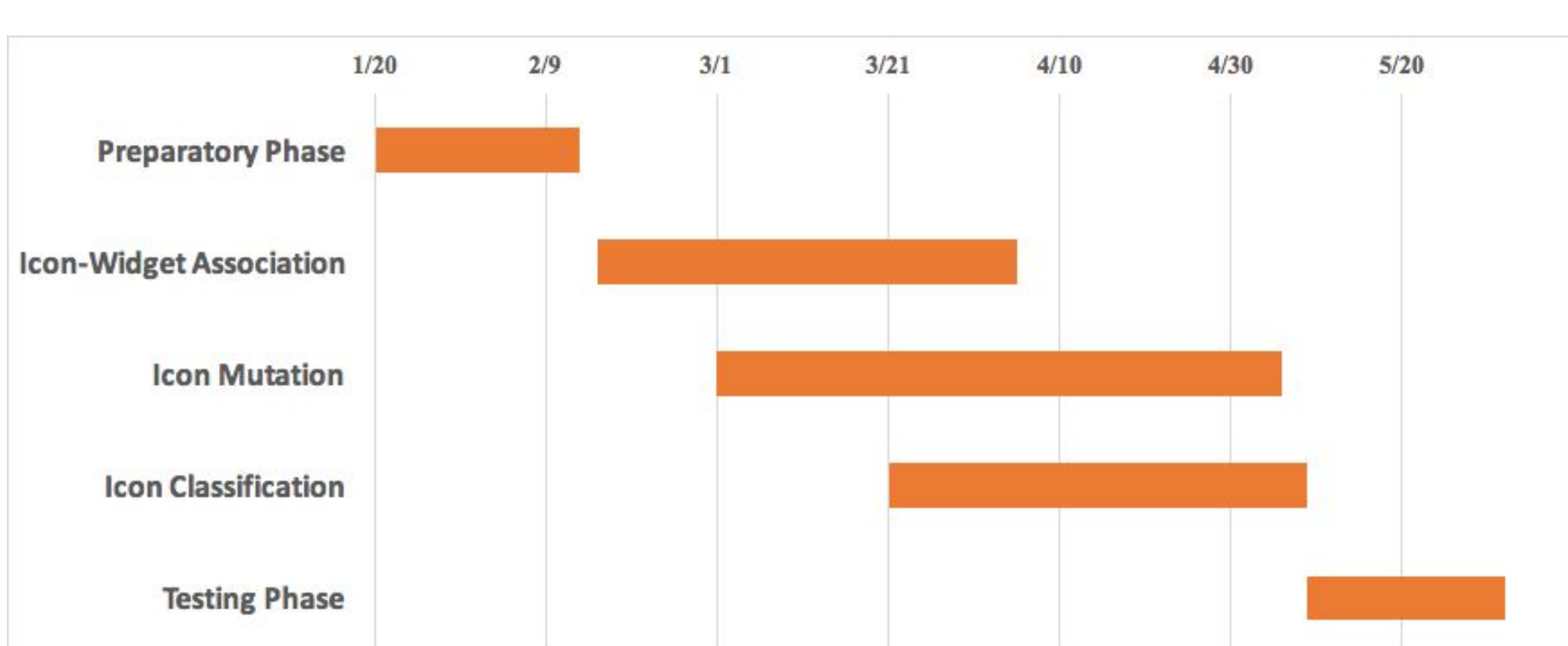
Therefore, we propose a novel app analysis framework to identify sensitive UI widgets in Android apps.

Methodologies



IconIntent leverages the synergy of computer vision and program analysis techniques to classify icons used by UI widgets.

Project Milestones



Methodologies

IconIntent consist with 3 modules:

- ***Icon-Widget Association:*** get information about which UI widgets are associated with a given icon.
- ***Icon Mutation:*** produce a set of mutated icons for each of the extracted icon.
- ***Icon Classification:*** classify two types of icons (object icons/text icons) into sensitive categories.

Methodologies

Object Icon Classification: **IconIntent** leverages object recognition to classify object icons based on a training icon set labeled with sensitive user-input category.

***Text Icon Classification*:** **IconIntent** analyzes the embedded texts of the icons to determine whether the texts are similar to keywords in the sensitive user-input categories.

Leveraged Technologies

Scale-Invariant-Feature-Transform (SIFT): a technique for object recognition on images.
Optical-Character-Recognition (OCR): a technique for text recognition on images.
SUPOR: a sensitive UI widget identification technique based on text analysis.

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Maintenance Optimization

Shadi Sanoubar, Lisa M. Maillart, Oleg A. Prokopyev

University of Pittsburgh, Department of Industrial Engineering

9/11/2019

PROJECT DESCRIPTION

The New York Times

SundayReview | OPINION

Let's Get Excited About Maintenance!

By ANDREW RUSSELL and LEE VINSEL JULY 22, 2017

It's been a bad summer for maintenance, especially in New York. Last month Gov. Andrew Cuomo declared a state of emergency for the Metropolitan Transportation Authority, underscoring a problem that New York subway riders understand

DATA SOURCES

- Failure Data
- Machine Health Parameters
- Cost Data
- Expert Knowledge

DETERIORATION MODELS

- Weibull Analysis
- Renewal Theory
- Markov Chain
- Gamma Process
- Brownian Motion

OPTIMIZATION CRITERIA

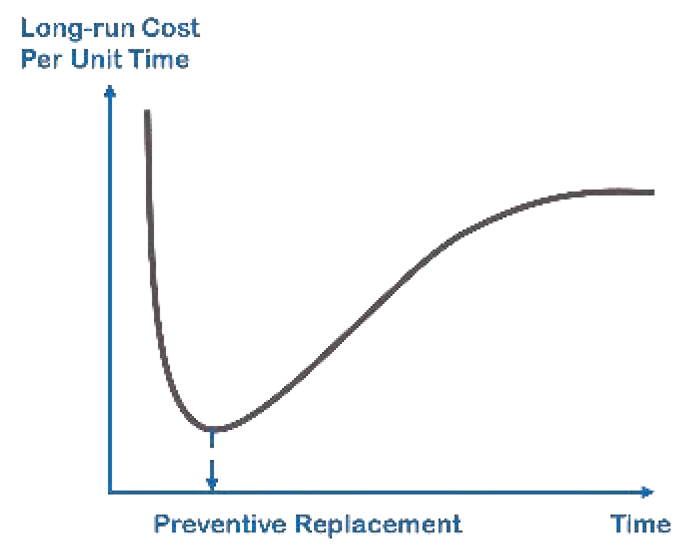
- Maintenance Costs
- Availability
- Reliability
- Inventory of Spare Parts
- Staff Scheduling and Routing
- Environmental Impacts
- Safety/Risk

Maintenance Optimization

METHODOLOGY

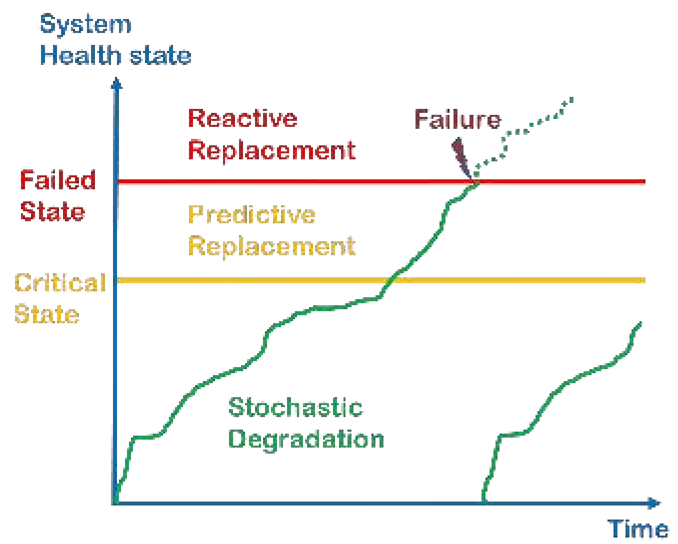
- Data Science
- Mixed Integer Optimization
- Global Optimization
- Multi-Objective Optimization
- Markov Decision Processes
- Dynamic Programming
- Simulation and Simulation Optimization

MAINTENANCE POLICIES



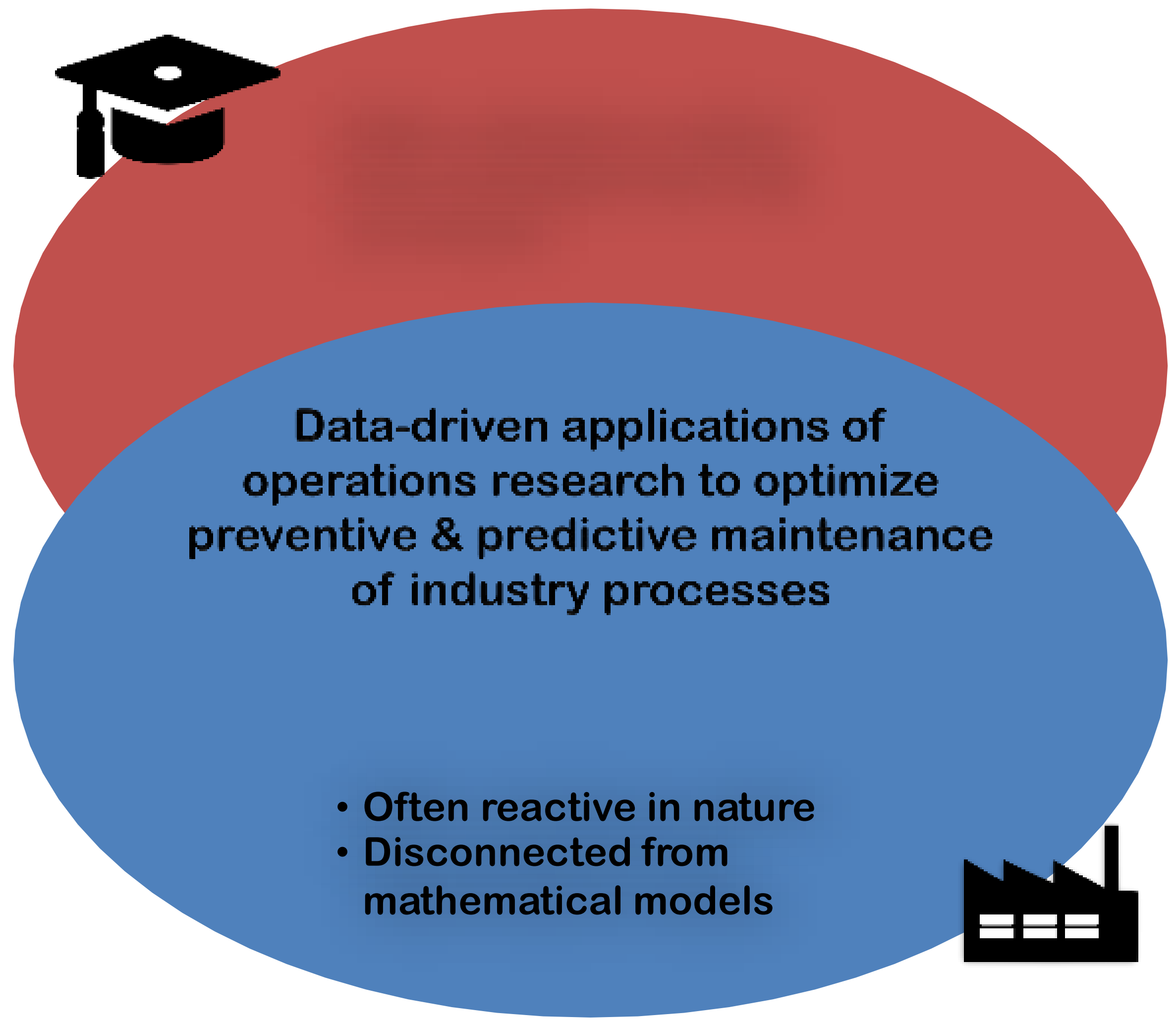
- Uses time to failure (TTF) data and statistical methods
- Low upfront costs

CONDITION-BASED MAINTENANCE



- Monitors parameters that track equipment condition (e.g., vibration, sound, heat)
- Continuous vs. periodic monitoring
- Relies on real-time sensor measurements
- Higher upfront costs

BRIDGING THE ACADEMIA-INDUSTRY GAP



SELECTED PREVIOUS WORK

- *Abdul-Malak, Kharoufeh & Maillart* (2019), Maintaining Systems with Heterogeneous Spare Parts
- *He, Maillart & Prokopyev* (2019), Optimal Sequencing of Heterogeneous, Non-Instantaneous Interventions
- *He, Maillart & Prokopyev* (2017), Optimal Planning of Unpunctual Preventive Maintenance
- *van Oosterom, Maillart & Kharoufeh* (2017), Optimal Maintenance Policies for a Safety-Critical System and Its Deteriorating Sensor
- *He, Maillart & Prokopyev* (2015), Scheduling Preventive Maintenance as a Function of an Imperfect Inspection Interval
- *Icten, Shechter, Maillart & Nagarajan* (2013), Optimal Management of a Limited Number of Replacements Under Markovian Deterioration
- *Batun & Maillart* (2012), Reassessing Tradeoffs Inherent to Simultaneous Maintenance and Production Planning
- *Ulukus, Kharoufeh & Maillart* (2012), Optimal Replacement Policies under Environment-Driven Degradation
- *Elwany, Gebraeel & Maillart* (2012), Structured Replacement Policies for Components with Complex Degradation Processes and Dedicated Sensors

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RESEARCH PROJECT

PV Packaging Material Degradation under Damp Heat Exposure

Menghong Wang, Muhammad Syaheen Sazally, Roger H. French

SDLE Research Center, Case Western Reserve University, Cleveland, Ohio 44106

Sept 11-12, 2019

PROJECT DESCRIPTION

PV packaging materials are crucial for the reliability of PV modules

- Provide insulation and mechanical support
- Also subjected to degradation
- Find out optimal packaging strategy
- Extend lifetime of PV module

Environmental stressors

- UV
- Humidity
- High T

Choice of materials

- Permeation properties
- Other synergistic effect

Change of properties

- Optical
- Mechanical
- Crystallinity or phase change
- Degradation products

Characterization

- Non-destructive

METHOD

Coupon sample structure

- Soda lime glass
- UV transparent encapsulant
- UV cutoff encapsulant
- Backsheet

Accelerated exposure

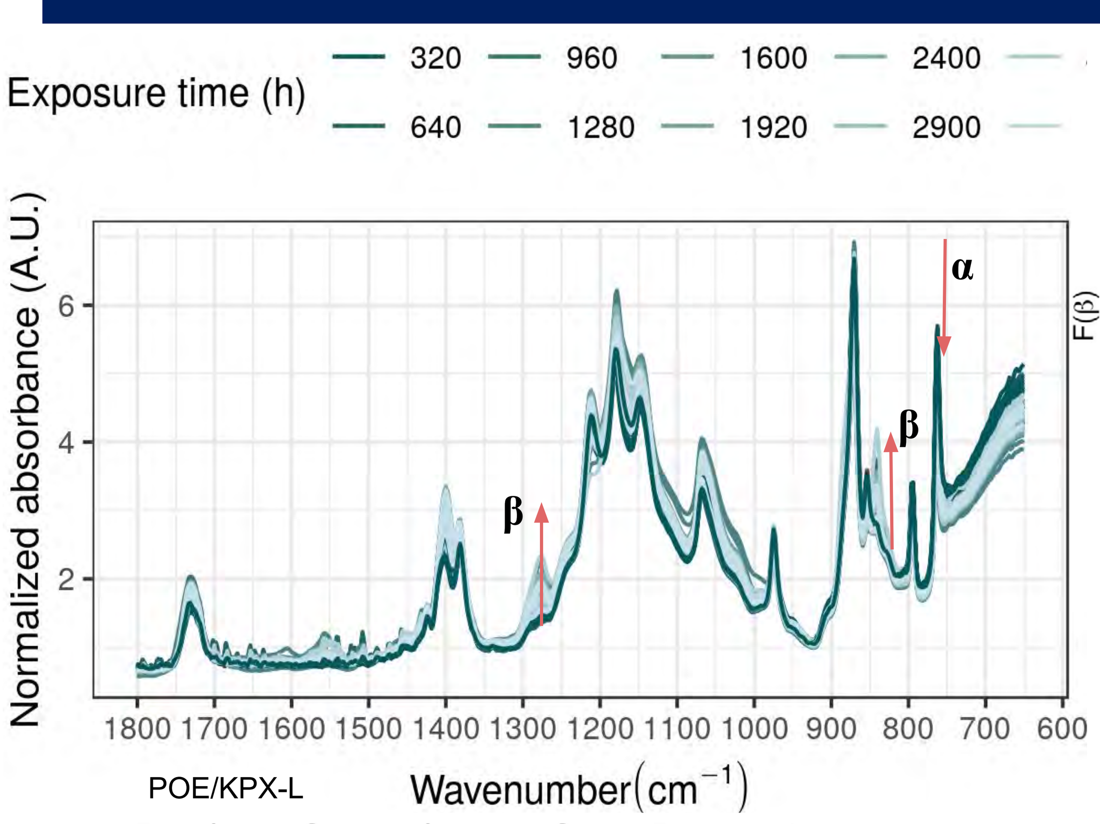
- Standard damp heat (DH)
- 85 ℃, 85 RH%
- For 4000h
- With stepwise measurements

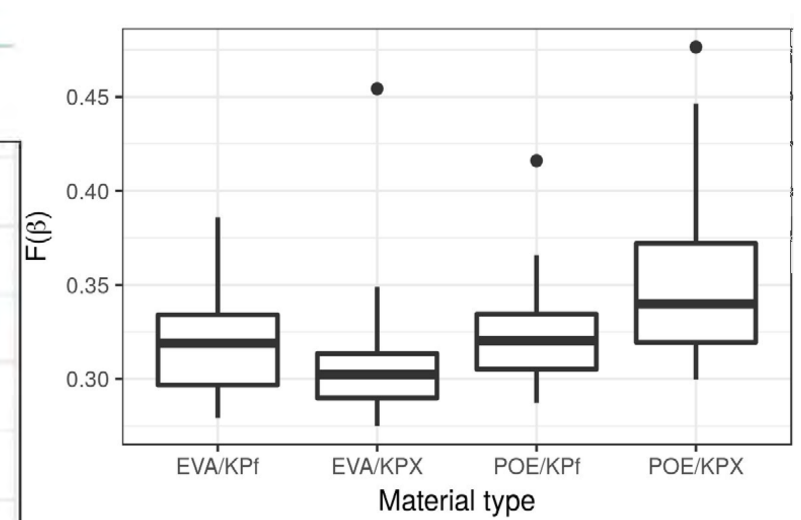
Measurements

- FTIR on backsheet
- Raman on encapsulant
- GC/MS on mini-module encapsulant

Encapsulant	Backsheet
EVA	KPX-L
	KPf-M
	PPf-H
POE	KPX-L
	KPf-M
	PPf-H

BACKSHEET PHASE CHANGE





Relative fraction of β phase is calculated by[2]:

$$F(\beta) = \frac{I_\beta}{\frac{K_\beta}{K_\alpha} I_\alpha + I_\beta} \times 100\%$$

β phase can be induced by **stress**

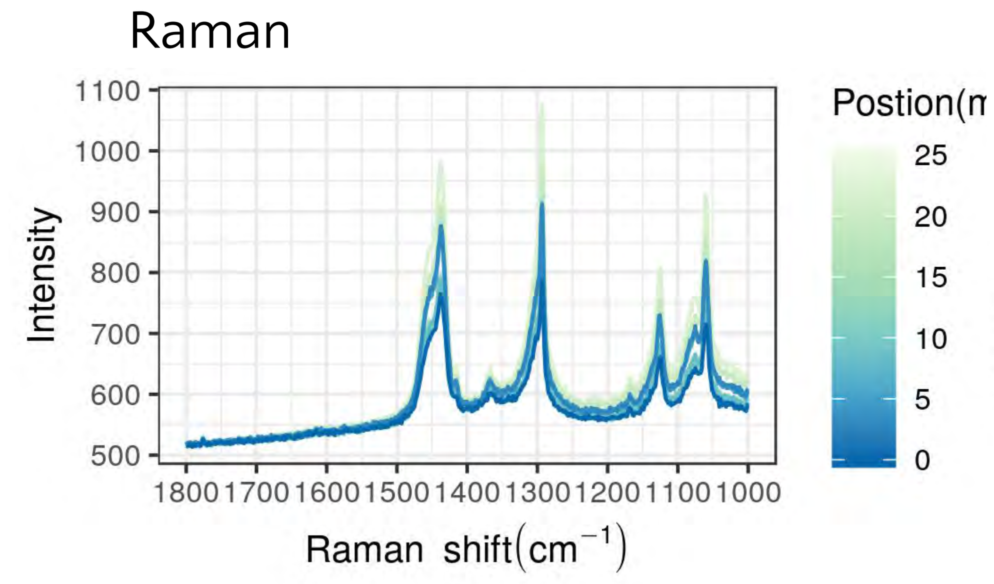
POE/KPX-L combination has

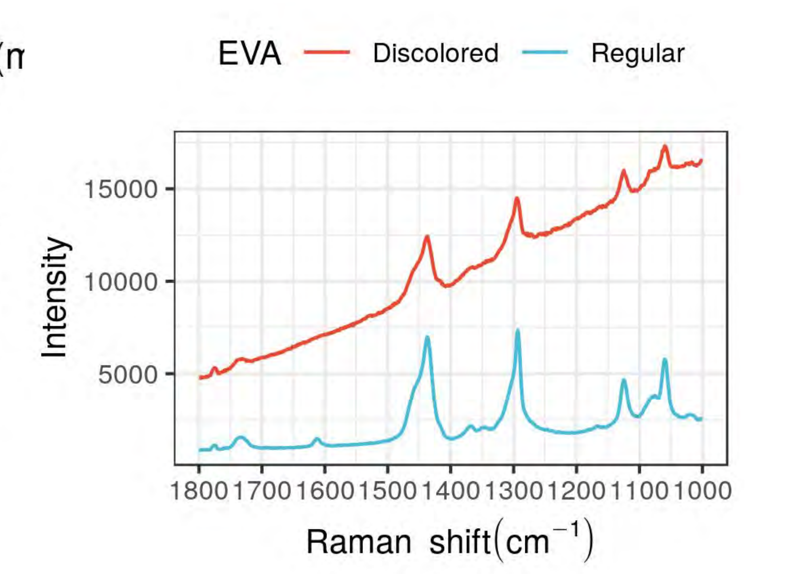
- highest internal stress level

RAMAN SPECTROSCOPY

Confocal Raman was used to measure the encapsulant of coupon and mini-module

- Line-scanning Raman was applied to coupon
- Two pieces of encapsulant were taken off from mini-module for Raman

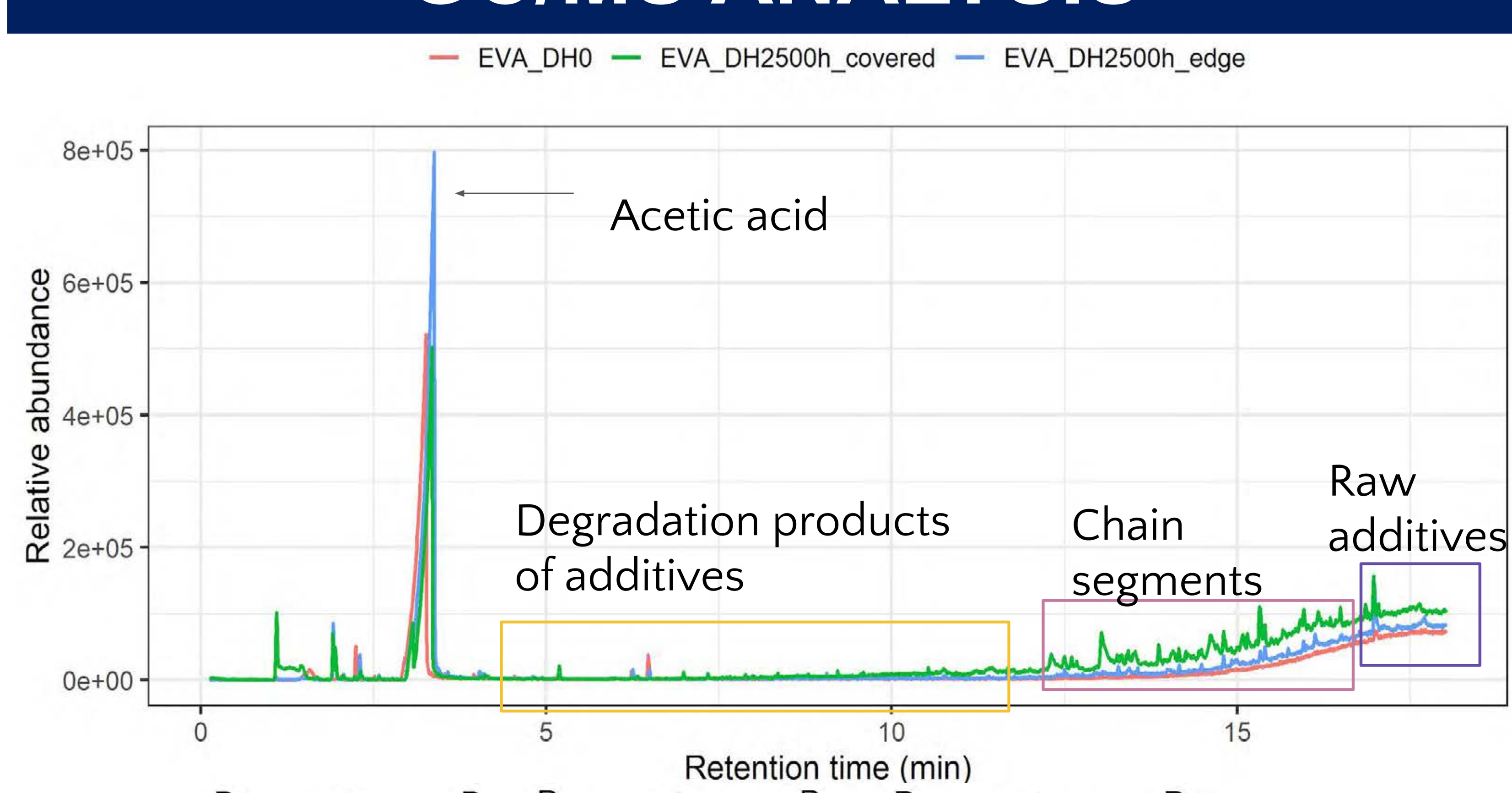


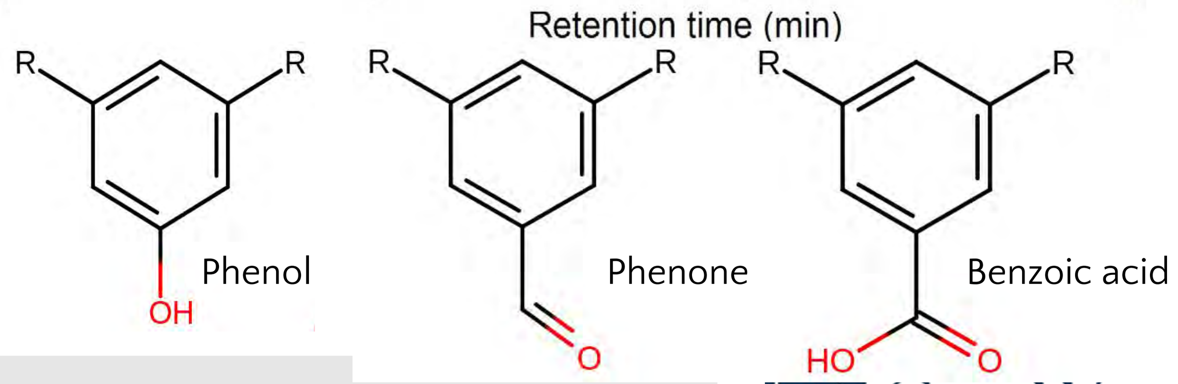


- No difference in background magnitude

- High fluorescence background
- Due to **condensed water**

GC/MS ANALYSIS





CONCLUSION

PV packaging materials exhibited physical or chemical changes under DH

- **PVDF** in PV backsheet showed sign of **phase transition**
  - Induced by internal stress
- **Antioxidant oxidation** resulted in encapsulant discoloration
  - Confirmed by Raman fluorescence background and GC/MS

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number DE-EE0008172

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RESEARCH PROJECT

Evaluation of Solar Plant Performance Loss Rate Calculation Methods

Alan J. Curran, C. B. Jones, Sasha Lindig, Joshua Stein, David Moser, Roger H French

Case Western Reserve University, Materials Science & Engineering

Sept 11–12, 2019

Motivation

Long term reliability of solar power systems

- typical warranties of 25-30 years outdoors
- most modules are nowhere near that old
- necessary to monitor systems as they operate
  - to determine performance trends/changes

Performance is observed from time series data

- data consists of power, irradiance, and temperature measurements
- extracting performance metrics from power time series is non-trivial

Models and Filter Criteria

There are many methods to evaluate performance

- from time series data
- filtering criteria on time series data
  - irradiance, clear sky, outlier filters
- power predictive models
  - to correct power for variations in weather

Models used

- XbX
- PVUSA
- XbX + UTC
- 6K

$$P = \beta_0 + \beta_1 I_{POA} + \beta_2 T + \epsilon$$

$$P = I_{POA}(\beta_0 + \beta_1 I_{POA} + \beta_2 T_{amb} + \beta_3 W)$$

$$P_{corrected} = \frac{P_{obs}}{1 + \gamma_T (T_{obs} - T_{rep})(\frac{I_{obs}}{I_{rep}})}$$

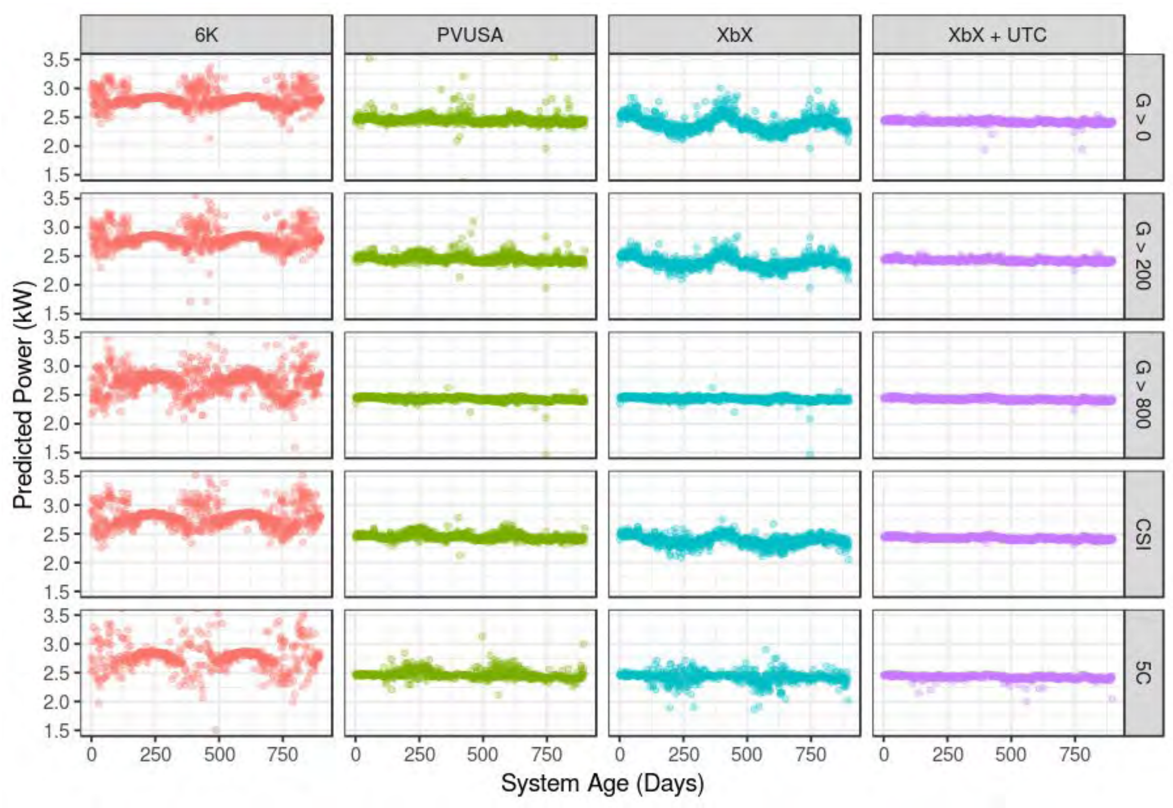
$$P_{corrected} = \beta_0 + \beta_1 I_{POA} + \epsilon$$

$$I' = I_{POA}/I_{STC}$$
$$T' = T_{mod} - T_{STC}$$
$$P = I'(P_{NP} + k_1 ln(I') + k_2 ln(I')^2 + k_3 T' + k_4 T' ln(I') + k_5 T' ln(I')^2 + k_6 T'^2)$$

Power Time Series Corrections

All methods applied to same outdoor data

- DOE RTC Baseline data set
  - 8 systems across Florida, New Mexico, Vermont, Nevada
- Resulting time series based on model/filter choice



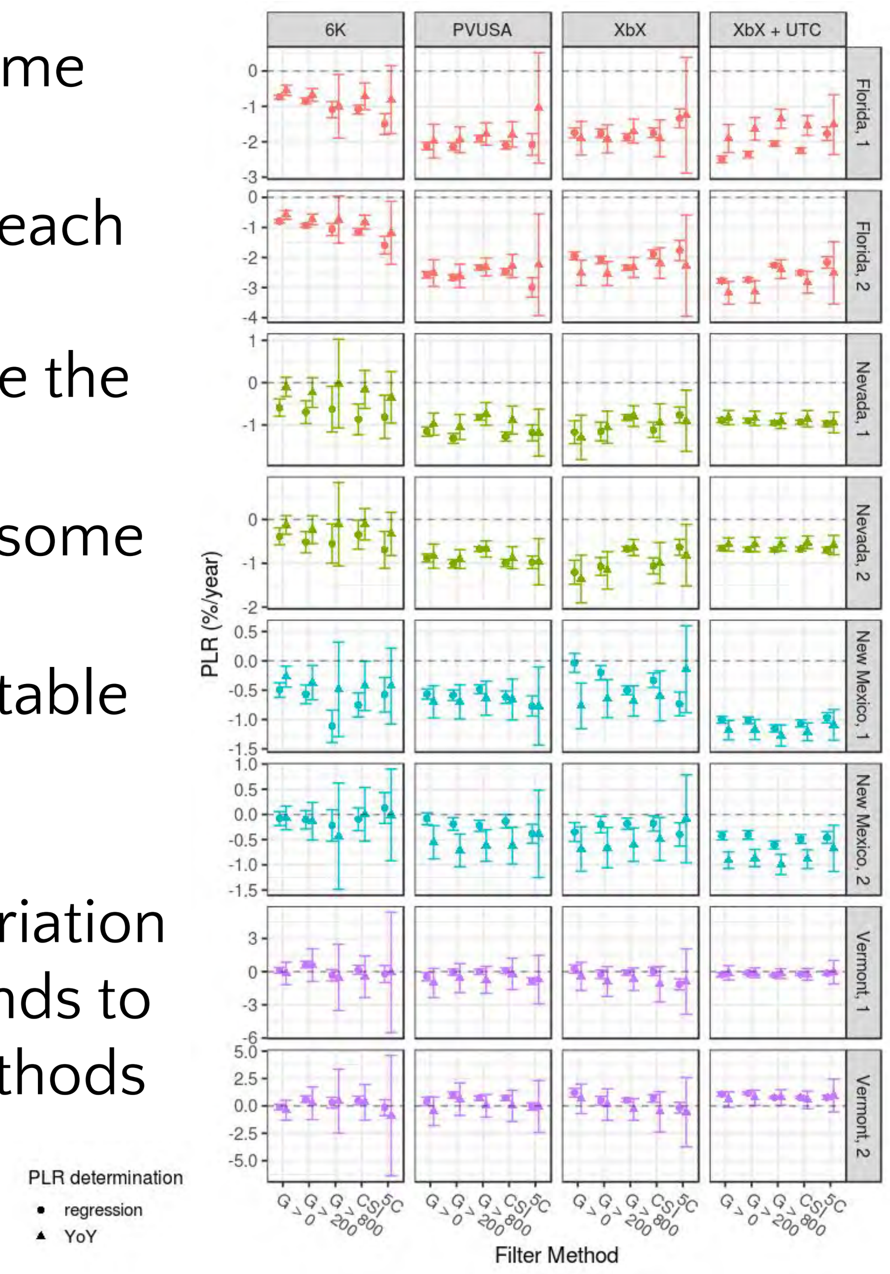
Performance Loss Rate Results

PLR results extracted from time series

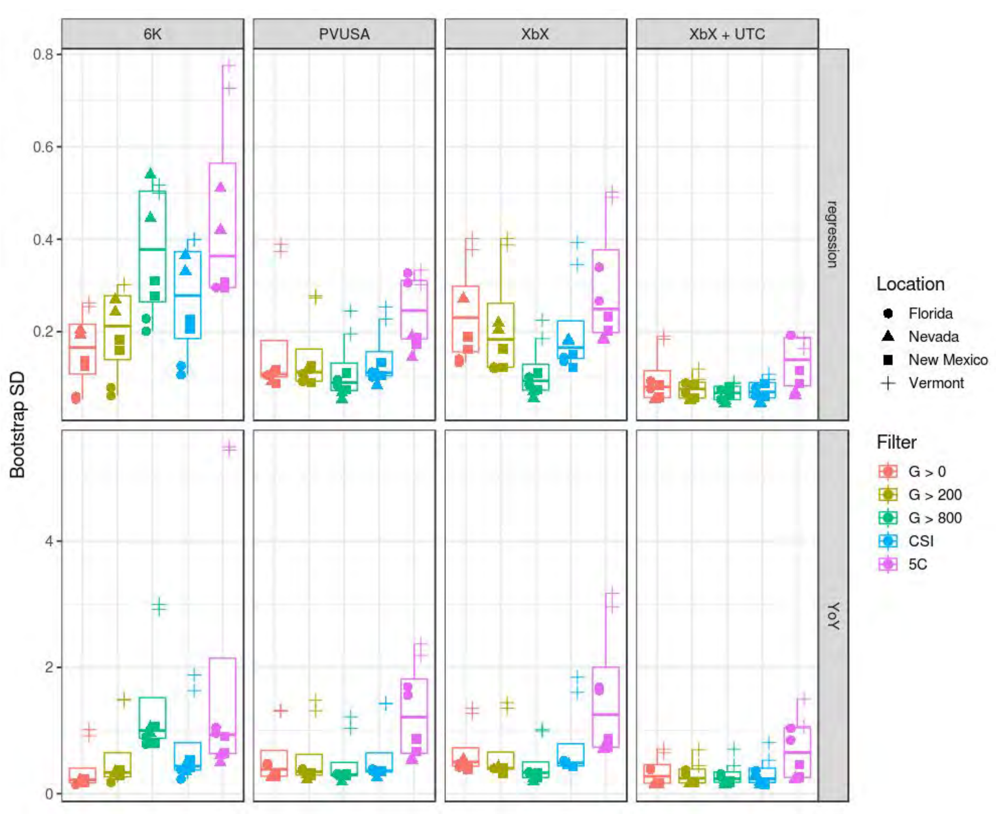
- 40 unique PLR values for each system
- ideally all results would be the same

Large discrepancies seen in some cases

- XbX + UTC shows most stable results
  - across filter methods
- 6K model shows most variation
  - PLR magnitude also tends to deviate from other methods



PLR Uncertainty



Uncertainty results

- evaluated through bootstrap

Different models show different filter sensitivity

- more complex models work best with more data

XbX + UTC tends to show lowest uncertainty

Conclusions and Acknowledgements

PLR magnitude and uncertainty shows strong dependance on evaluation method

- suggests bias can be introduced in calculation
- Further study is needed to evaluate accuracy/precision of different methods

XbX + UTC model shows highest precision

- in both magnitude and uncertainty

1. **This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number DE-EE-0008172.**
2. **This work made use of the High Performance Computing Resource in the Core Facility for Advanced Research Computing at Case Western Reserve University.**

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CENTER RESOURCES / CAPABILITIES

Studying Structural Dynamics Down to the Atomic Scale in Reactive Environments

Stephen D. House & Judith C. Yang

Environmental TEM Catalysis Consortium (ECC) @ U. Pittsburgh

www.engineering.pitt.edu/ecc

AskECC@pitt.edu

11th September 2019

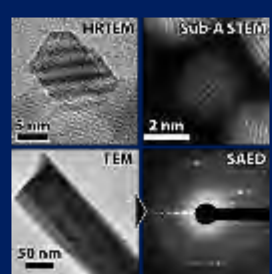
Transmission Electron Microscopy (TEM)

Direct characterization of:

- Structure
- Composition
- Chemistry
- Electronic info
- Magnetic info ...and more

...spatially resolved at the micro- to atomic scale!

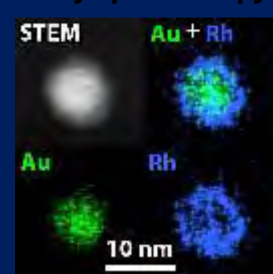
TEM/STEM, Diffraction



Structure & Morphology

Sub-Å resolution

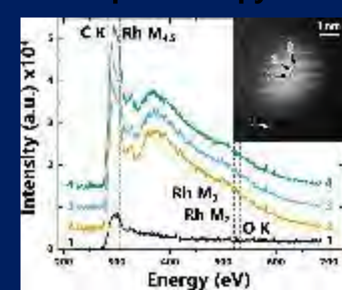
Energy-Dispersive X-ray Spectroscopy



Composition & phase distribution

Up to atomic res & ~0.1% sensitivity

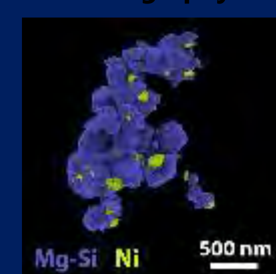
Electron Energy-Loss Spectroscopy



Chemical/bonding info; e.g., oxidation state, plasmons, etc

Up to ~0.15 eV res

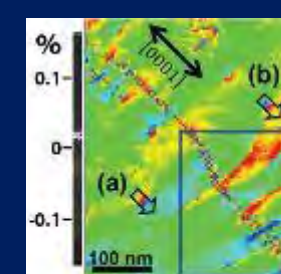
Electron Tomography



3D structure and spectroscopy

~1 nm resolution

"4D STEM"

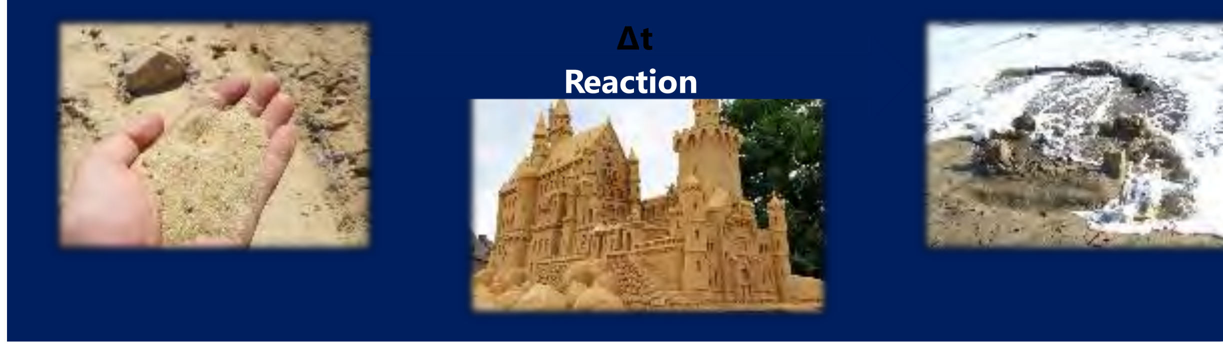


Orientation, order, strain, etc

C. Ophus, Micros & Microan, 25(3), 2019

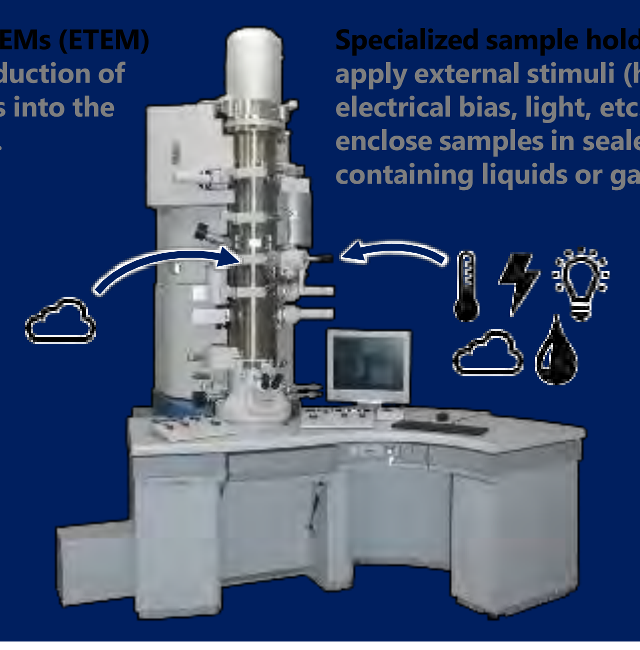
Dynamic systems need dynamic characterization!

It is critical to know how these systems evolve during reaction under working conditions (e.g., thermal, gas, liquid, bias, mechanical). Structure pathways and transient states are not observable by *post mortem* analysis alone.

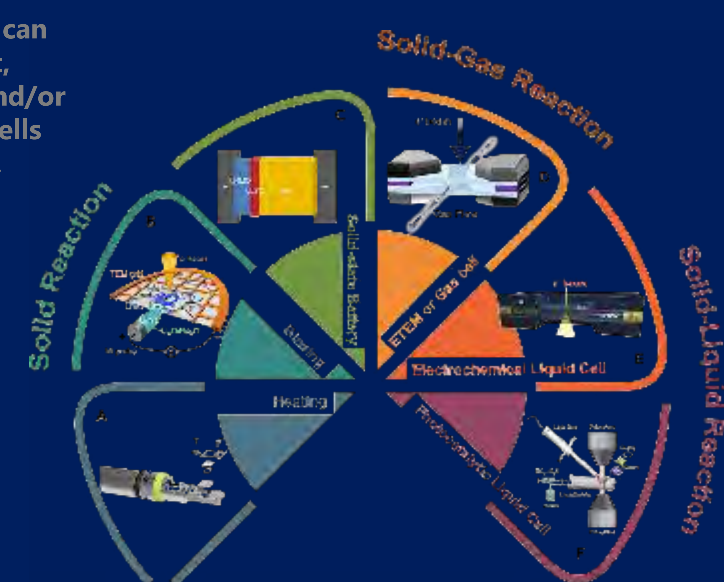


Creating Reaction Conditions Inside the TEM

Environmental TEMs (ETEM) enable the introduction of gases and vapors into the sample chamber.



Specialized sample holders can apply external stimuli (heat, electrical bias, light, etc.) and/or enclose samples in sealed cells containing liquids or gases.



J. Li, et al., *Joule*, 3(1), pp.4-8 (2019)

Advanced (Environmental) TEM Capabilities at Pitt

Hitachi H-9500 ETEM

Dynamic characterization under reaction conditions

Computer-controllable gas manifold with fume hood

≤ 2 gases + 1 vapor @ ≤ 0.1 Pa

H_2, O_2, CO, CO_2, CH_4, CH_3OH...

Heating ≤ 1000 °C

Double-tilt 3mm disk "bulk" & MEMS-style holders

Liquid flow cell holder

Liquid phase experiments

FEI Themis G2 S/TEM

Atomic-resolution imaging and spectroscopy

70 pm STEM resolution

Super-X quad-EDS

High accuracy and sensitivity quantitative elemental mapping at up to atomic resolution

TEM, STEM, and EDS Tomography

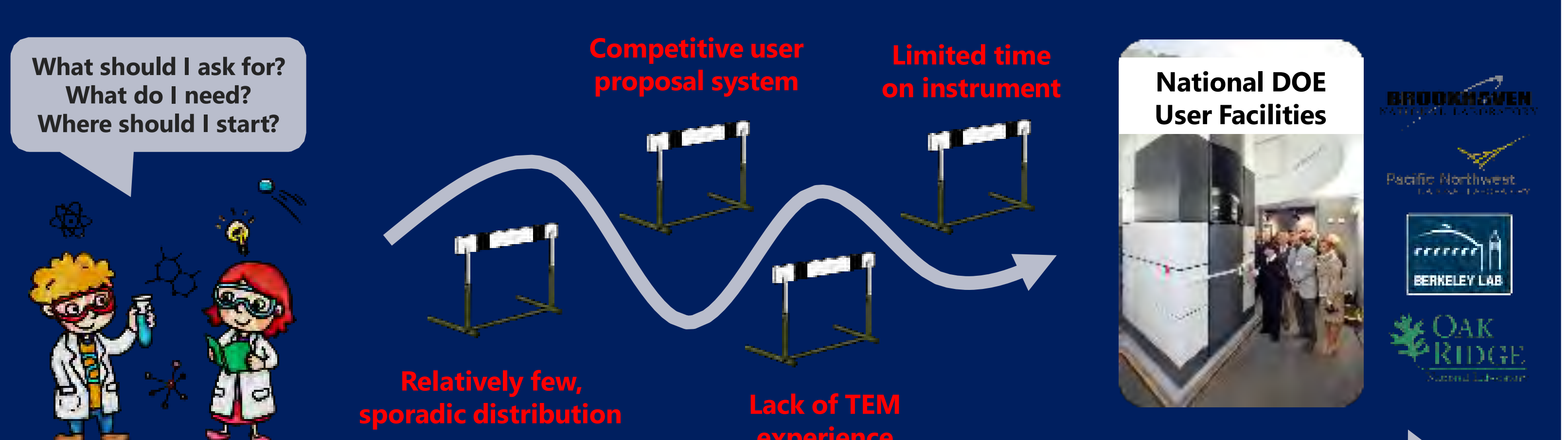
3D structure and composition

In situ nanomanipulation

Tribology, indentation, etc.

Environmental TEM Catalysis Consortium (ECC)

The ECC makes it easier to access and exploit environmental TEM capabilities



1. Contact the ECC to discuss your project, needs, and goals

AskECC@pitt.edu

www.engineering.pitt.edu/ecc

2. Together, work out an experimental plan
   - What to perform at Pitt
   - What needs partner facilities
3. Carry out experiments
   - In person @ Pitt or mail-in
   - Facilitate access and usage of partner facilities
4. Post-experiment assistance
   - Data analysis and new experimental plan
   - Proposal assistance (e.g., collab, support, etc.)

Nationwide Network of ECC Partners

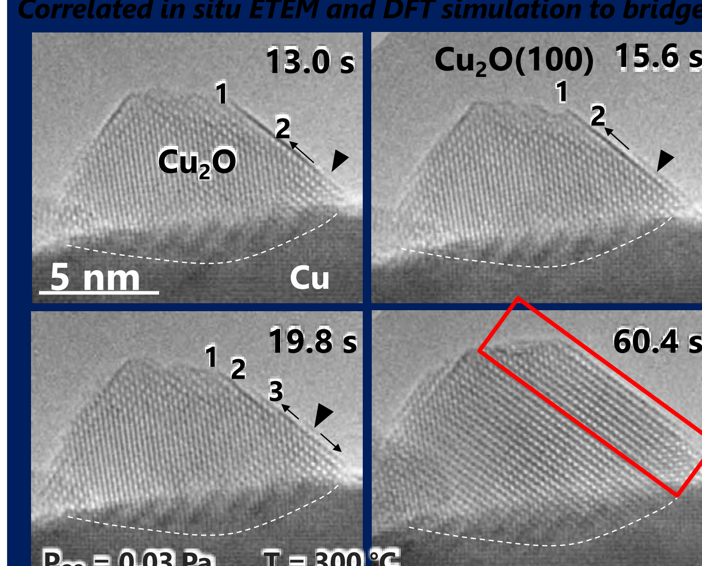
- **User & non-user facilities** with environmental TEM and other advanced TEM capabilities
- **Computation partners** (U. Washington, U. Pittsburgh)
- **Synchrotron Catalysis Consortium** (SCC) at the National Synchrotron Light Source (NSLS-II) at BNL

The ECC is financially supported by the University of Pittsburgh and Hitachi High Technologies

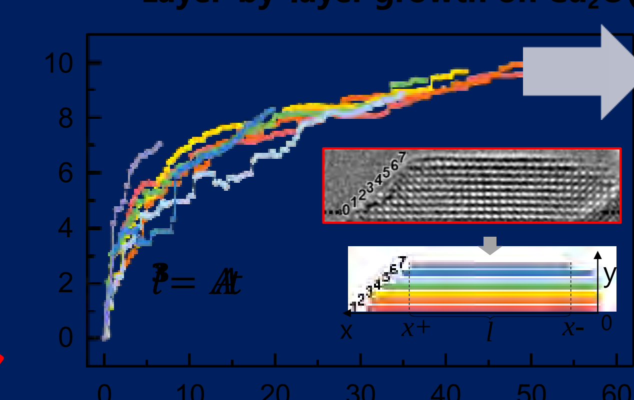
Example Environmental TEM Studies at Pitt

Structural dynamics and mechanisms of Cu oxidation for catalysis and corrosion

Correlated in situ ETEM and DFT simulation to bridge the gap between surface science and bulk oxidation/corrosion



Layer-by-layer growth on $Cu_2O(110)$ facets

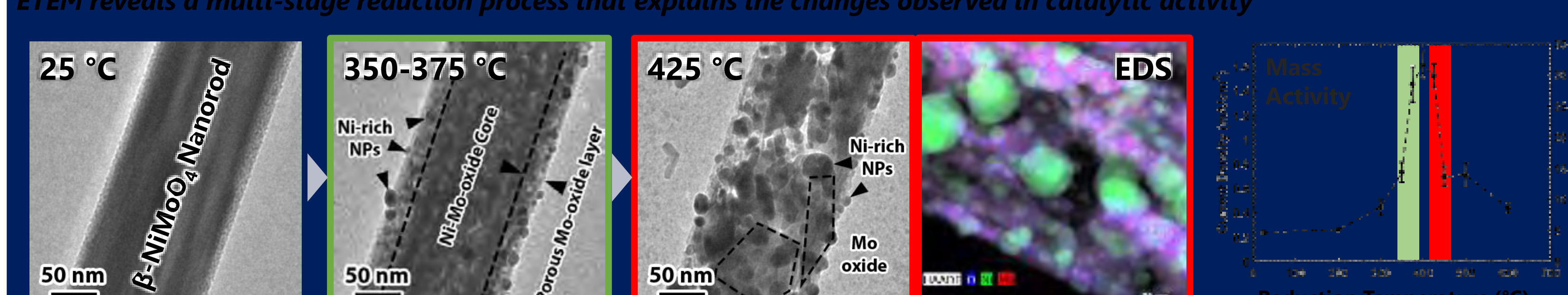


- Extract **growth rates**, **nucleation sites**, etc
- **Correlate with DFT** for thermodynamic and kinetic energetics
- Determine growth **mechanism** and develop **kinetic models**

Data courtesy Dr. Meng Li (Judith Yang group)

Understanding the complex transformations during Ni-Mo electrocatalyst synthesis

ETEM reveals a multi-stage reduction process that explains the changes observed in catalytic activity



P_{H2} = 1.1×10^{-2} Pa

T ≤ 25-500 °C

Small Ni-rich nanoparticles closely interfaced with porous MoO_x "skin"

Nanoparticle coarsening and phase segregation

Collaboration w/ James McKone group

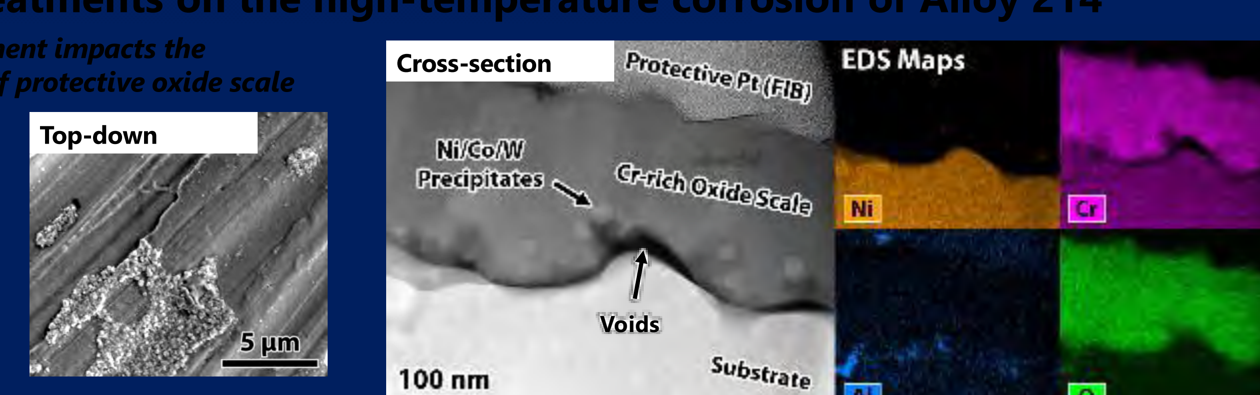
Effect of surface treatments on the high-temperature corrosion of Alloy 214

Revealing how surface treatment impacts the formation and composition of protective oxide scale

Surface treatment:
500-grit SiC sanding

Corrosive environment:
800 °C in air, 2 hr

In situ ETEM corrosion studies underway!



Collaboration w/ Brian Gleeson group

MATERIALS DATA SCIENCE RELY

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RESEARCH PROJECT

Electroluminescence and Current-Voltage Correlation for Mechanistic and Electrical behavior of Photovoltaic Module using Computer Vision and Machine Learning Methods

Roger French, Ahmad Karimi

Case Western Reserve University, Department of Computer and Data Science

09-11-2019

MOTIVATION

Degradation and reliability performance photovoltaic materials

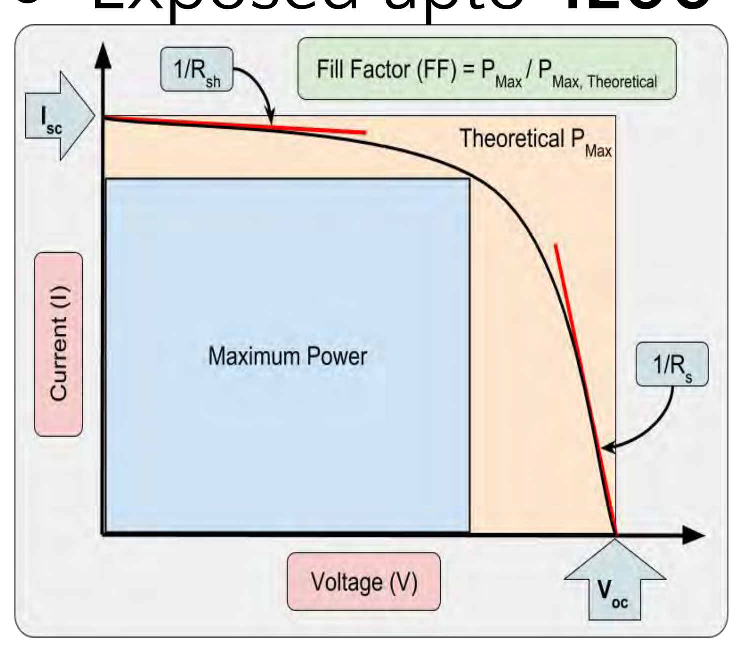
- Interest to a product's future design

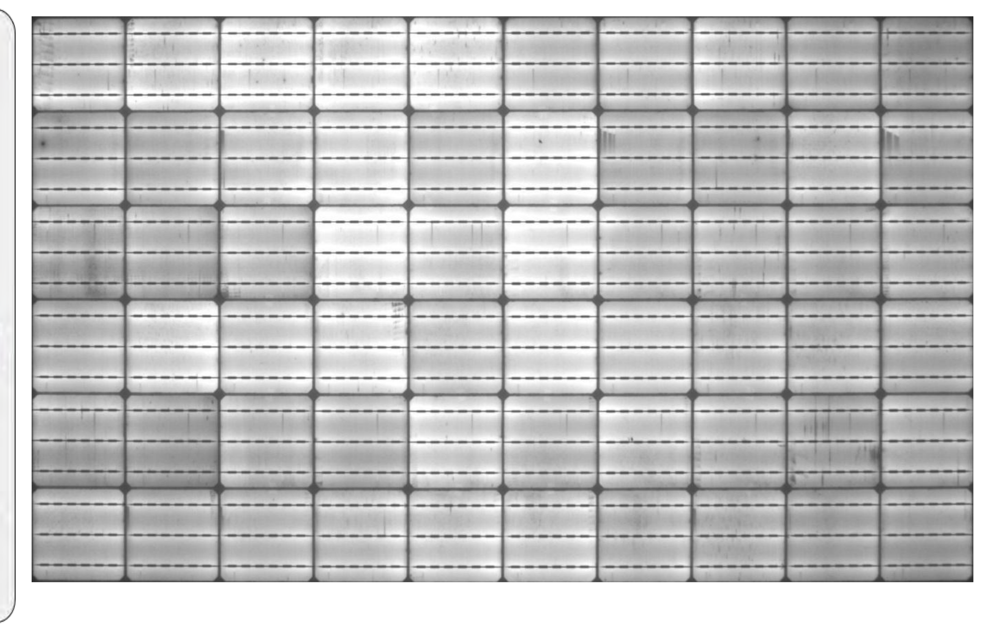
Correlation of Mechanistic and Electrical behavior

- Statistical model for EL image & I-V characteristic
- Method to evaluate PV module degradation mechanisms under accelerated applied stress using EL imaging and current – voltage (I-V) tracing of solar cells for quantitative analysis

DATASET

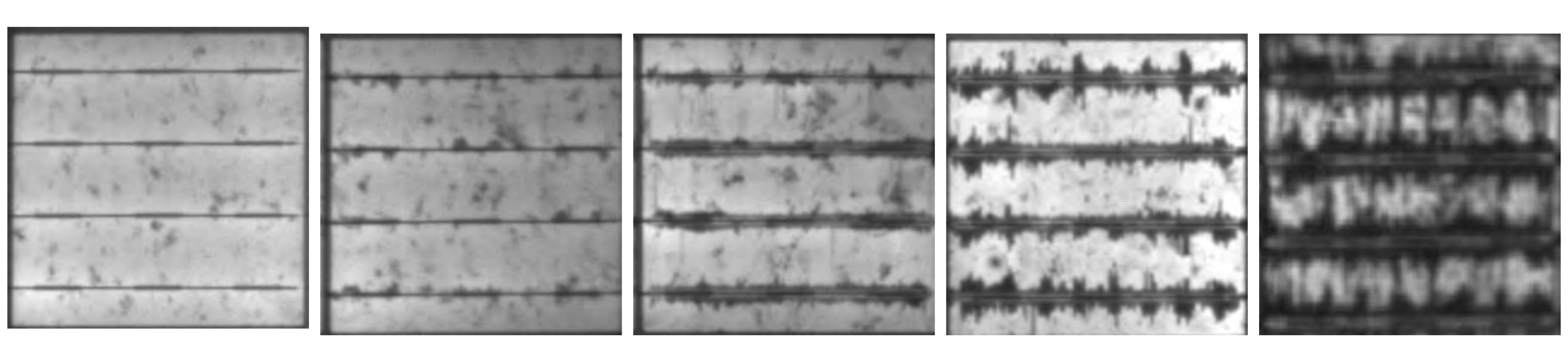
- **Five brands** each have five photovoltaic modules
- Exposure types: **Damp-heat** & **Thermal cycling**
- Each exposure type has three modules
- Exposed upto **4200 hours**





CELL CLASSIFICATION AND FEATURE RATIO (FR)

- **Extracted cells** from the modules are classified into five Corrosion levels (CL) 0,1,2,3,4
- **Feature ratio** are calculated for brands undergoing degradation primarily by busbar corrosion
- **Mean value** of all the cell class in a module is a feature ratio of the module image



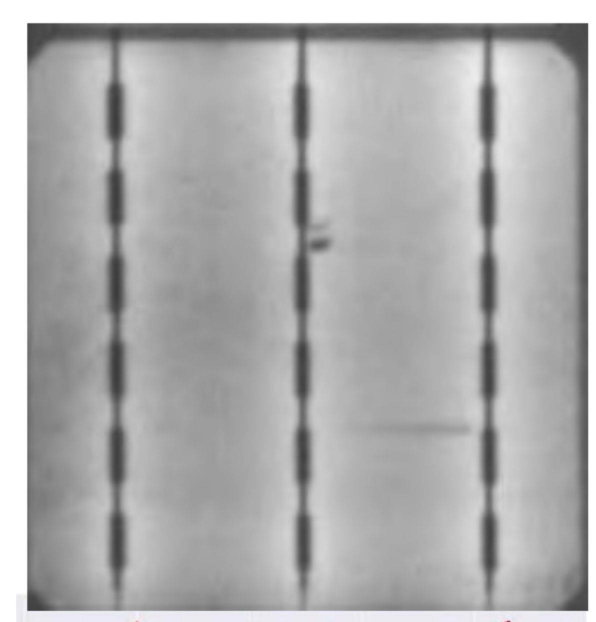
CL 0 CL 1 CL 2 CL 3 CL 4

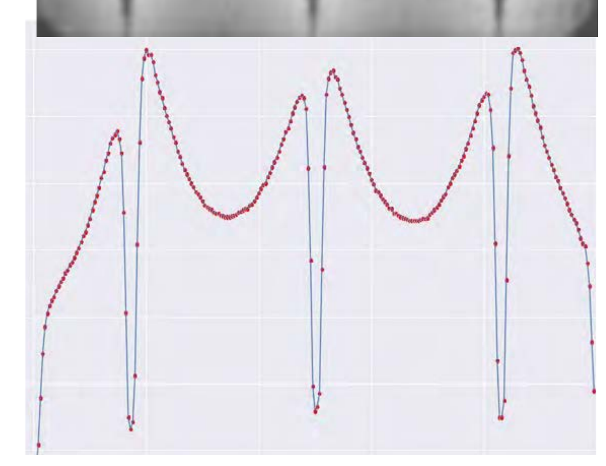
NORMALIZED BUSBAR WIDTH (NBBW)

- Extent of busbar darkening
- Derived variable for predicting power loss
- Value is normalized for number of pixels and number of busbars

$$NBBW = \frac{\sum_{i=1}^{n} W_i}{n \times L}$$

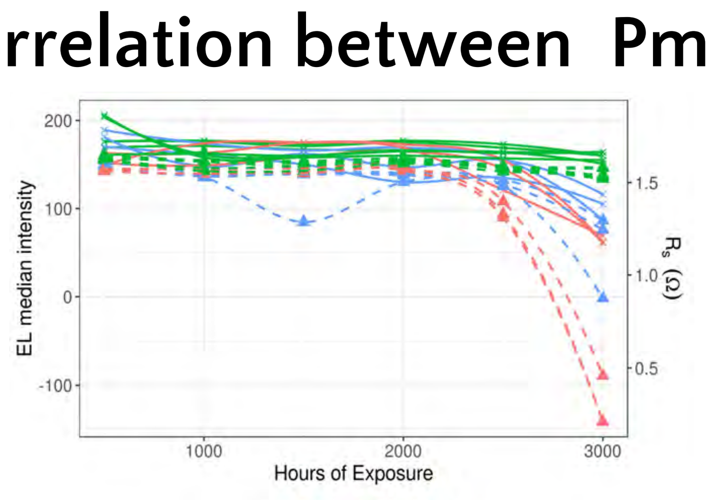
- n is number of bubars, L is width of the cell images and W_i is the width of ith busbar.

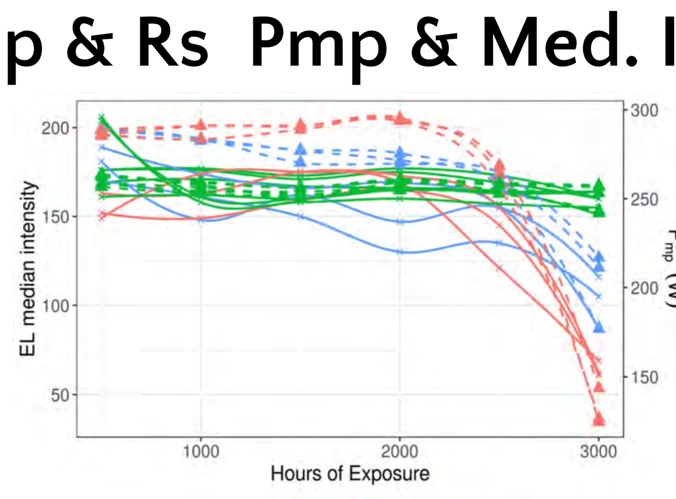




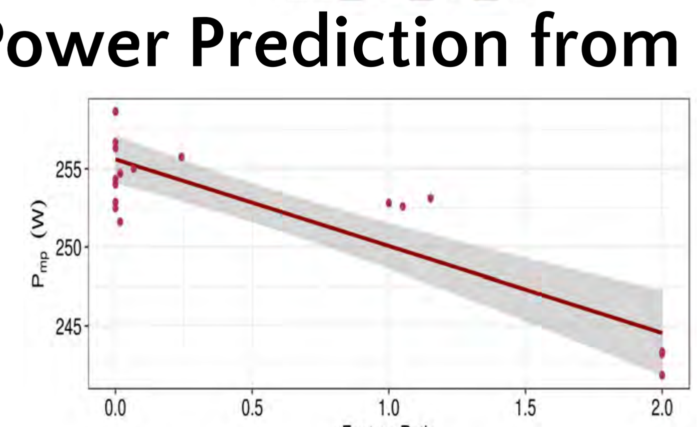
RESULTS

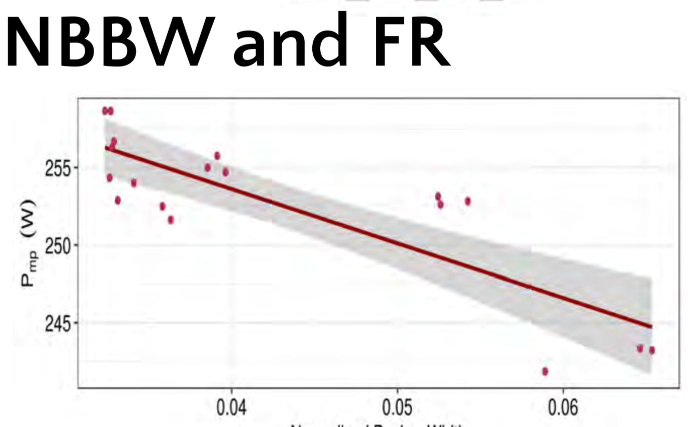
- **Correlation between Pmp & Rs Pmp & Med. Intensity**





- **Power Prediction from NBBW and FR**





Pmp vs Feature Ratio Pmp vs NBBW

LEVERAGED TECHNOLOGIES

Modules and Packages

- pvimage
  - noise reduction
  - Lens correction
  - Planar index
  - Cell segmentation method
- ddiv package & I-V curve tracing
  - Short circuit to open voltage sweeps
  - Yields I-V parameters:
    - Pmp , FF, Isc , Voc , Imp , Vmp, Rseries , Rshunt

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RESEARCH PROJECT

Image Processing on Crystallization Growth of Rotating and Levitated Alloys

Ben G. Pierce[1], Ahmad M. Karimi[1], Laura G. Wilson[1], Andrew J. Loach[1], Sonoko Hamaya[2], Justin S. Fada[1], Masayoshi Adachi[2], Hiroyuki Fukuyama[2], Roger H. French[1], and Jennifer W. Carter[1]

1. Case Western Reserve University, Cleveland, United States

2. Tohoku University, Sendai, Japan

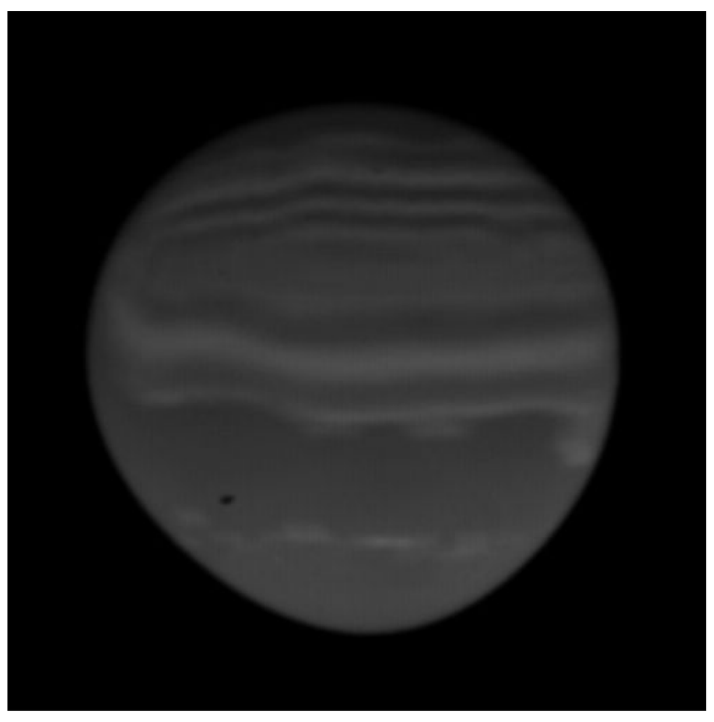
PROJECT DESCRIPTION

- Magnetically levitated molten droplet
  - Aluminum Nickel alloy (AlN)
- Observed undergoing nitridation (N_2 gas)
  - From two angles by high-speed cameras
  - While rotating upon a vertical axis
- Dataset includes videos of 3 samples at different temperatures (1910K, 1960K, 2008K)
- Objective: determine nitridation behavior with respect to time
  - Does temperature influence nitridation rates?
- Industry relevance
  - Aluminum nitride is a promising substrate material for AlGaN-based UV-LEDs, used for diverse scientific applications

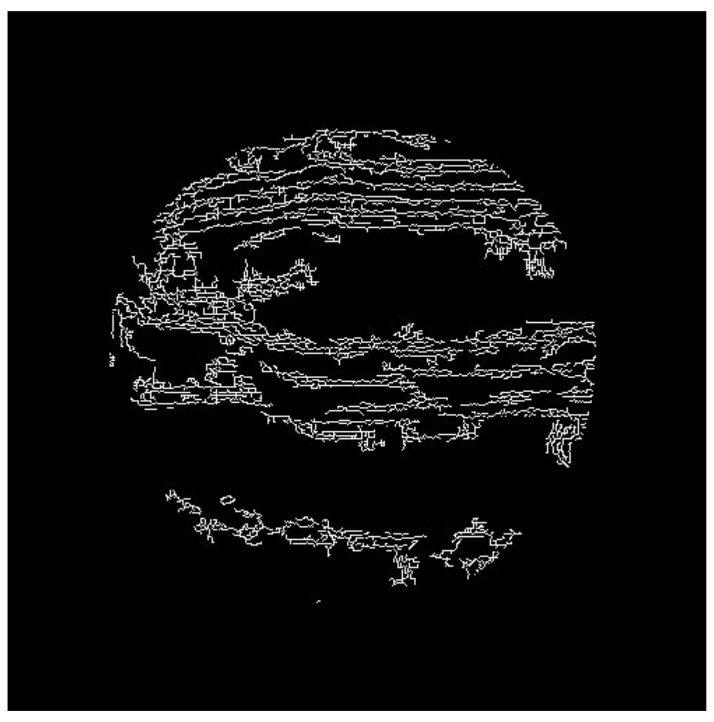
OVERALL APPROACH

- **Find area of entire droplet**
  - to find a proportional area
- **Remove outside edge of the droplet**
  - isolate interior points
- **Cluster interior points**
  - Some samples have multiple crystals
- **Find area enclosed by clusters**
  - Convex hull
- **Account for rotation of droplet**
  - Select "main" frame, sum others

FILTERING

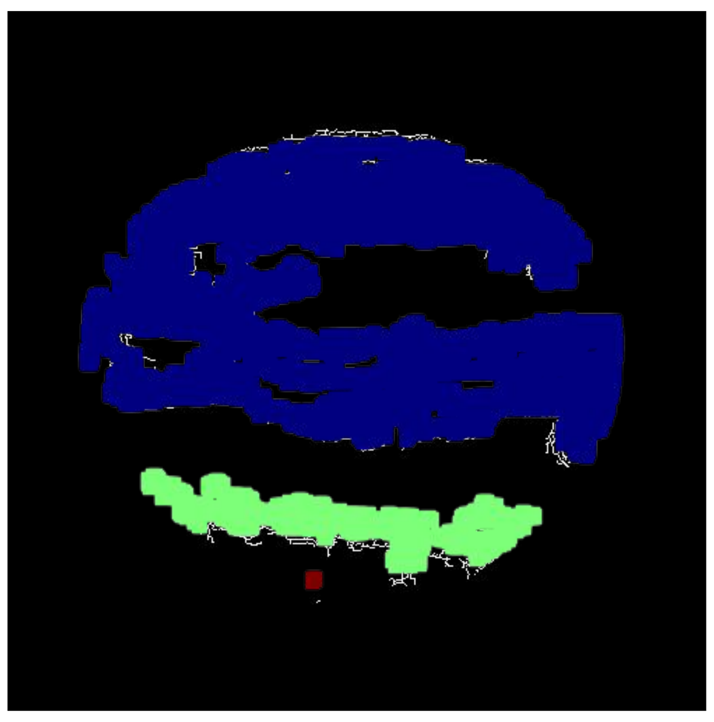


- Crystallized region has striated ridges
- Easy to detect with classical edge detection methods
- Variable intensity -> difficult to classify by threshold



- A Canny edge detection filter is applied to extract intensity changepoints
- All points on the border within a threshold distance are removed, leaving the interior points behind

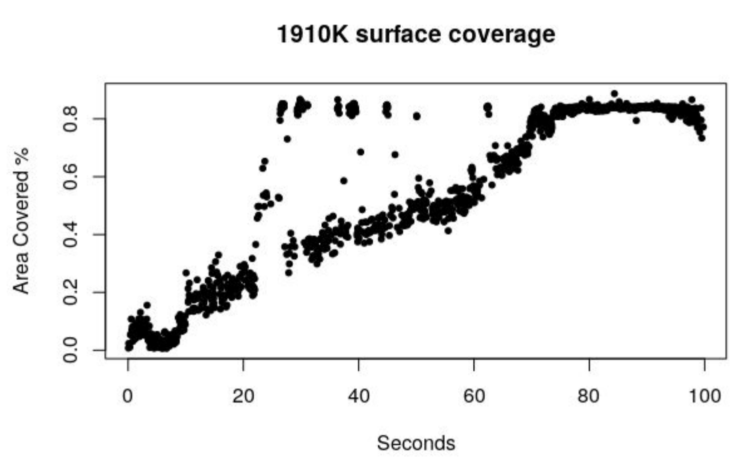
CLUSTERING + AREA ANALYSIS

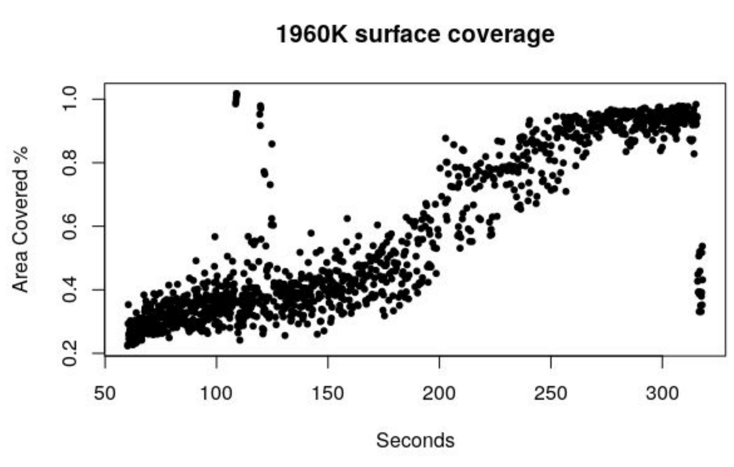


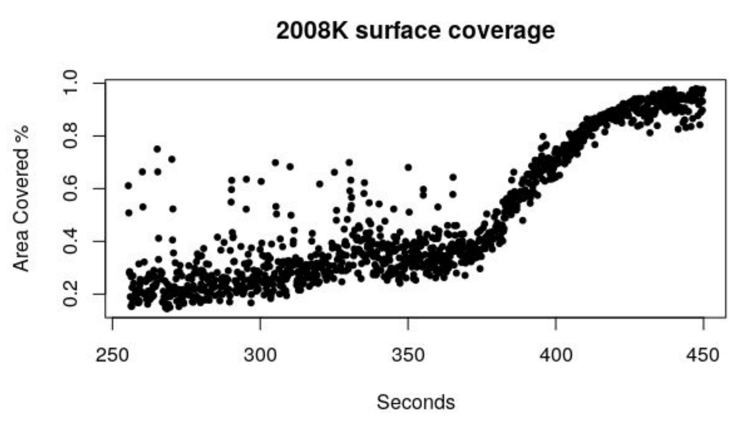
- The DBSCAN clustering algorithm is applied
  - Can have arbitrary number of crystals
- Disregards most far outliers caused by filtering error

- A convex hull is found for each cluster, which defines the bounding convex polygon for a set of points
- Can then extract area from this polygon

RESULTS

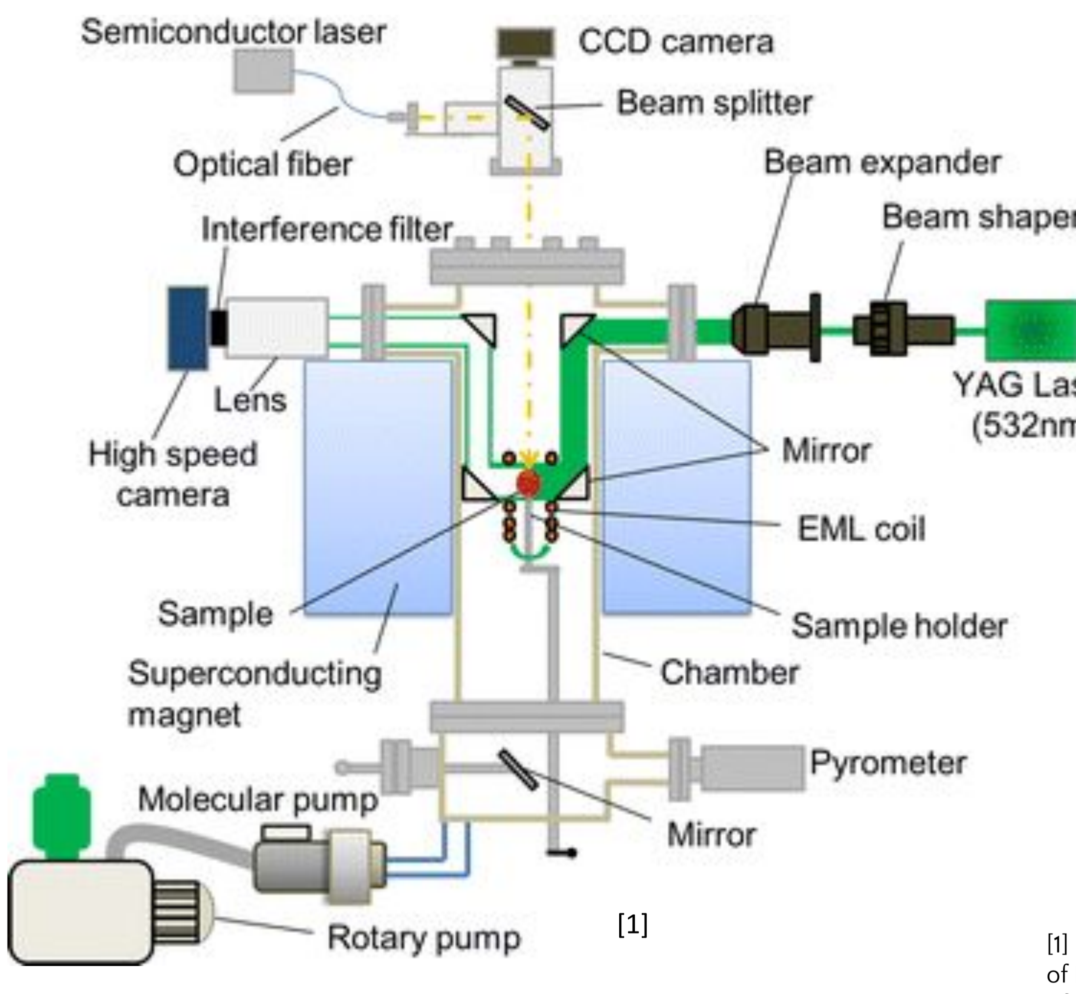






- 1910K converges to 80% -> missing frames near the end
  - Reduces sum of averages
- 1960K, 2008K converge to 100% as expected
- Small outliers due to number of factors
  - Motion blur
  - Clustering error
  - Filtering error
- 2008K appears to nucleate at a faster rate
  - Crystallizes later in time than others

LEVERAGED TECHNOLOGIES



OpenCV

- Utilized existing apparatus at Tohoku University
- Used Python libraries for data analysis + visualization

[1] M. Watanabe, M. Adachi, and H. Fukuyama, "Densities of Fe–Ni melts and thermodynamic correlations," Journal of Materials Science, vol. 51, no. 7, pp. 3303–3310, 2015.

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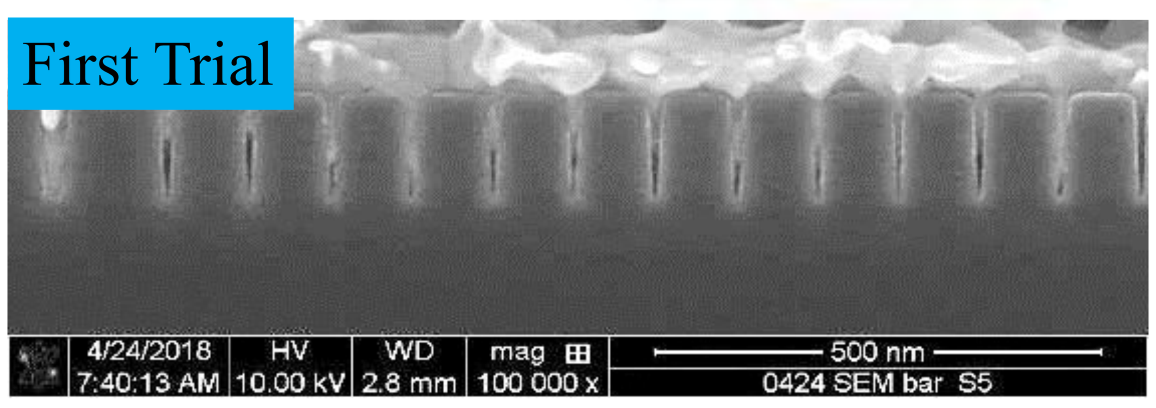
NEW PROPOSAL

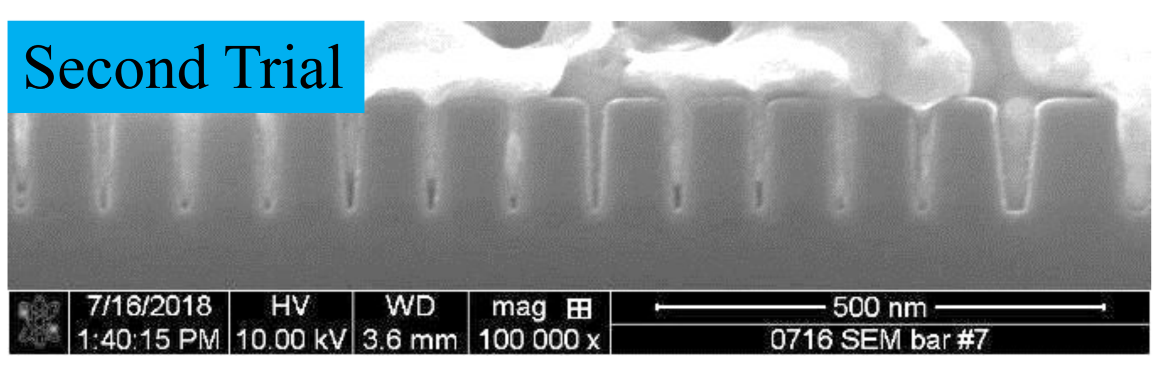
Printing of High Performance Microgrid for High Efficiency, Flexible Organic Light Emitting Diode

Melbs LeMieux, Paul W. Leu and Ziyu Zhou

University of Pittsburgh

MOTIVATION





- Particle free
- Low curing T

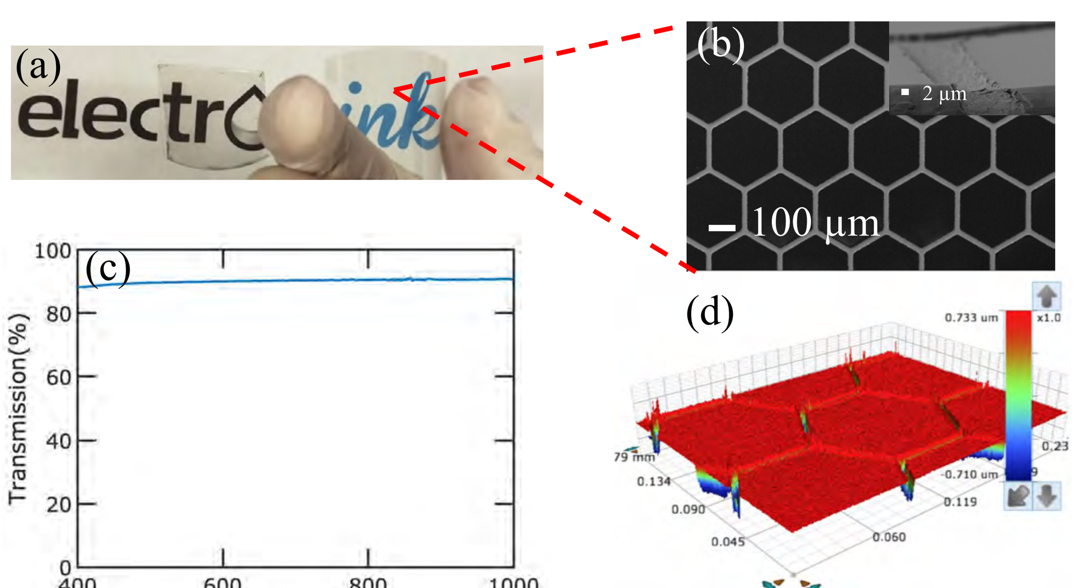
MAIN OBJECTIVES

- OLEDs have emerged as a low cost, high resolution technology for a variety of optoelectronics and lighting applications
- Flexible electrodes may also enable new applications such as wearables or flexible displays.

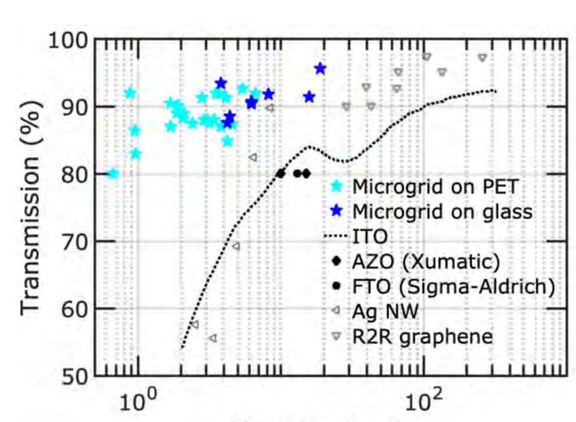
Technical Objectives

- Transparency > 90%
- Low sheet resistance $R_s < 1\Omega$/sq
- Large area > 10 ×10 cm^2
- Low Temperature processable < 120℃
- Smaller width size (≤ 5 µm)
- Large thickness (> 1 µm)

CHARACTERIZATION

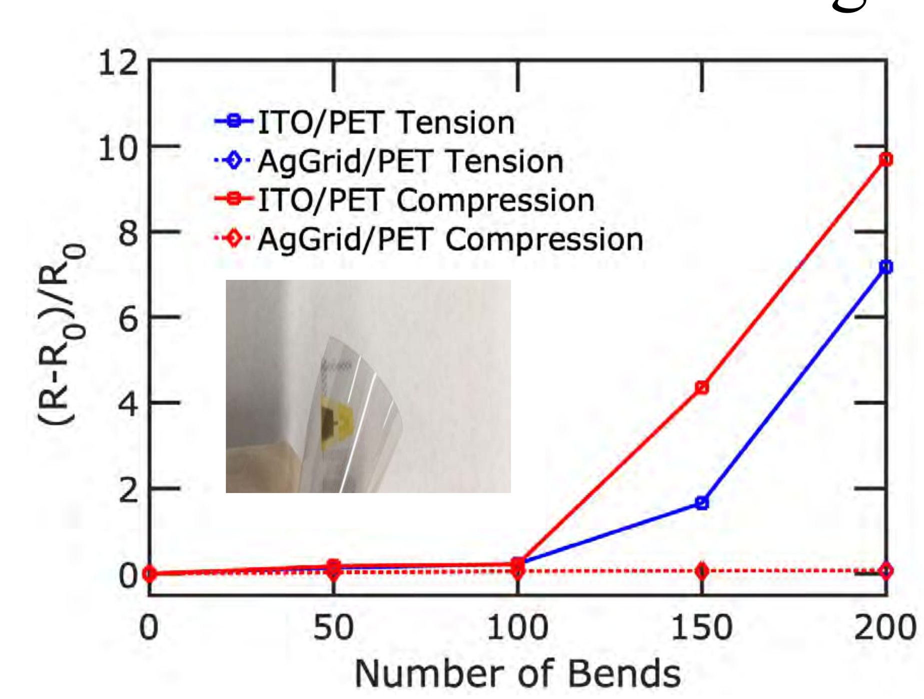


- Uniformity
- High transparency
- High conductivity



DURABILITY TEST

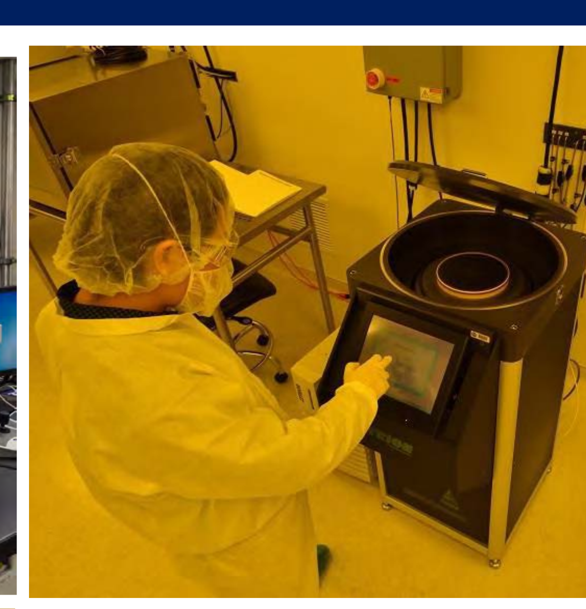
- Bending radius 0.25 inch
- Sheet resistance increase 7% after 200 cycles
- Folding test and tape adhesion test will be conducted on both ITO/PET and AgGrid/PET

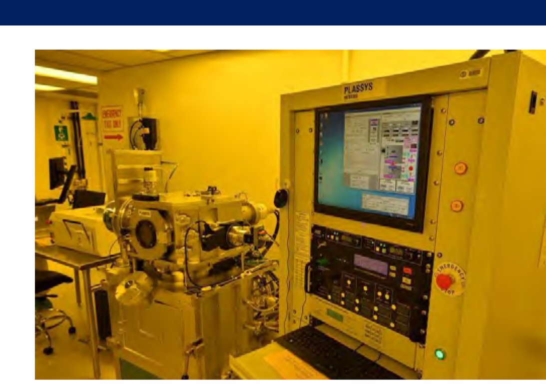


PROJECT MILESTONES

Milestone 1			Milestone 2	
2019.12	2020.3	2020.6	2020.9	2020.12

LEVERAGED TECHNOLOGIES





- Reactive Ion Etching System
- Scanning Electron Microscope
- Angstrom Sputtering System
- LAMBDA™ 750 UV/Vis/NIR
- Plassys E-Beam Evaporation System

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RESEARCH PROJECT

Network Modeling Applied to PV Systems

Sameera Nalin Venkat, Roger H. French, Laura S. Bruckman

Case Western Reserve University, Materials Science & Engineering

September 11-12, 2019

Introduction

- Photovoltaic (PV) systems: strong competitor to fossil fuels; important energy resource
  - But they degrade: lifetime & degradation science (L&DS) to the rescue!
- **L&DS: 'data-driven statistical and physical approach to PV system reliability'**
- L&DS: based in network structural equation modeling (netSEM)

netSEM: What is it all About?

- netSEM: R package developed by SDLE Center
  - Includes active degradation pathways & mechanisms
  - Metrics + metrology + tools for analysis of PV modules
- Different mechanisms can be joined forming a network of degradation pathways
- <S|M|R> and <S|R>: two pathway models
  - S: stressor, M: mechanism, R: response

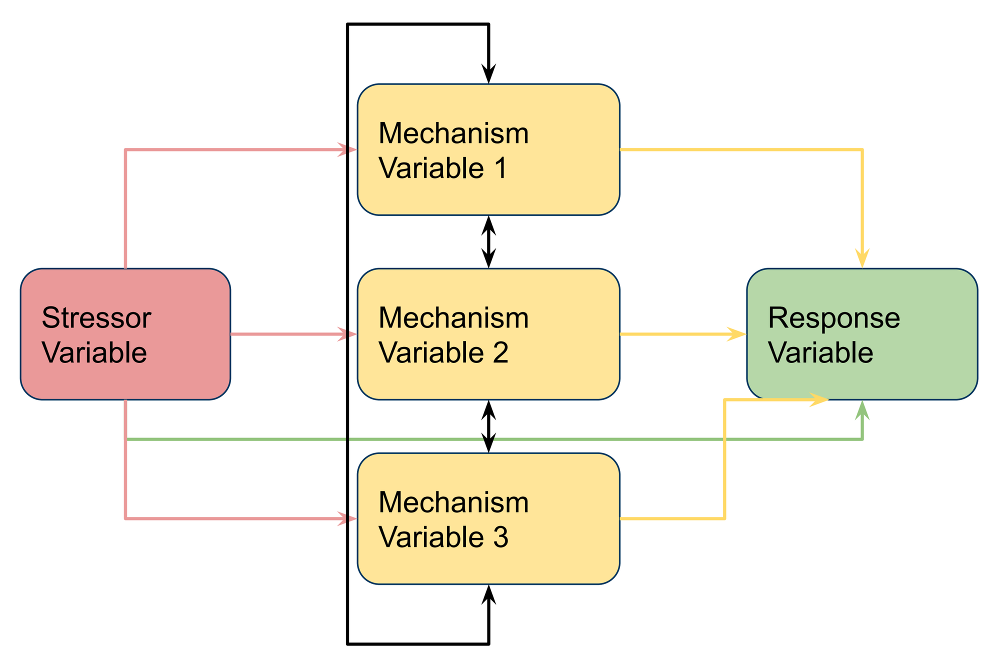

Figure 1: <S|M|R> pathway.

PV Degradation Pathways: Exp. 1

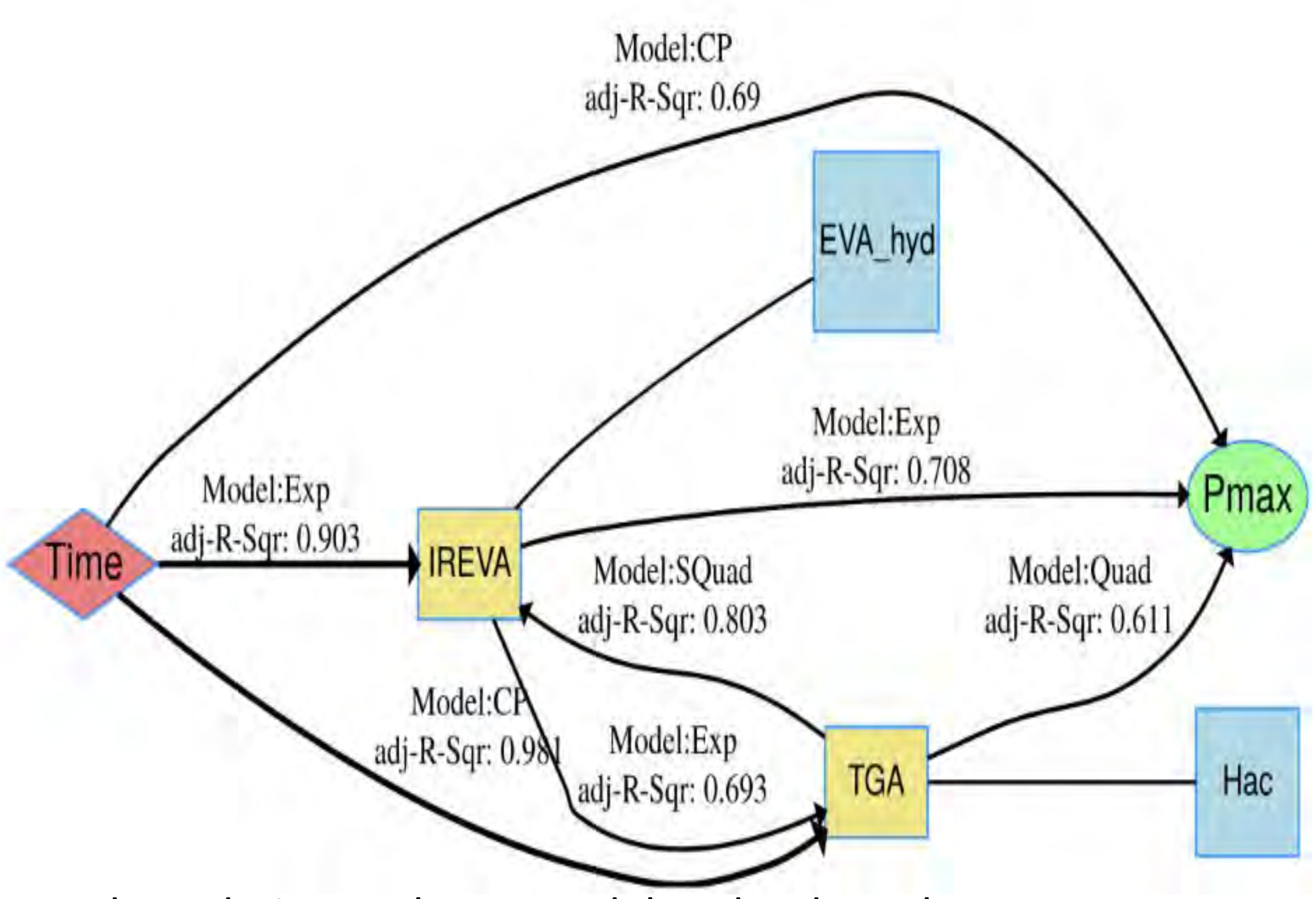

Figure 2: PV degradation pathway model under damp heat exposure. Mechanisms tracked using FTIR peaks of EVA and TGA measurements of the PET backsheet.

PV Degradation Pathways: Exp. 2

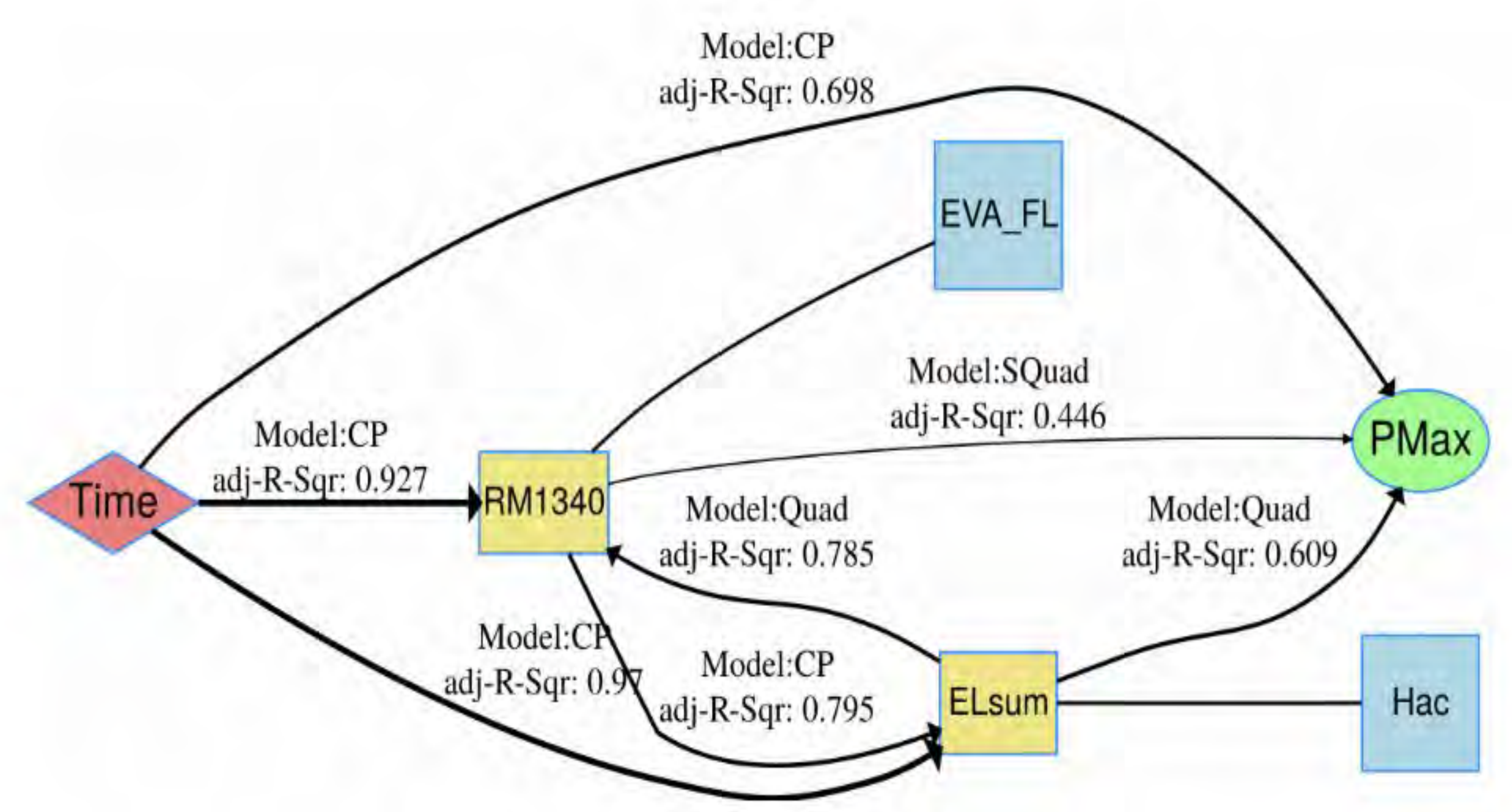

Figure 3: Mini-module PV degradation pathway model under damp heat exposure. Mechanism tracked using confocal Raman spectroscopy and electroluminescent image processing.

Advantages of netSEM

- Used to find the dominant mechanisms and the degradation pathways
- Can be sequential mechanisms on pathway
- Or parallel (competing) pathways
- It's easy to map stressors, degradation mechanisms and responses using R and netSEM
- netSEM application to long-term data: used along with lab-based (accelerated) data to study degradation

References

- French, Roger H., et al. "Degradation Science: Mesoscopic Evolution and Temporal Analytics of Photovoltaic Energy Materials." *Current Opinion in Solid State and Materials Science.* 19.4 (2015): 212-226.
- Gok, A.K., et al. "Degradation Science and Pathways in PV Systems." *Durability and Reliability of Polymers and Other Materials in Photovoltaic Modules*. 1 (2019): 47-93.
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This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Solar Energy Technologies Office (SETO) Agreement Number DE-EE0007140.

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RESEARCH PROJECT

Assignment of Climate Zones for outdoor weatherability and degradation testing use ‘kgc’ R package

Raymond Wieser, Chelsey Bryant, Nicholas R. Wheeler, Franz Rubel, Roger H. French

Case Western Reserve University

9/1/19

BACKGROUND

Köppen Geiger Climate zones are a type of classification used to denote different climate areas across the globe. They are divided into five main climate classifications: Equatorial, Arid, Warm Temperate, Snow, and Polar. After the main designation they are subdivided by the amount of precipitation and temperature. Traditionally, the climate zone classification has be assigned from estimating the studies position on the map. However, this method is unreliable and can prove erroneous in locations that straddle two seperate climate zones.

DATASET

The Dataset is representative of the climate zone classifications from 1950-2000

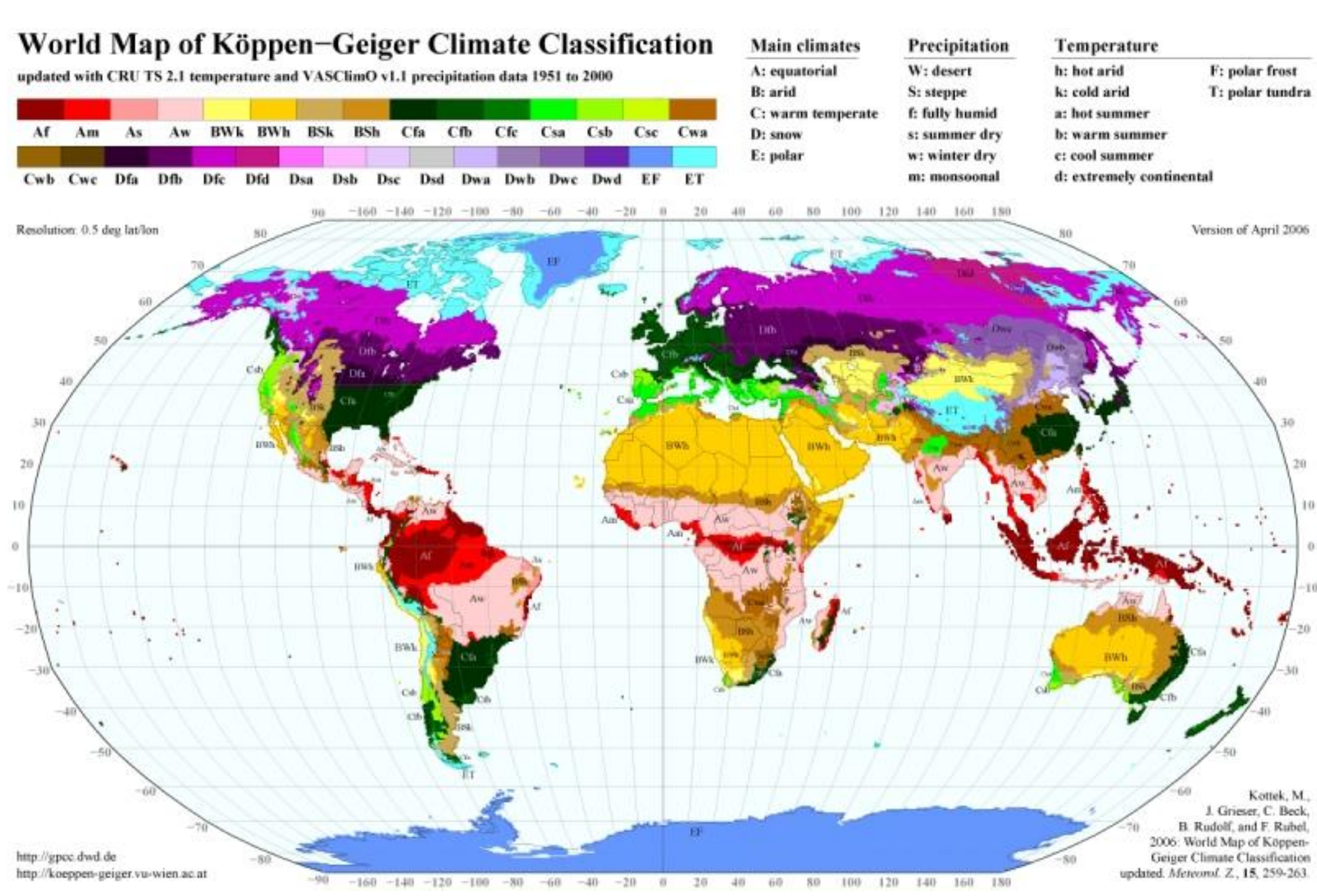
- Updated in 2006
- Spatial resolution of 0.5 degree or 30 arcminutes

HELPER FUNCTIONS

These are the two functions that run the program. They both require dataframes as inputs

- LookUpCZ()
  - Takes in a data frame that has columns labeled
    - roundCoord.lat
    - roundCoord,lon
  - Returns Climate Zone
- CZUncertainty
  - Takes in dataframe with
    - roundCoord.lat
    - roundCoord.lon
    - Climate.Z
  - Returns uncertainty, and other possible climate zone classifications

KÖPPEN-GEIGER CLIMATE MAP



Classification of the Köppen Geiger Climate zones updated in 2006 [1]

LOOKUP FUNCTIONS

These are functions that assist in the use of the program.

- RoundCoordinates()
  - Automatically rounds coordinates to the nearest 0.25 or 0.75 degree
- TranslateZipCode()
  - Translates US zip code into latitude and longitude coordinates
- RunExample()
  - Simplifies the program so that only latitude and longitude or zip code are needed

OUTCOMES

The project goal was to index each latitude and longitude and develop a simple program to output the Koppen Geiger climate designation

- Can either take latitude and longitude values or US zip code
- Rounded to the nearest 0.25 or 0.75 degree
- Can also output an uncertainty for classification based on nearby climate zones

CITATIONS

1 Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of the Köppen-Geiger climate classification updated. *Meteorol. Z.*, **15**, 259-263. DOI: 10.1127/0941-2948/2006/0130.

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NEW PROPOSAL

Bio Inspired, Mechanically Durable, Self-Healing, Anti Icing and Transparent Encapsulation Coatings

Paul W. Leu and Anthony J. Galante
University of Pittsburgh, Department of Industrial Engineering
9/11/2019

Anti Icing Coating

1. **Alleviate the economic loss and hazards from the deposition of ice and water vapor for various transportation and industrial applications**
- Develop a cost-effective, mechanically durable, anti-icing, liquid repellent nanomaterial paint coating for various substrates

Applications


Ships & Automobiles

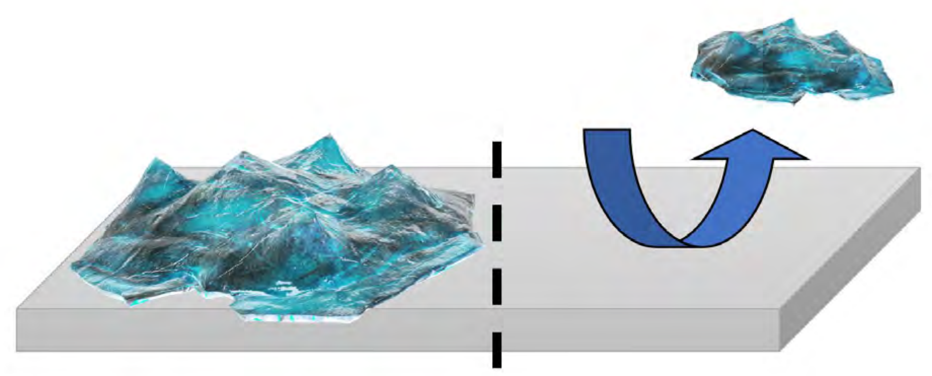

Aerospace & Aircrafts


Wind & Other Natural Energy Systems


Power Lines & Heating Systems

Anti Icing Objectives

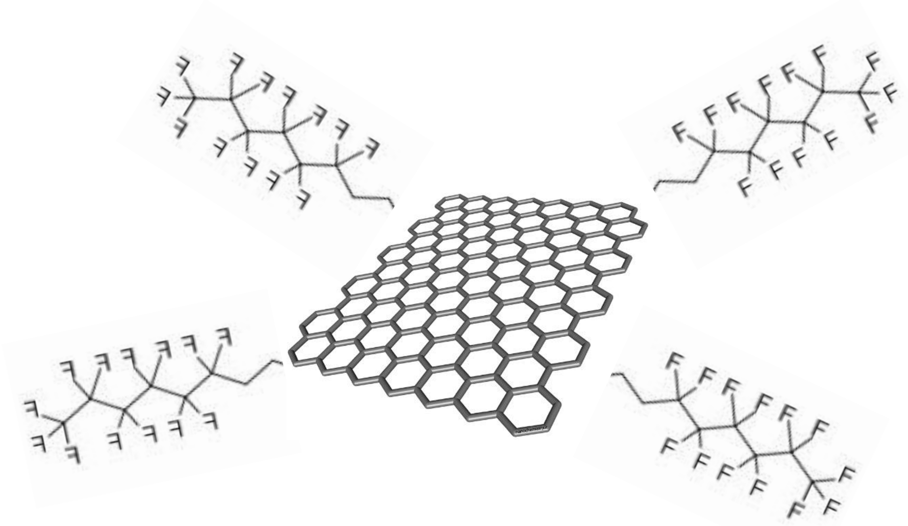
- Demonstrate anti-icing performance under various conditions
- Achieve excellent mechanical and liquid impalement durability
- Measure cost/performance for industrial uses


Schematic comparing ice deposition behavior of uncoated (left) and coated (right) surfaces.

- Other requirements for the coating include:
  - Exceptional liquid repellency
  - Dynamic pressure robustness
  - Mechanochemical robustness

LEVERAGED TECHNOLOGIES

- Coal derived, fluoro-functionalized graphene oxide for scalable production of water repellent carbon nanosheets (provided by NETL)

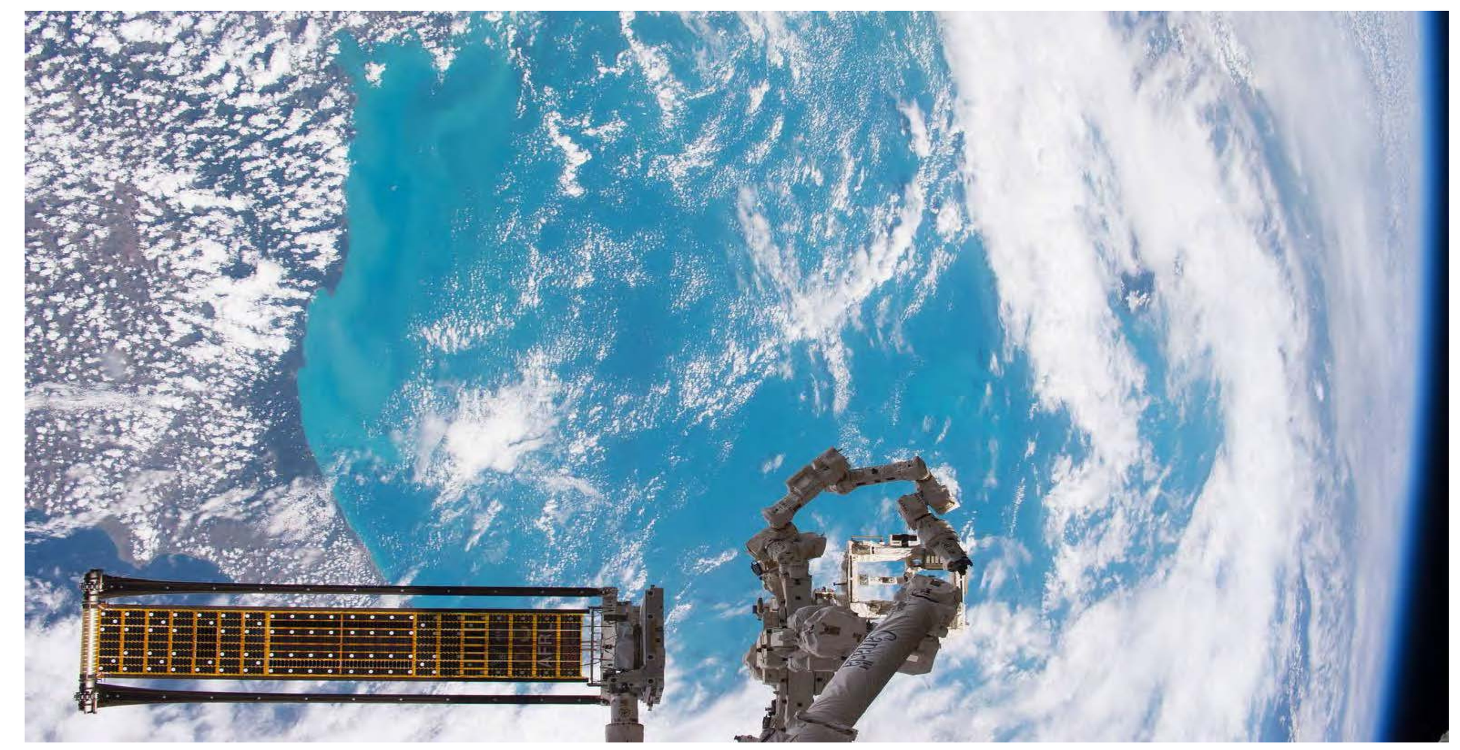


Encapsulation Coating

2. **Extend the lifetime and efficiency of flexible organic electronic devices to overcome commercialization obstacles**
- Create a transparent, nanomaterial encapsulation coating for enhancing development of organic electronic devices
- Eliminate transmission of water vapor and oxygen – main culprits of organic electronic device degradation

Applications

Flexible Organic Solar Cells


Flexible solar cell panel being rolled out from a satellite over the United States.


Advancements in Wearable Electronics

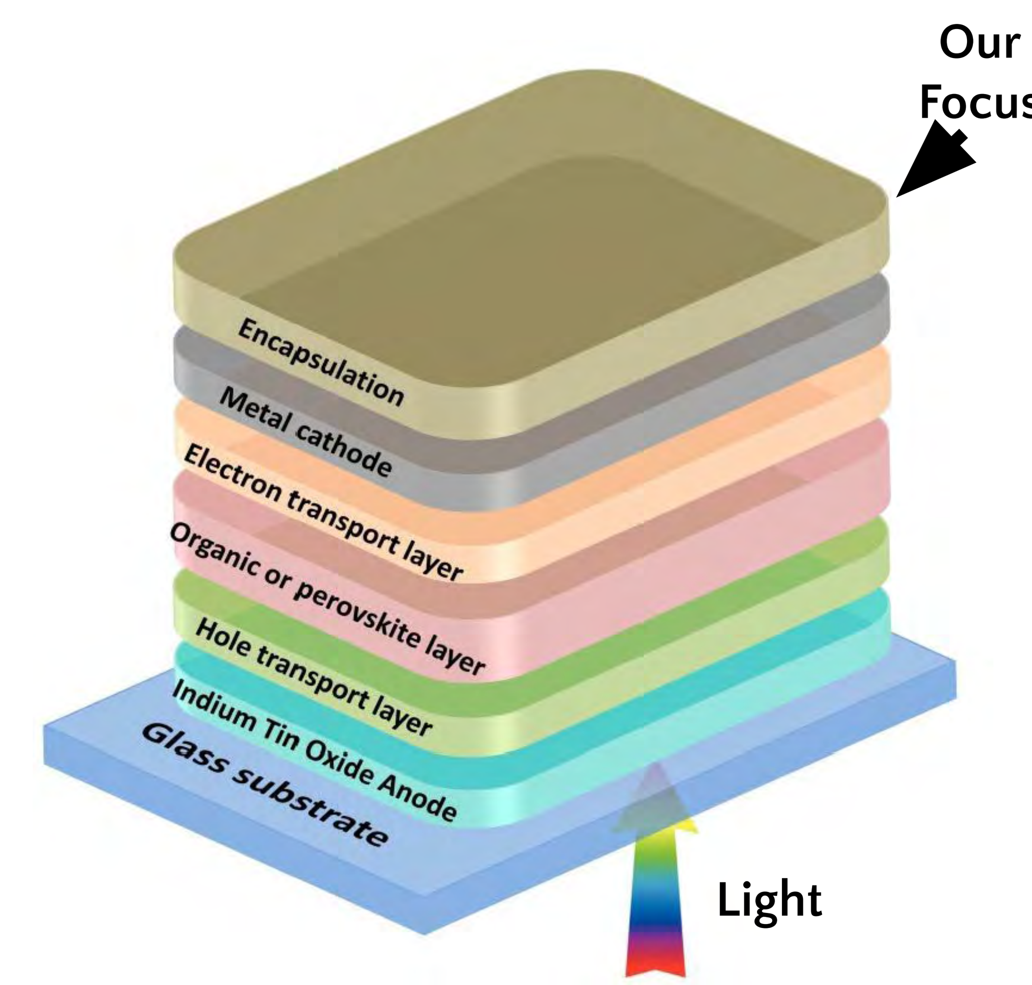

Flexible OLED Displays

Encapsulation Objectives

- Maximize transparency with minimal haze and water vapor transport for perovskite solar cell applications
- Measure durability and encapsulation impact on performance efficiency of organic electronic devices
- Extend the commercialization horizon for organic electronic devices

What is Encapsulation?

- Water and oxygen molecules permeate and degrade the integrity of the organic layer within these electronic devices
- Encapsulation limits this transport of water and oxygen
  - Essential for development and application of new organic electronic devices
  - Extends the device lifetime and efficiency



Layers of a standard organic solar cell with the encapsulation layer on top. [1]

References & Acknowledgements

[1] A. Uddin, M. B. Upama, H. Yi, and L. Duan, "Encapsulation of Organic and Perovskite Solar Cells: A Review," *Coatings*, vol. 9, no. 2, p. 65, Feb. 2019.

We would like to acknowledge NSF, as well as Chris Matranga and Conjun Wang from NETL for their work.

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RESEARCH PROJECT

Real-world PV Module Degradation across Climate Zones Determined from Suns-Voc , Loss Factors and I-V Steps Analysis of Eight Years of Time-series Pmp , I-V Datastreams

Roger H. French, Wei-Heng Huang, Jennifer L. Braid, Jiqi Liu, Menghong Wang, Alan J. Curran

Case Western Reserve University, Materials Science & Engineering

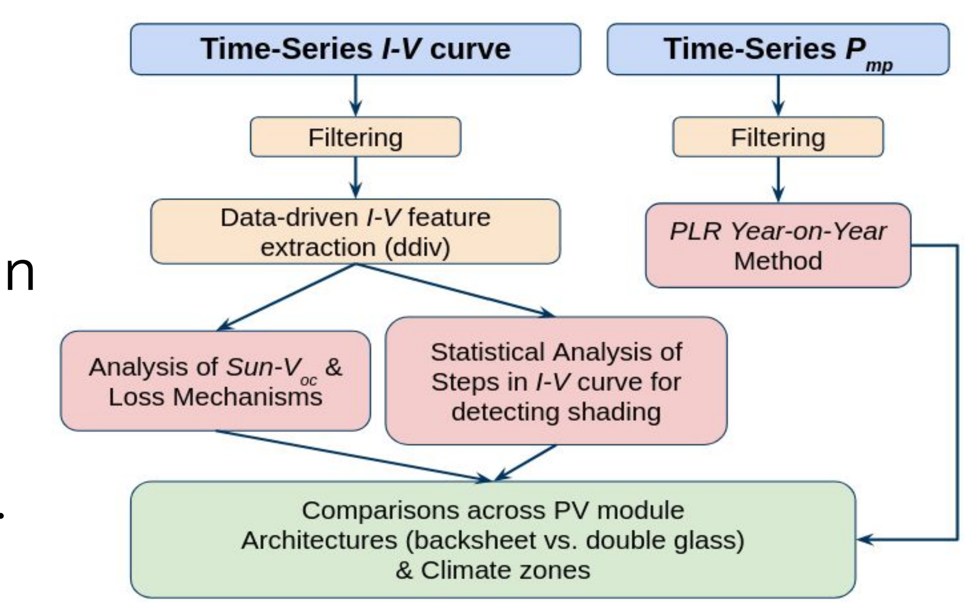
September 05, 2019

PROJECT DESCRIPTION

- Our study uses acquisition of I-V and Pmp time-series data streams in to better understand field performance and degradation mechanisms of PV systems
- Being a reliable source of renewable energy, the size of the global solar energy market has been growing rapidly. The long term reliability of PV modules in real world exposure conditions is becoming an increasingly critical research area, as it plays an important role in determining the lifetime performance and levelized cost of electricity (LCOE)
- Our study can be used to monitor and analysis the degradation of general performance and mechanisms for PV modules installed in field

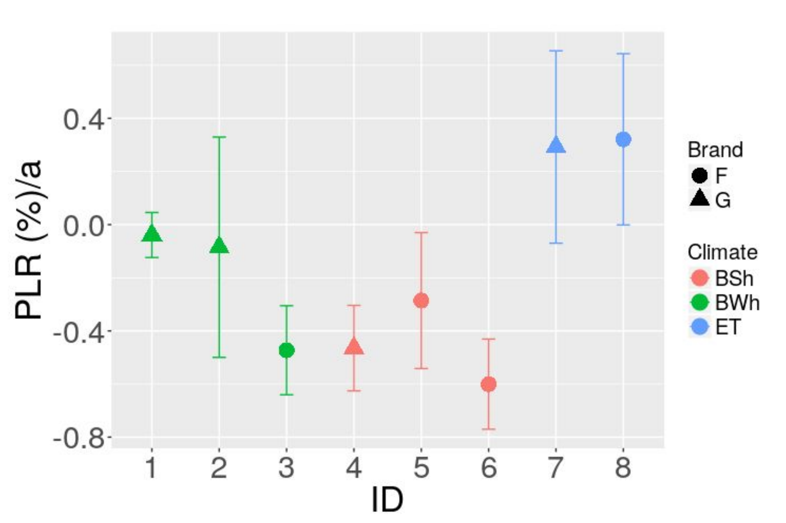
Study Process

- ddiv[1] is applied to eight years of time-series I-V curves to obtain the I-V features and to detect steps in the I-V curves for identify potential partial shading.
- The PLR of each module is calculated by Pmp time-series datastreams. Then the time-series Suns-Voc curves are determined for each module for dominant degradation mechanisms.
- Evaluate the degradation of PV modules with comparisons between two brands with differing architecture across climate zones.



Dataset Description & PLR

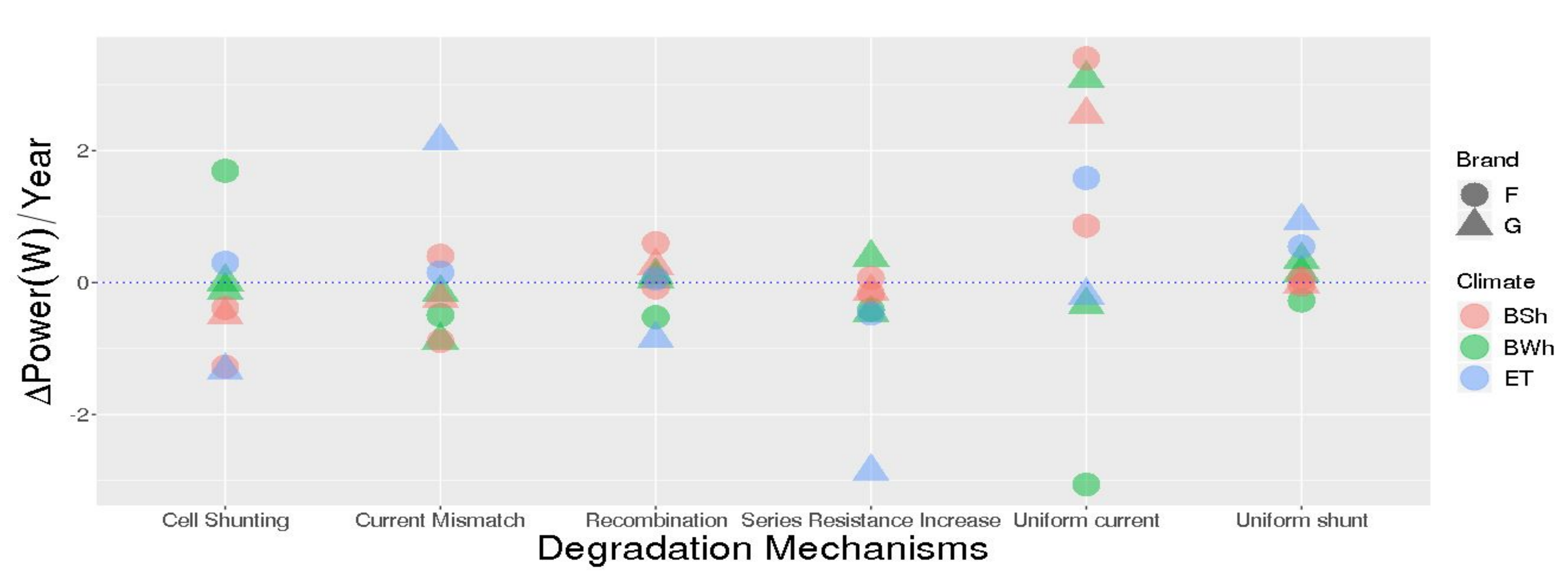
- 8 modules with system age from 3 to 8 years, belong to F or G brands & located in 3 climate zones[2].
- PLR[3] result:
  - F(GB) modules have larger PLR than G(DG) Modules: in BWh, quite comparable in other 2 CZs
  - BSh climate zone, most aggressive exposure



CZ / Location	GB: F (%/yr.)	DG:G (%/yr.)
BWh / Gran Canarias	-0.47	-0.062
BSh / Negev	-0.44	-0.46
ET / Zugspitze	0.32	0.29

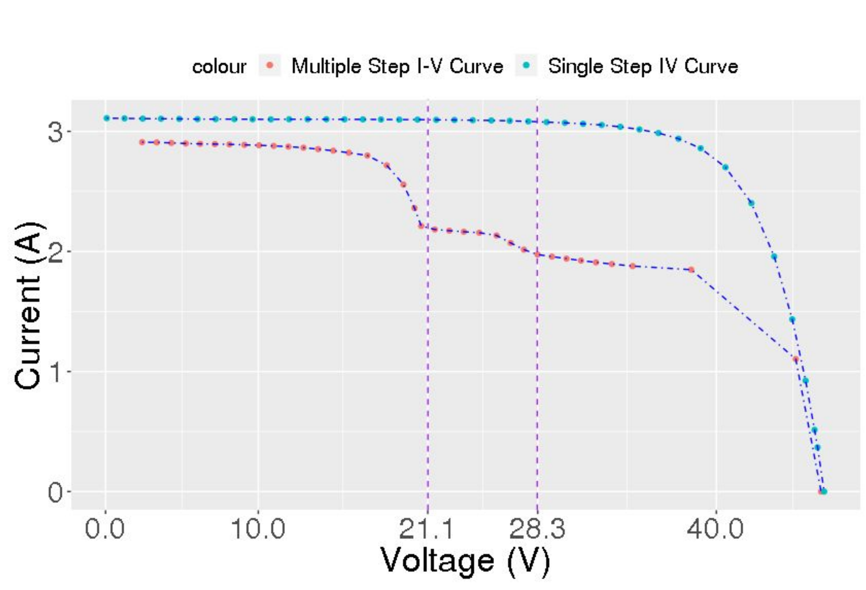
Time-Series Suns-Voc[4]

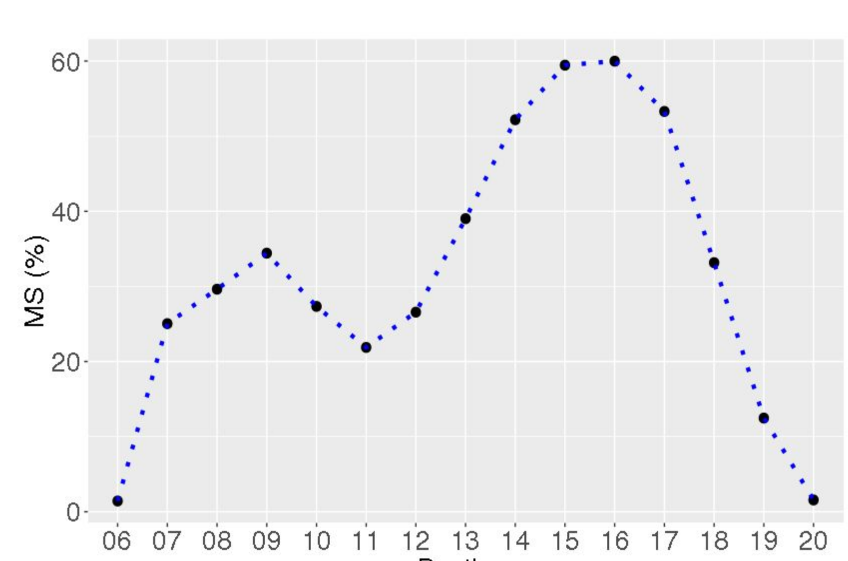
- Climate zone dependency: Common mechanistic loss factors in a KG-CZ[2]
  - BWh: Current Mismatch
  - BSh: Cell shunting
  - ET: Series resistance increase



Steps & Shading Detection

- ddiv[1] can detect the steps in I-V curves with extraction of I-V features at each step include
  - Pmp, Isc, Imp, Voc, Vmp, Rs, Rsh , FF
- The distribution of MS (percentage of multiples steps I-V curve) vs. Time in a day
- shows the relative position of the obstruction to the observed module





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This work was supported by the DOE-EERE SETO award DE-EE-0007140. Research was performed at the SDLE Research Center, which was established through funding through the Ohio Third Frontier, Wright Project Program Award tech 12-004. This work made use of the Rider High Performance Computing Resource in the Core Facility for Advanced Research Computing at CWRU

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RESEARCH PROJECT

Structural Equation Modeling (SEM) for Lifetime and Degradation Science (L&DS) using netSEM

Roger H. French, Laura S. Bruckman, Kunal Rath

Case Western Reserve University, Macromolecular Science and Engineering

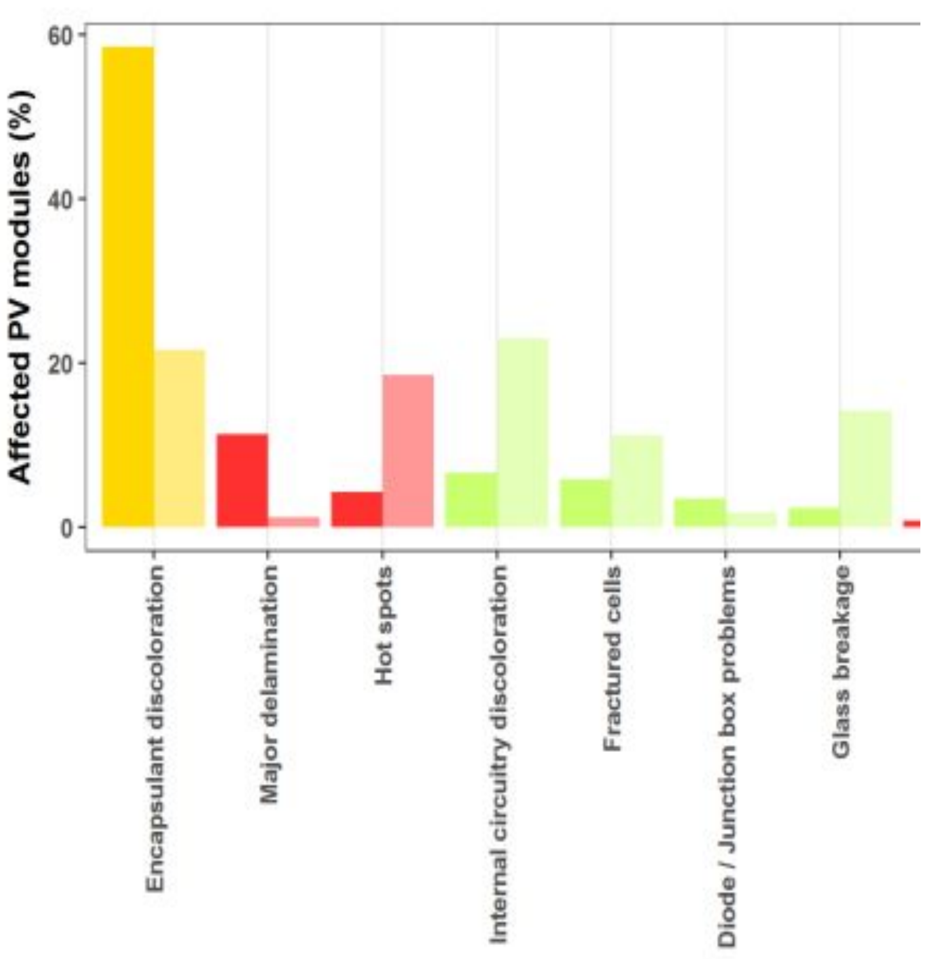
September 9th, 2019

Package Description

The SDLE lab has produced a methodology and an R package called netSEM, which adds quadratic, exponential, and logarithmic modeling to traditional structural equation modeling through an R package.

The R package contains example datasets as well as the function to generate netSEM from data.

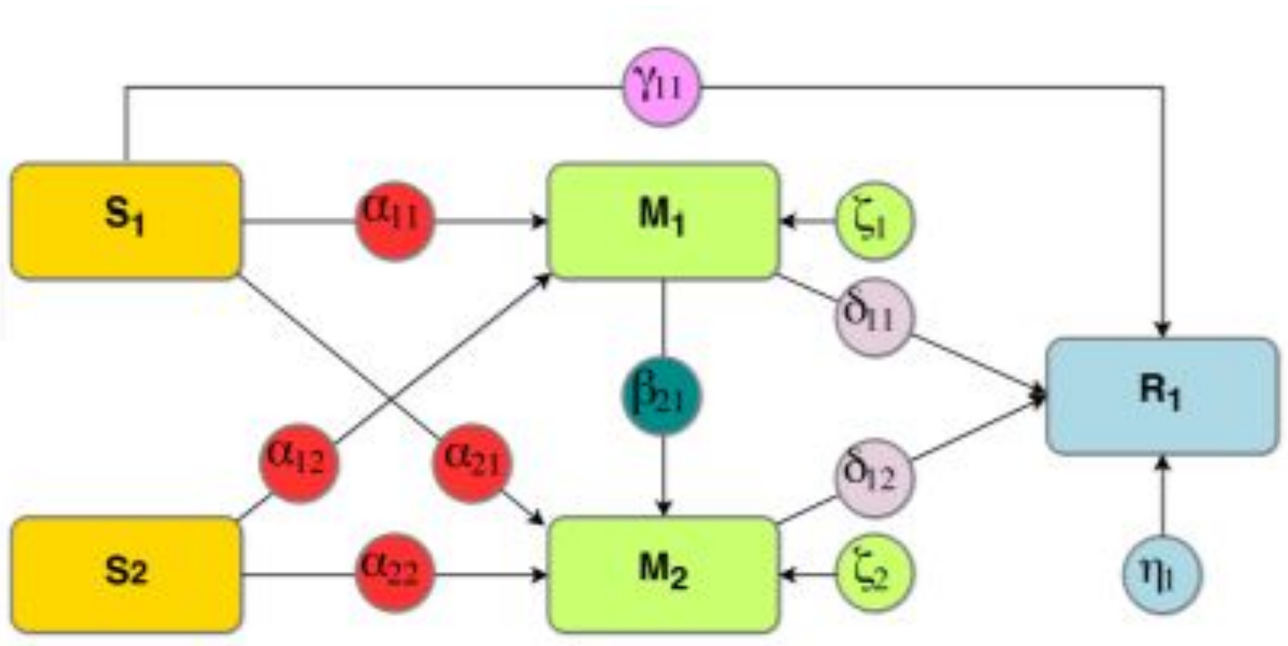
Common Degradation Mechanisms of PET



Yellowness index (YI) is a good main endogenous variable to use both because it is observed in a large number of PV modules, and because it is caused by a combination of known mechanisms.

Generalized Applications

Network SEM can be applied to stressor/response systems with included mechanisms (<S|M|R>). Primary endogenous variable can be selected based on the factor of interest, and intermediate variables can be selected based on available instrumentation/measurement techniques.

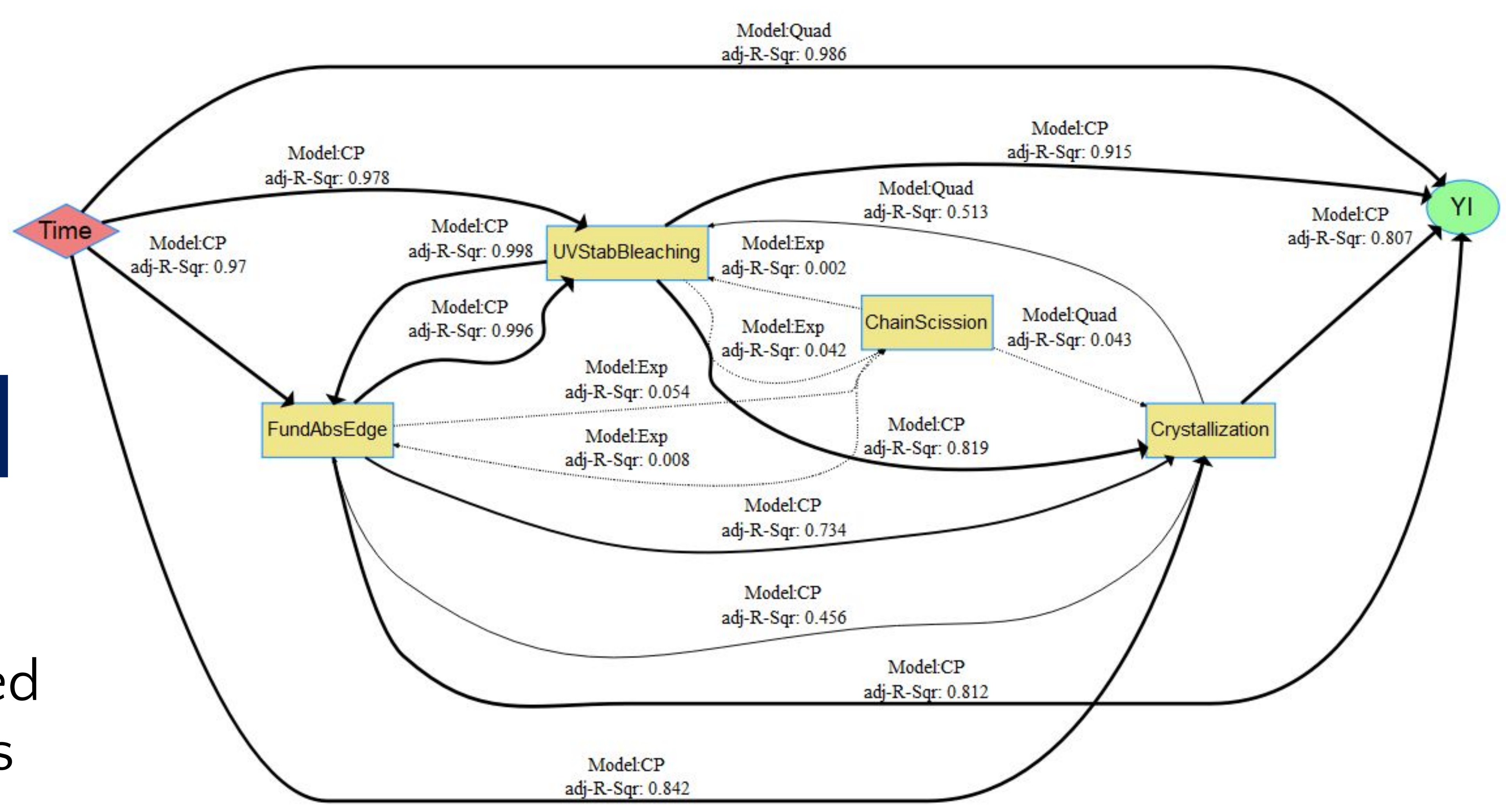


$$M_1 = x + \alpha_{11} S_1 + \alpha_{12} S_2 + \zeta_1$$
$$M_2 = y + \alpha_{21} S_1 + \alpha_{22} S_2 + \beta_{21} M_1 + \zeta_2$$
$$R_1 = z + \gamma_{11} S_1 + \delta_{11} M_1 + \delta_{12} M_2 + \eta_1$$

Vignettes

- Datasets in package
  - crack, acrylic, **PET,** backsheet, IVfeature, metal: datasets that study mechanical and electrical degradation pathways
  - PET: study of photolysis and hydrolysis of UV stabilized PET
    - ASTM G-154 Cycle 4 standard accelerated weathering conditions
    - YI (yellowness index) is the main response variable
    - intermediate response variables measured by optical and infrared (IR) spectroscopy
- netSEMm(): applies netSEM to dataframe, endogenous/exogenous variables can be defined

netSEM::data(PET) Network Diagram



References

French, Roger H., et al. "Degradation Science: Mesoscopic Evolution and Temporal Analytics of Photovoltaic Energy Materials." *Current Opinion in Solid State and Materials Science*. 19.4 (2015): 212-226.

Gok, A.K., et al. "Degradation Science and Pathways in PV Systems." *Durability and Reliability of Polymers and Other Materials in Photovoltaic Modules*. 1 (2019): 47-93.

W.-H. Huang, et al. netSEM: Network Structural Equation Modeling, 2018. https://CRAN.R-project.org/package=netSEM (accessed December 2, 2018).

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MULTI-FUNCTIONAL OPTOELECTRONIC SUBSTRATES

Sajad Haghanifar, Michael McCourt, Bolong Cheng, and Paul W. Leu

Research Keywords:
Optoelectronic
Rigid and flexible substrates
Photon Management
Superomniphobic Substrates

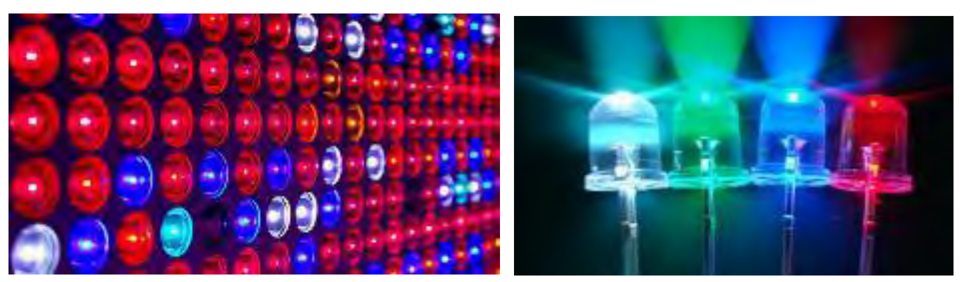
Optoelectronic

Applications

Displays

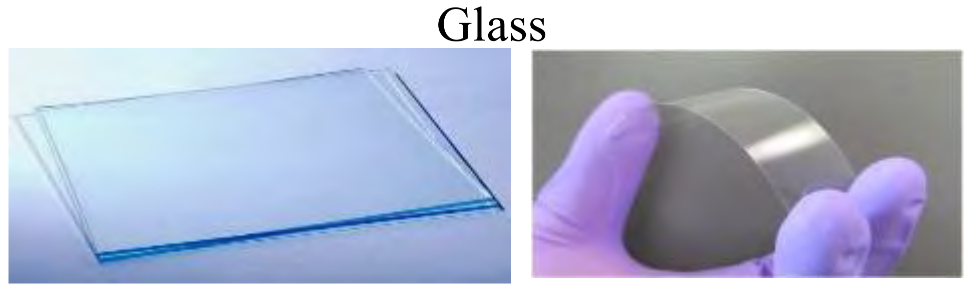
Solar Cells

Light Emitting Diodes (LED)



Substrates

Glass



Plastics | Papers (Transparent)

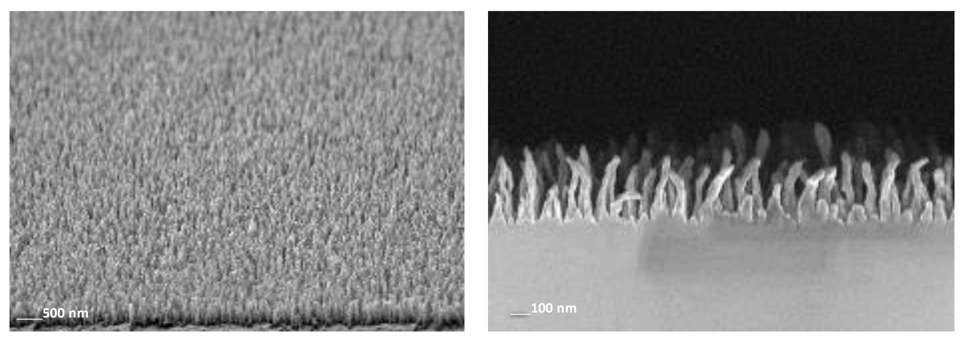
Requirements

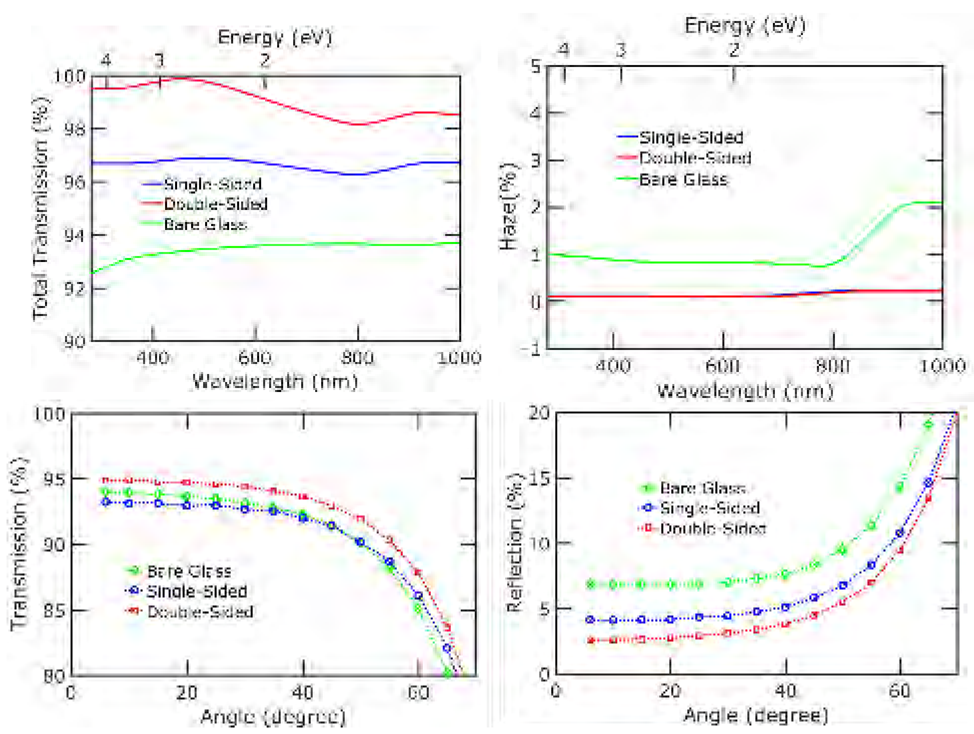
Transparency | Self-Cleaning | Durability

Optical properties

- ❑ For display applications high transparency and low haze is preferred.
- ❑ For solar cell and LED's high transparency and high haze is preferred.

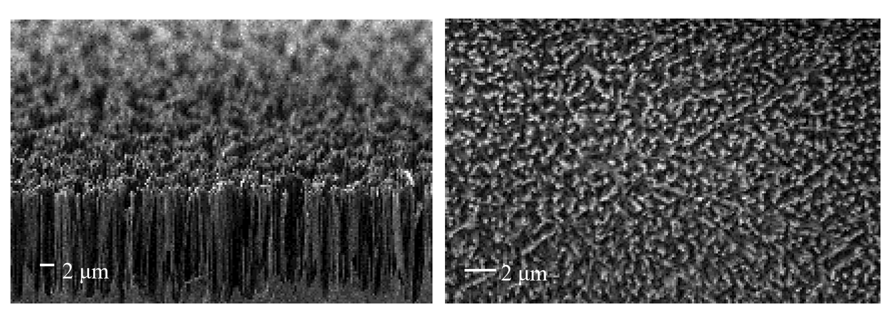
High transparency, low haze glass substrates



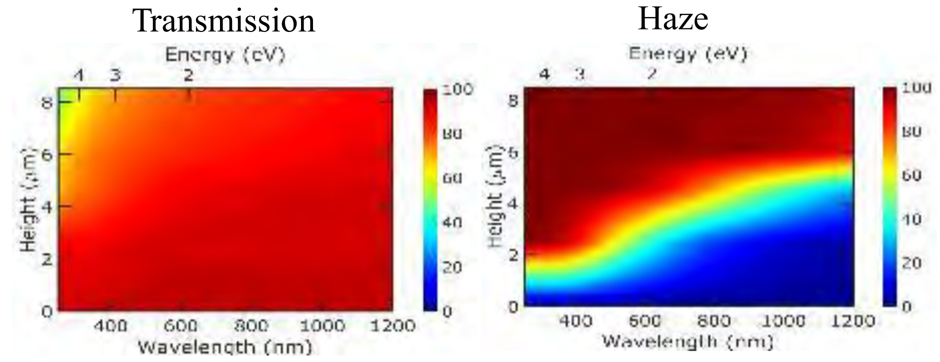


- ❑ 99.5% transmission at 550 nm wavelength
- ❑ Low reflection even at high incident angle

High transparency, high haze glass substrates



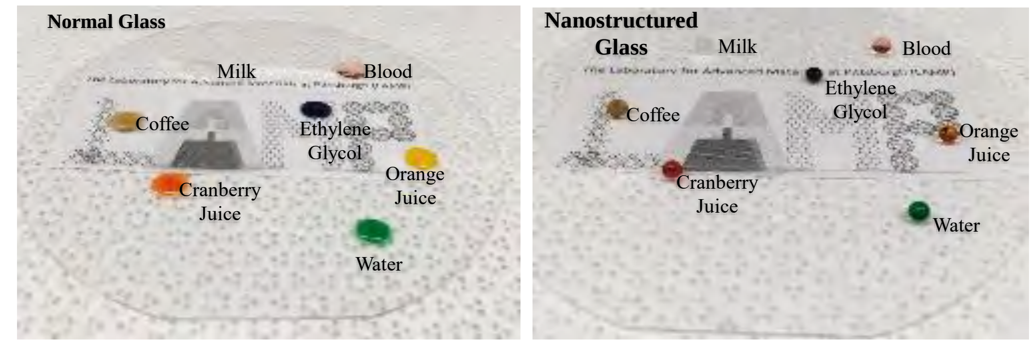
Transmission | Haze



- ❑ Transmission and haze more than 90%

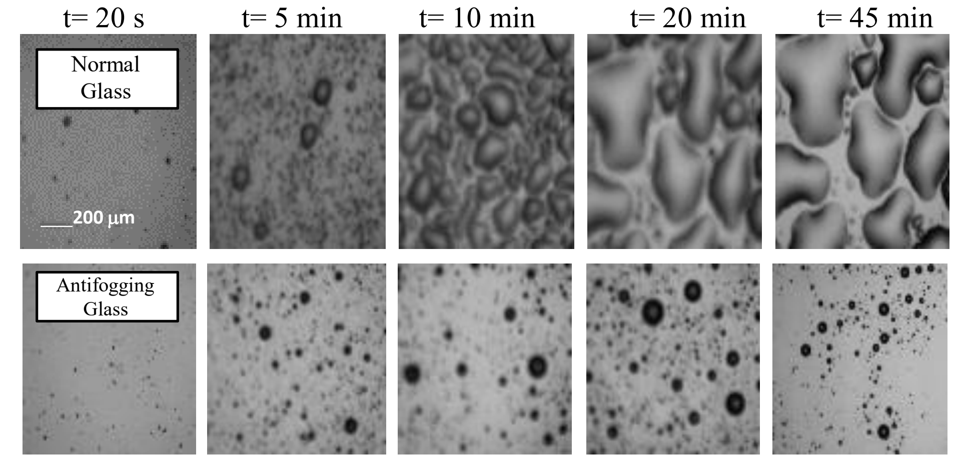
Wetting properties

Superomniphobic, high transparent, low haze



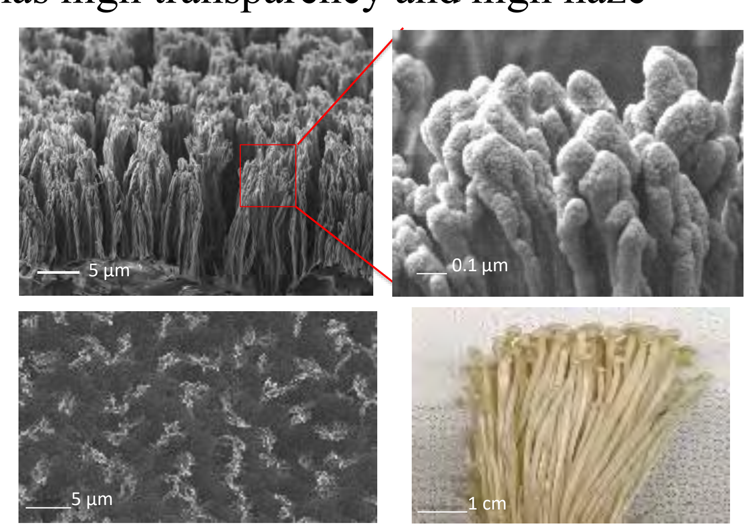
- ❑ It can repel wide variety of liquids, including ethylene Glycol (47 mN/m)
- ❑ Fabrication process directed by machine learning, using SigOpt

Anti-fogging, Anti-Condensation



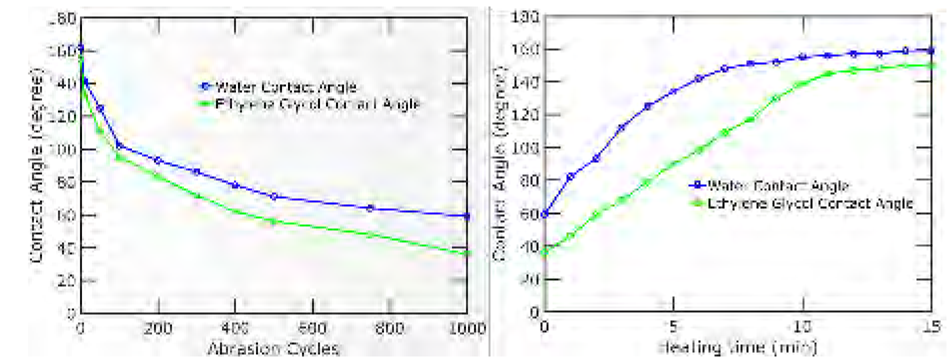
Superomniphobic, high transparent, high haze

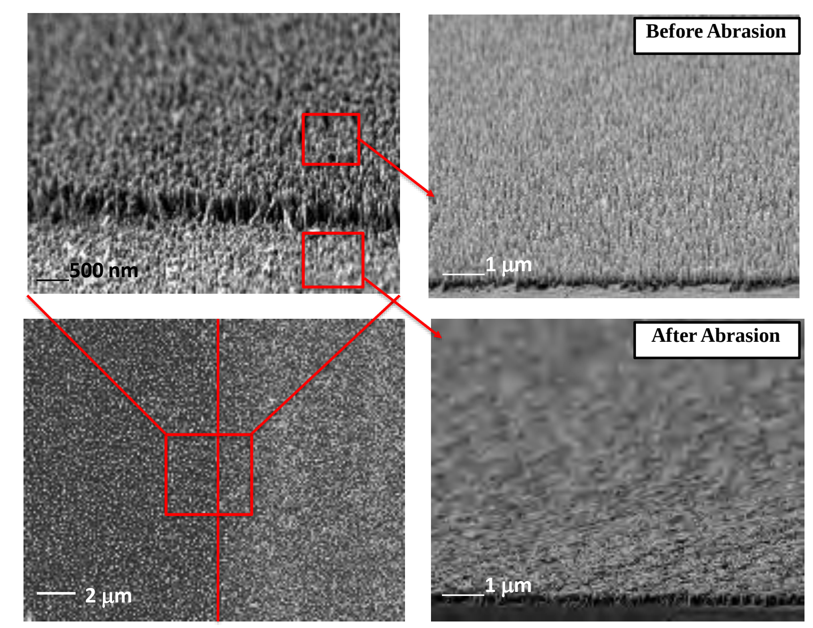
- ❑ It can repel wide variety of liquids, including hexadecane (27.7 mN/m)
- ❑ It has high transparency and high haze



- ❑ Nano-Enoki mushrooms! High aspect ratio

Mechanical Properties





- ❑ Water and oil contact angles reduce after abrasion
- ❑ By heating the substrate after abrasion, water and oil contact angle increase significantly
- ❑ No change in optical properties observed after abrasion
- ❑ Self-healing properties

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Acknowledgment

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RESEARCH PROJECT

Mechanical Reliability of Metallic AM Parts

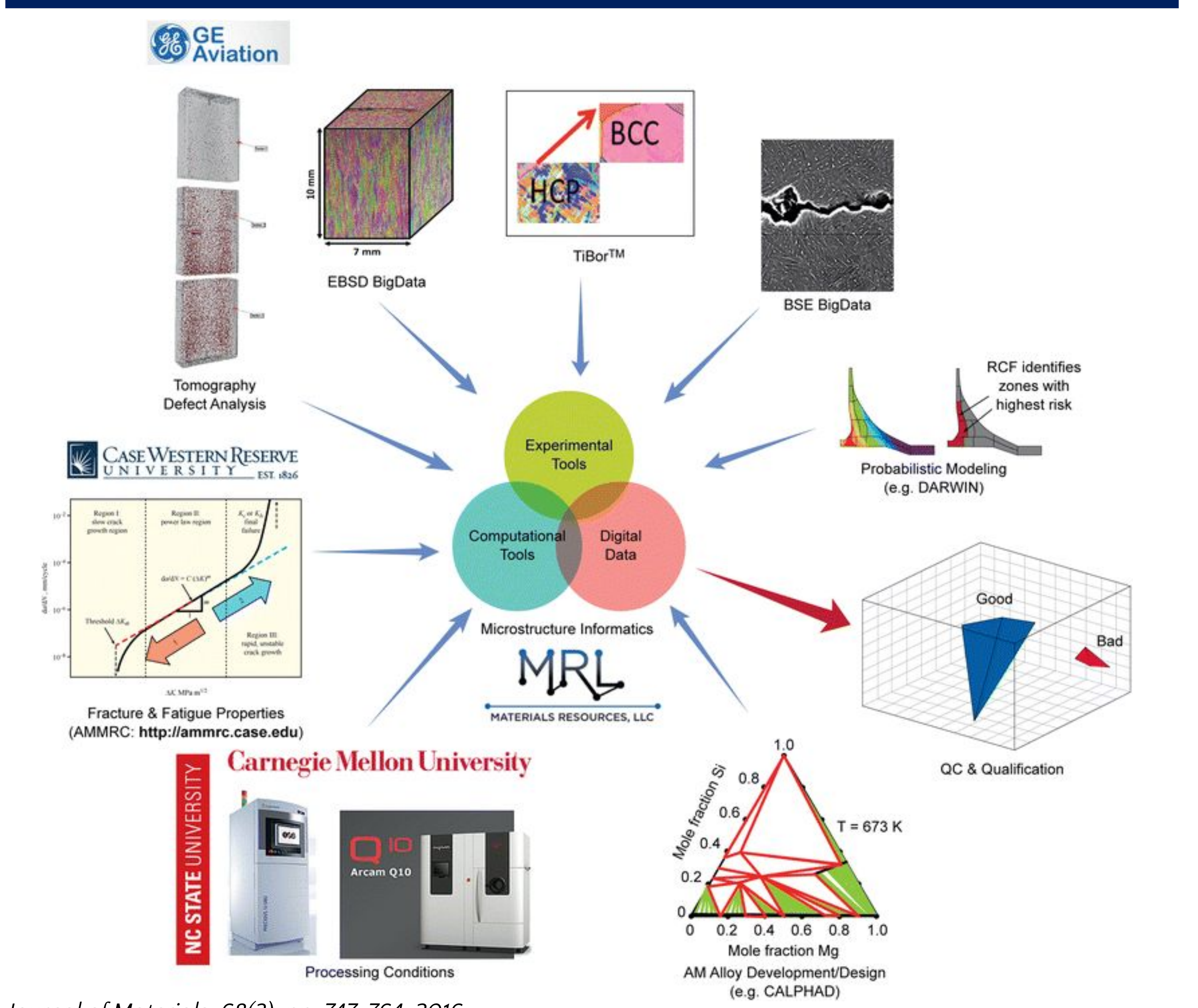
John Lewandowski, Austin Ngo, Hannah Sims, David Scannapieco, and Janet Gbur

PROJECT DESCRIPTION

This review highlights some of the key aspects regarding materials qualification needs across the additive manufacturing (AM) spectrum.

- Process qualification
- Processing-mapping studies
- Microstructure qualification
- Informatics – EBSD/BSE
- Fracture-modeling activities
- Fatigue and fracture testing
- Nondestructive testing and µCT
- Surface roughness effects
- Orientation effects

COLLABORATIVE PLATFORM



Journal of Materials, 68(3), pp. 747-764, 2016

MODEL PROTOTYPES

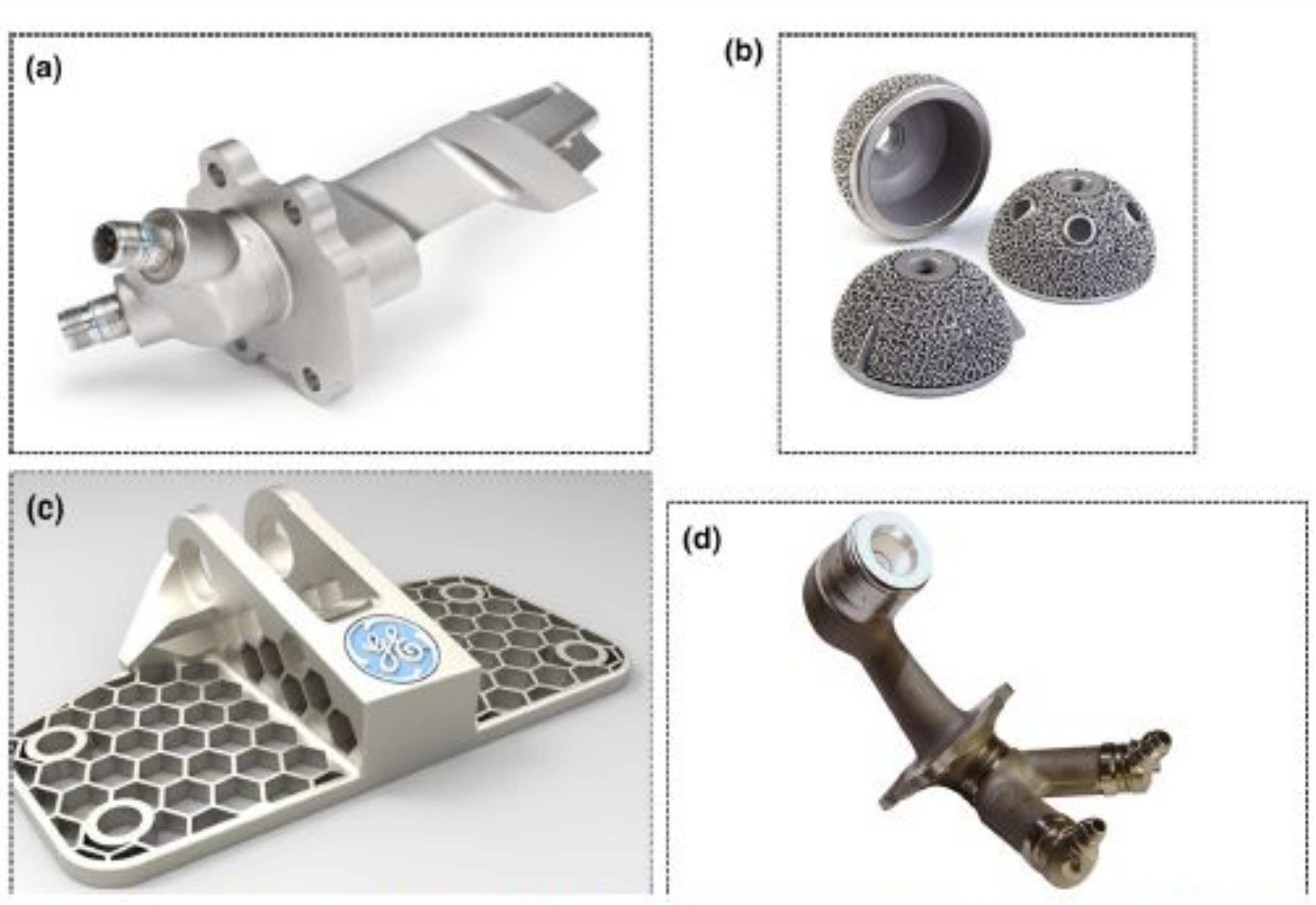


Fig. 4. Examples of parts/components made by Powder Bed Fusion AM technologies. (a) Inlet temperature sensor housing for jet turbine engine, roughly 7.5 mm tall; (b) Ti-6Al-4V acetabular cup produced by electron beam melting, EBM (i.e. Arcam); (c) Bracket produced via laser-based powder bed (i.e. EOS); (d) GE LEAP engine Co-Cr fuel nozzle produced via direct metal laser melting, DMLM (i.e. EOS).

Journal of Materials, 68(3), pp. 747-764, 2016

SPECIMEN ORIENTATION

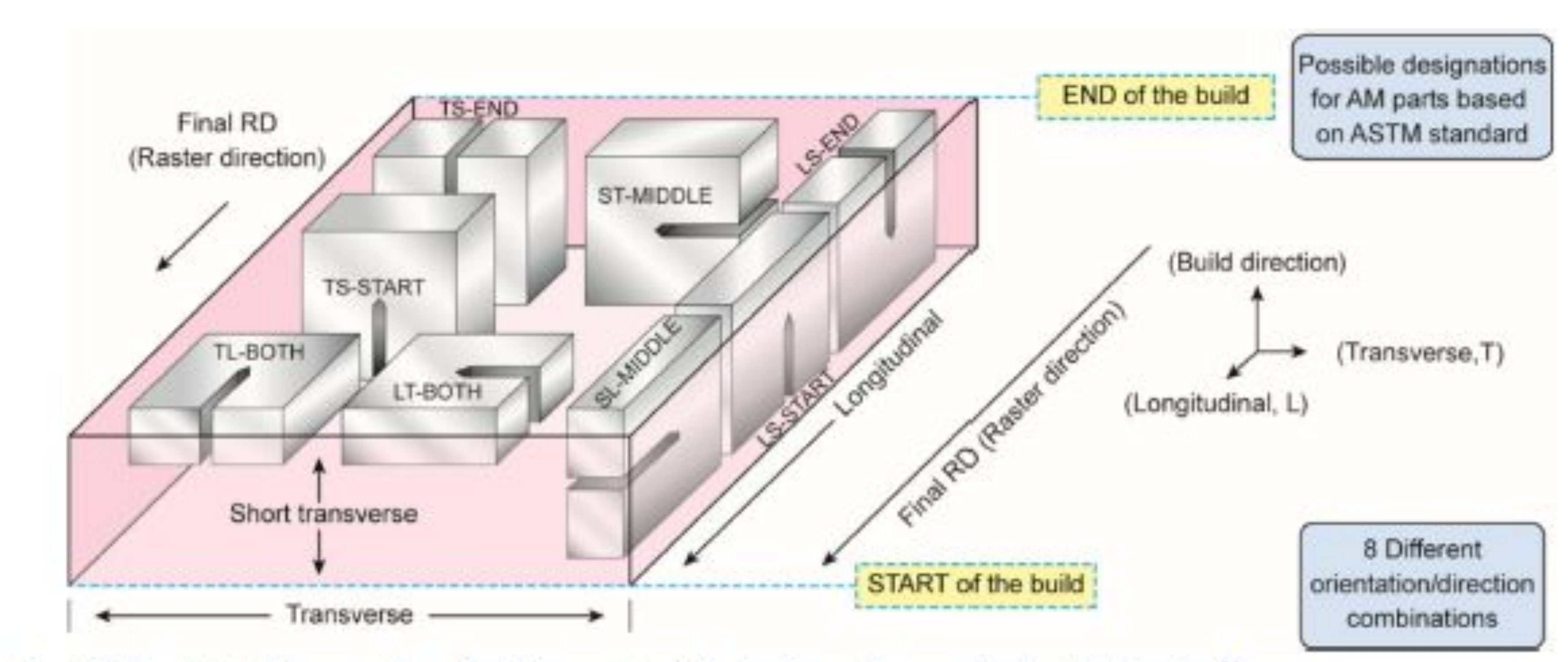
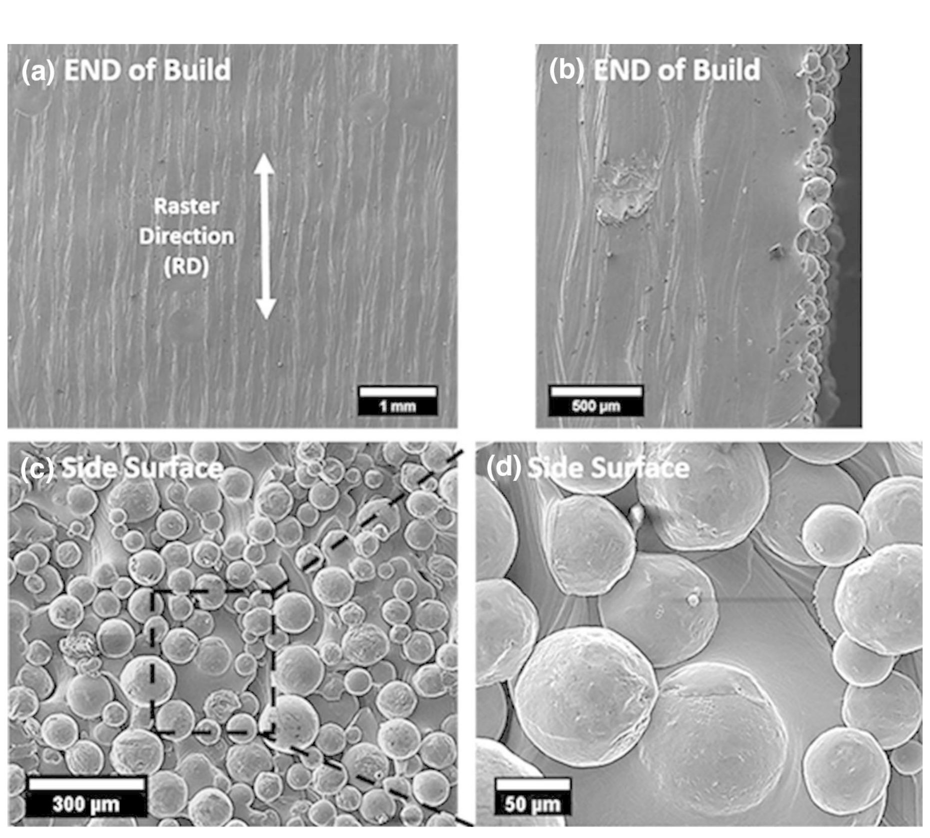


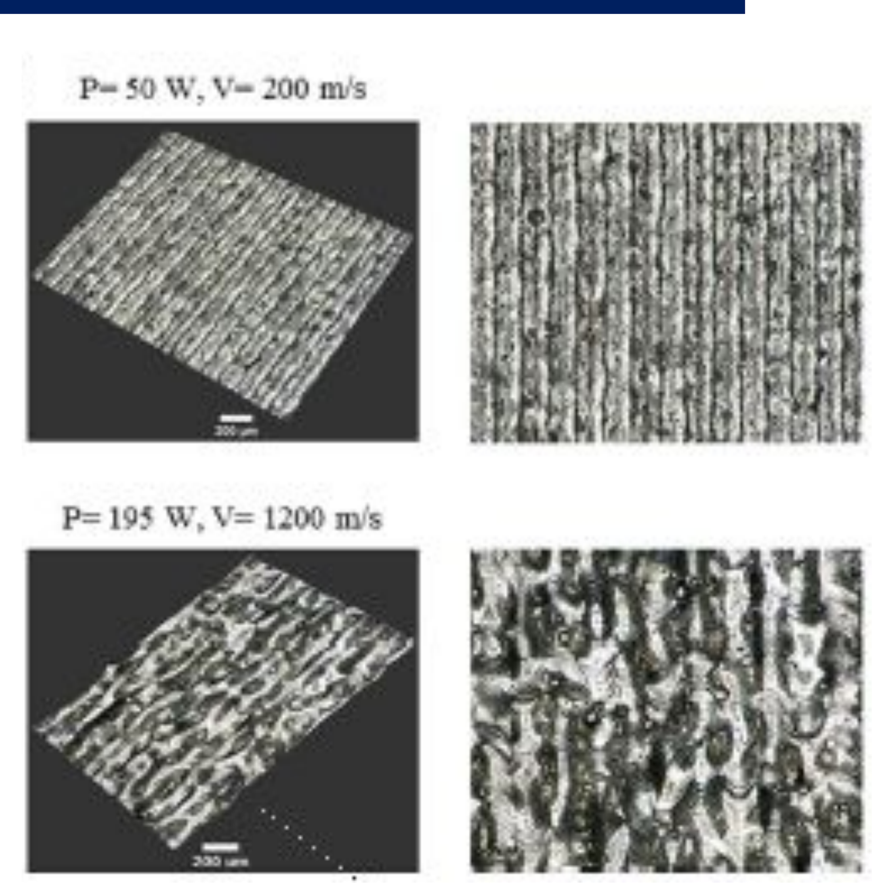
Fig. 12. Possible ASTM nomenclature illustrating crack growth directions with respect to the build direction.[11]

Journal of Materials, 68(3), pp. 747-764, 2016

AM SURFACE ROUGHNESS

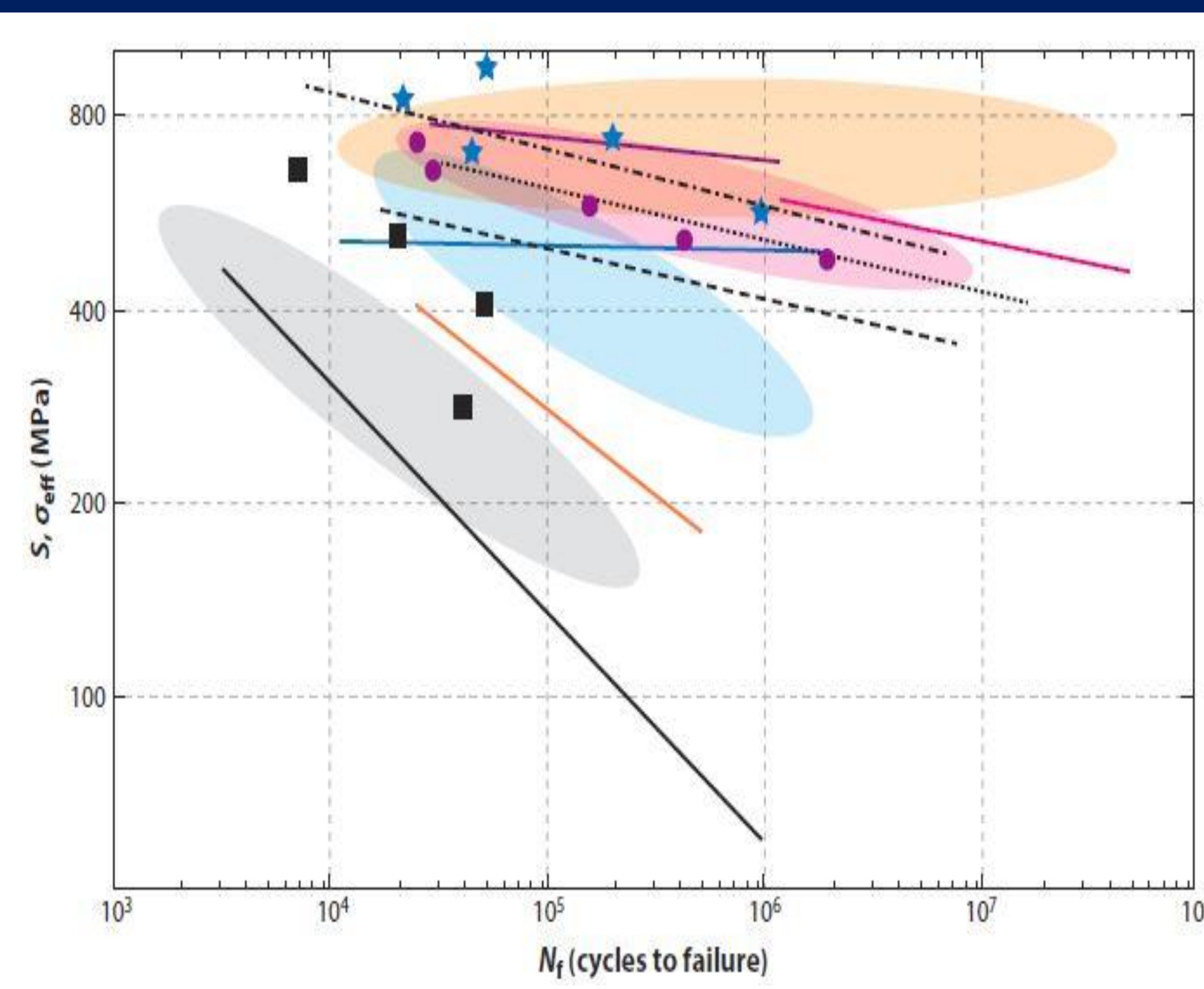


Journal of Materials, 67(3), pp. 597-607, 2015



Journal of Materials, 68(3), pp. 747-764, 2016

AM FATIGUE RESULTS



Annual Review of Materials Research, 46, pp. 151-186, 2016

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RESEARCH PROJECT

Advanced Manufacturing and Mechanical Reliability Center (AMMRC)

John J. Lewandowski and Chris Tuma

Case Western Reserve University – Materials Science and Engineering

PROJECT DESCRIPTION

Established in 1987 and housed in the Charles M. White Building, the AMMRC provides advanced manufacturing (e.g. deformation processing, extrusion, forming, etc.) and mechanical characterization (e.g. mechanical testing, reliability testing, fatigue, etc.) expertise to the CWRU campus, medical, industrial, legal, outside university, and government lab communities.

- Long-term testing at pro-rated charges
- Training available on equipment for clients
- Remotes access controls on some test frames
- Monotonic and cyclic fatigue testing available
- Metals, ceramics, polymers, composites, electronic and biomedical materials

SERVO-HYDRAULIC

MTS and Instron Test Frames

- Tension, compression, fatigue
- Load, stroke, or strain control
- Low T and high T testing
- Low cycle, high cycle fatigue
- Fatigue crack growth
- Fracture toughness
- DCPD – FTA software

MTS

- 50 Kip (2), 20 Kip, 10 Kip, 3 Kip
- Temperature: -125°C to 600°C
- High T alignment grips

Instron

- 5 Kip
- Temperature: -125°C to 225°C

MTS Model 1331

MTS Model 810

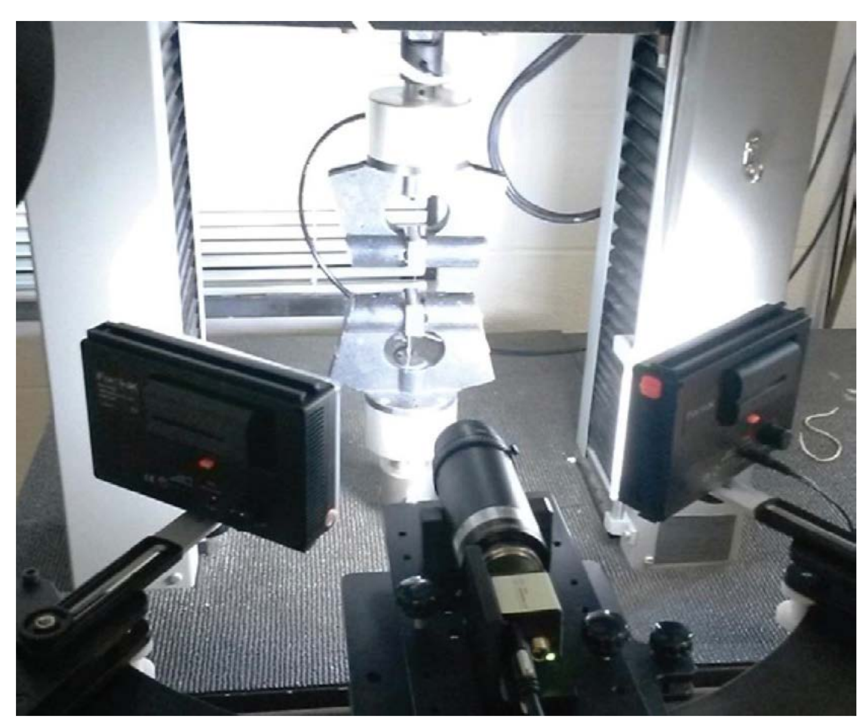
ELECTRO-MECHANICAL

Instron/MTS Test Frame

- Capable of 1 µm/hr test rate
- Temperature < 1500°C
- Environmental testing cells
- Controlled humidity testing
- Load, stroke, or strain control

Left: MTS Insight ReNew test frame

MECHANICAL CHARACTERIZATION



Above: UVID, Inc. Arion 1-D non-contact video extensometer

Left: Example fiducial markings on tensile test specimens

Non-contact Extensometer

- Arion 1-D and 2-D
- Localized strain determination
- Frame rate up to 60 FPS
- Scalable to >100% elongation
- Ideal for wire, thin film, tissue

MICROSCALE WIRE FATIGUE

Jovil Flex Ductility Tester

- Capabilities for R = -1, R = 0 @ 1-17 Hz
- Mandrels up to 31.9 mm diameter

Positool Rotating Bending Tester

- Capabilities for R = -1 @ 60 Hz
- Wet or dry testing

EnduraTEC Test Bench

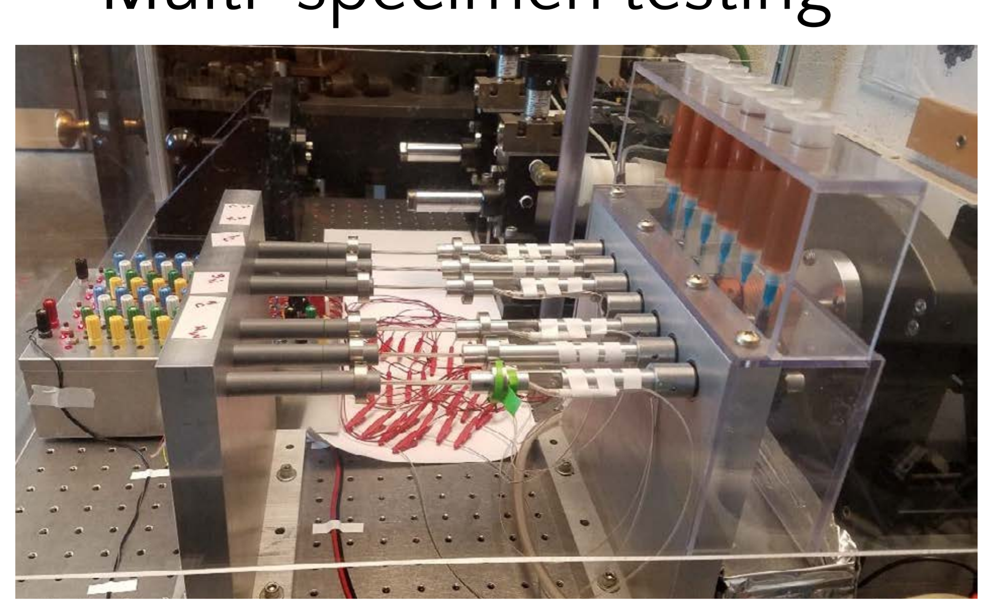
- Load cells: 5 lb, 25 lb, 50 lb, 500 lb, 2 Nm
- Load or displacement control
- Cyclic frequency up to 10 Hz

Flex fatigue tester

CUSTOM FATIGUE SOLUTIONS

Subcomponent/component testing

- Axial, flex, crush, rotary fatigue
- Electrical signal monitoring
- Multi-specimen testing



Multi-specimen rotational fatigue showing functional monitoring

Multi-specimen flex bending fatigue

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MATERIALS DATA SCIENCE
RELY

MDS-Rely Center

www.mds-rely.org
Led by CWRU & PITT
An NSF Industry/University Cooperative Research Center

NSF

RESEARCH PROJECT

Fatigue and Fracture of Wires and Cables Used in Biomedical Applications

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Case Western Reserve University – Materials Science and Engineering
International Materials Reviews, 61(4), pp. 231–314, 2016

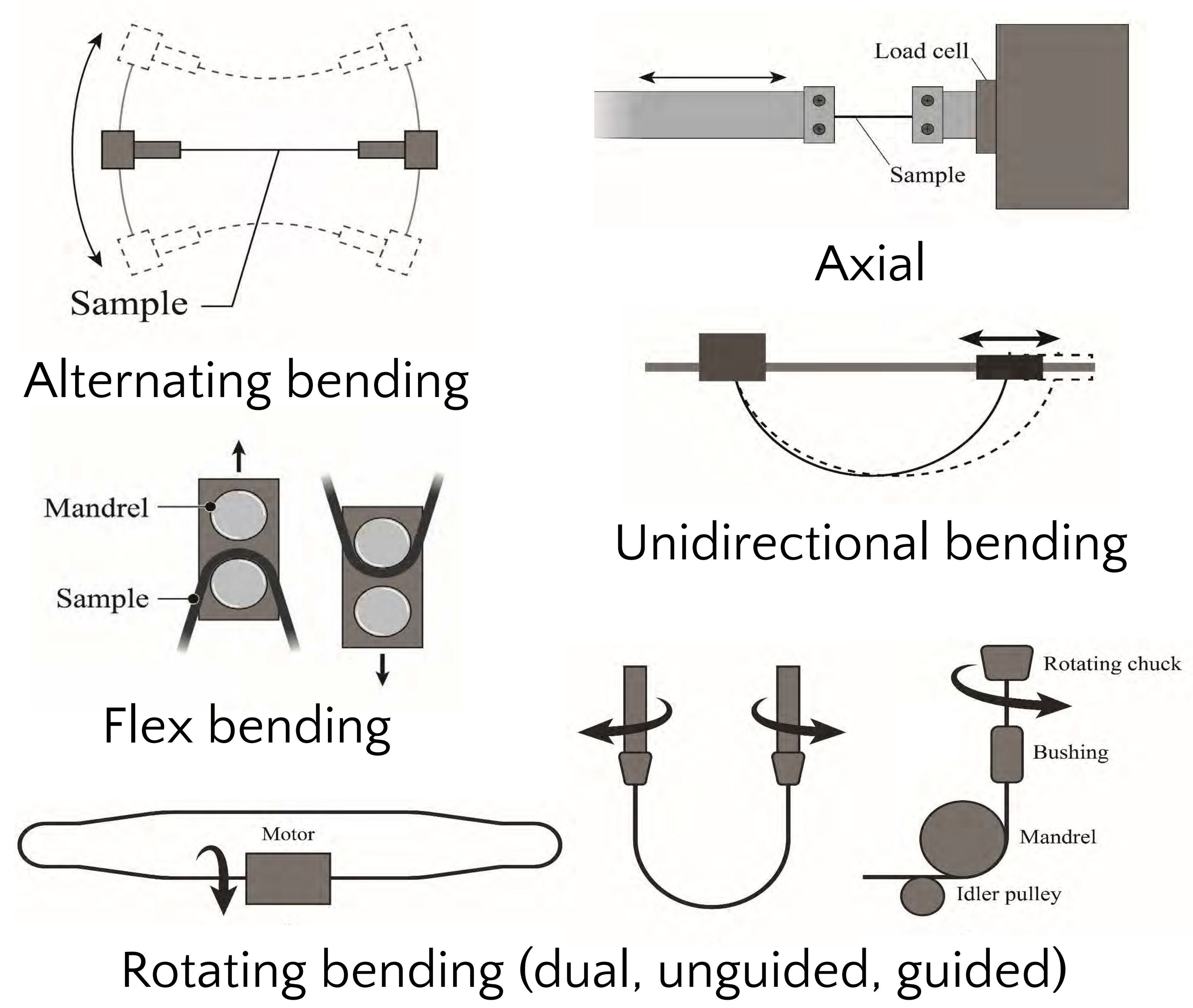
PROJECT DESCRIPTION

Biomedical devices may incorporate fine wires, cables, or coils that transmit recording or stimulation signals depending the treatment modality.

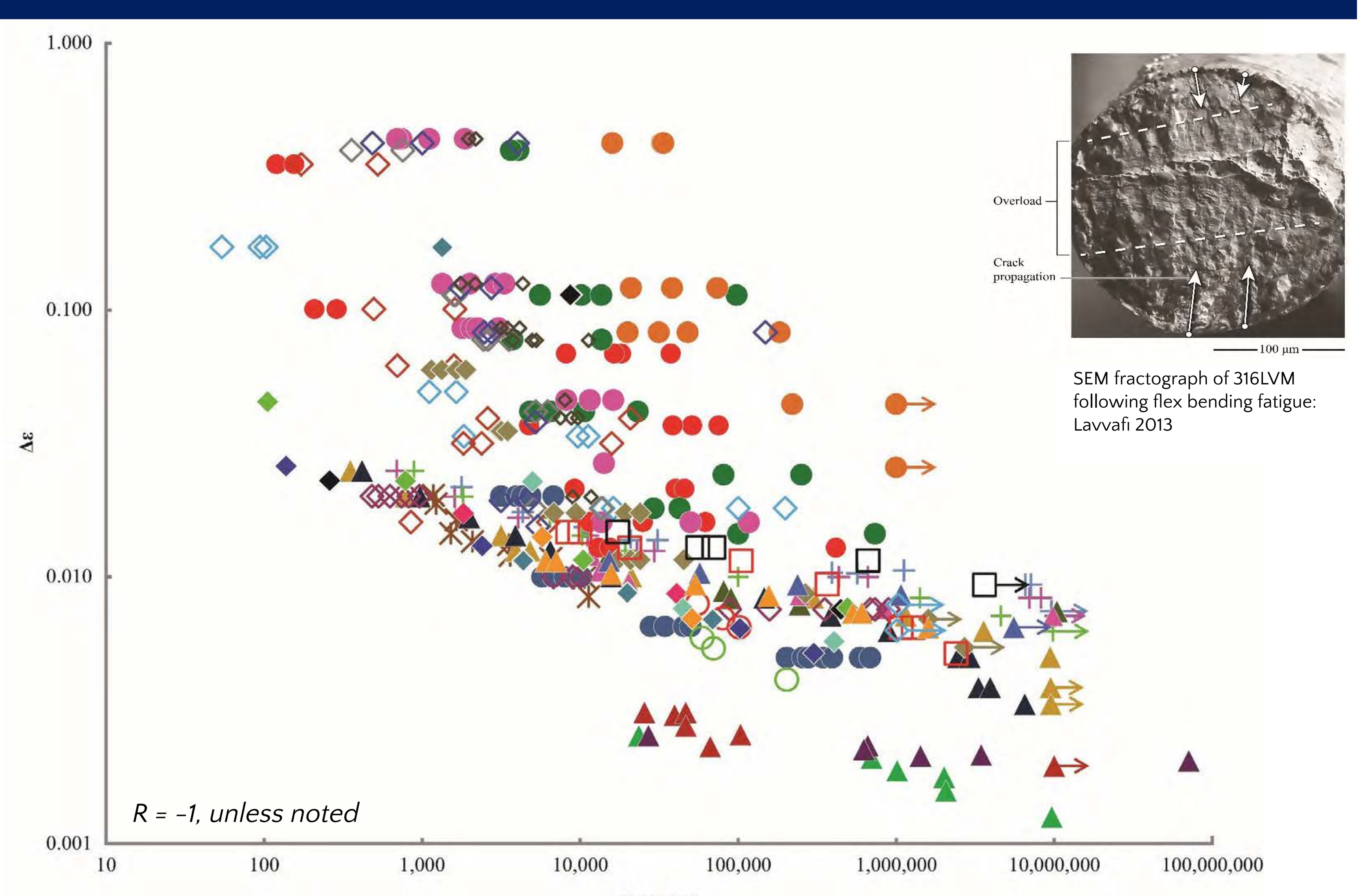
Design and validation of these systems requires an understanding of the factors governing fracture and fatigue behavior.

- Comprehensive literature review
- Identify common architectures, geometries
- Discuss testing methodologies and conditions
- Analyze fatigue data from common materials
- Determine gaps in published knowledge

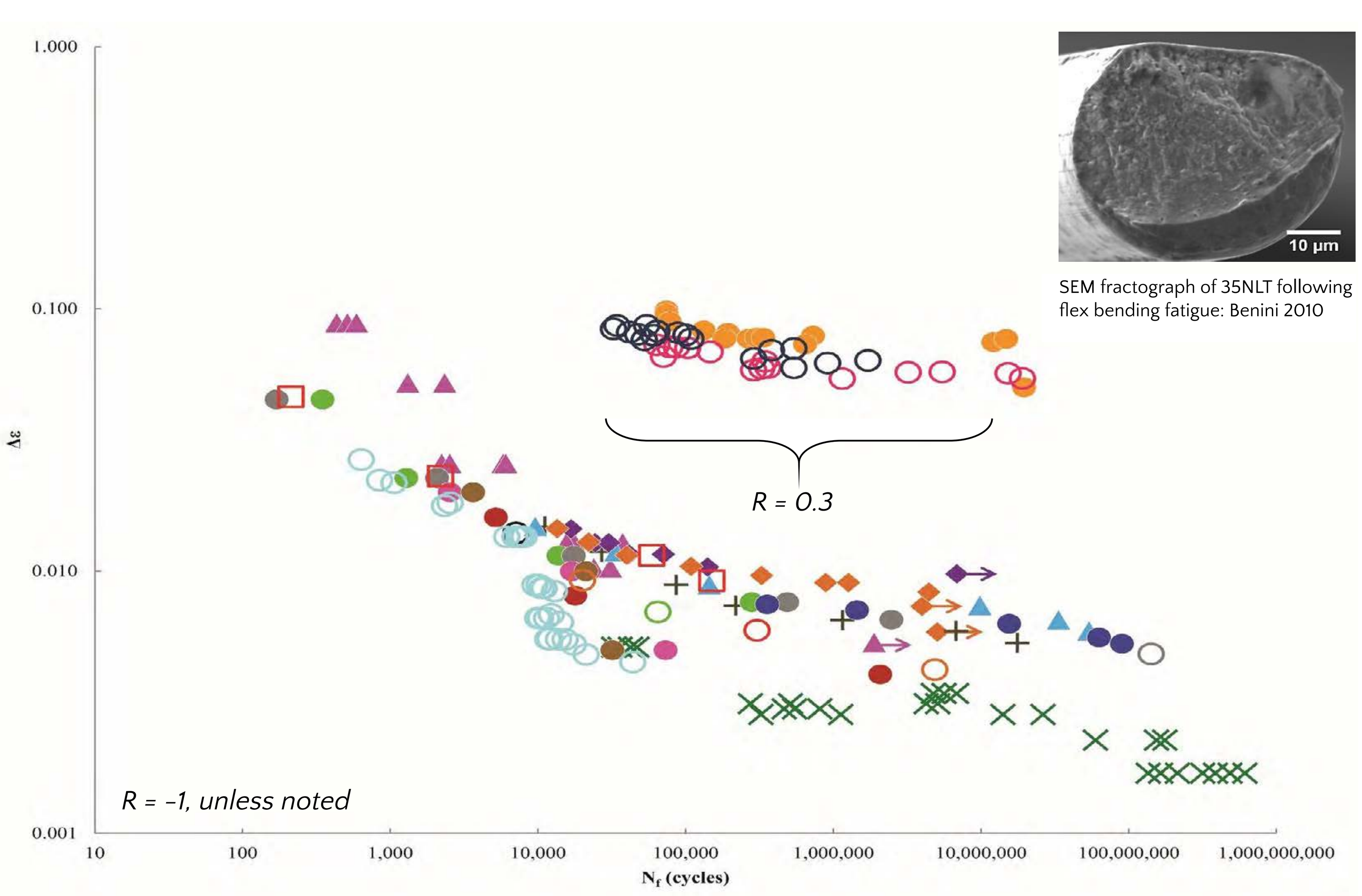
FATIGUE TEST METHODS



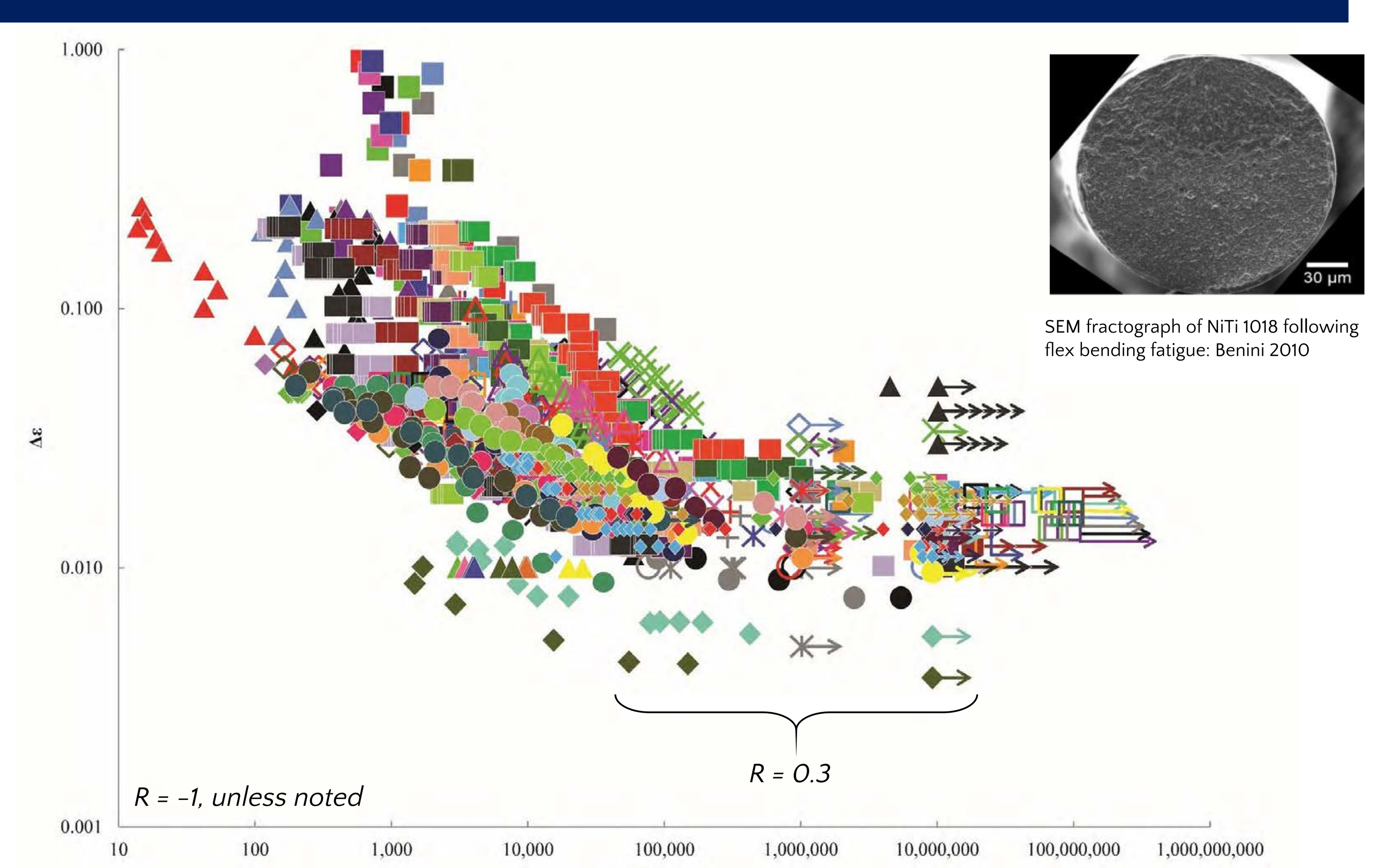
STAINLESS STEELS



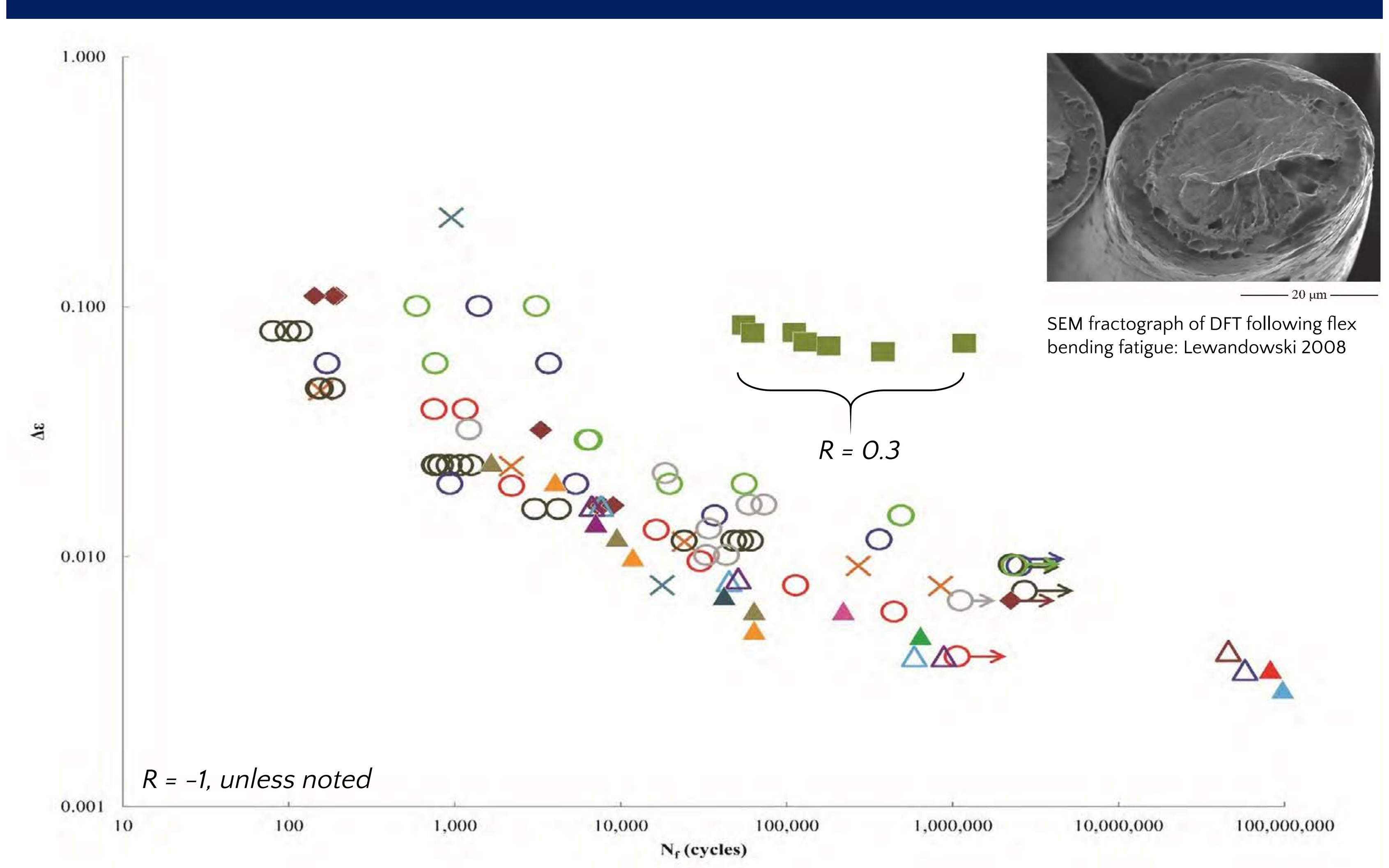
COBALT-CHROMIUM ALLOYS



NITINOL ALLOYS



METALLIC COMPOSITES



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Understanding Kinetics of Carbon Transport across Length-Scales at Diamond-Transition Metal Interfaces

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Introduction/Motivation

- Diamond is the hardest material in nature, and is a promising material in many scientific and industrial areas. However, due to its supreme hardness, it's hard to structure diamond via normal mechanical methods.
- It was observed that diamond tool wear severely when it used for workpieces contains transition metals such as Fe, Ni, Nb, Ti…
- Existing methods used for diamond pattern still have some limitation, such as low efficiency, high cost, and hard to control topography of patterns.
- High efficiency, low cost, and easily controllable diamond patterning method based on transition metal diffusion.

Introduction/Motivation

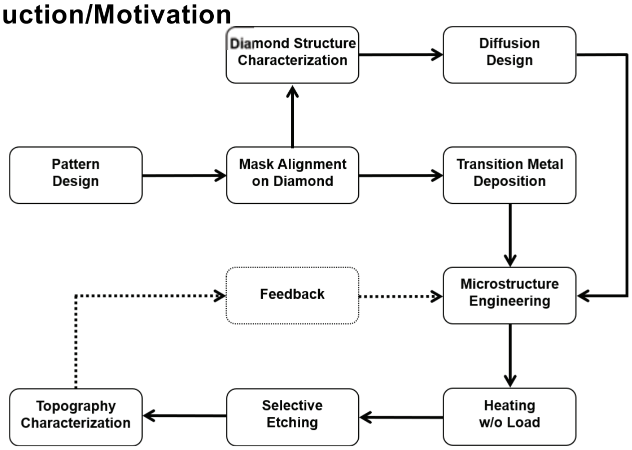

Fig. 1 Process of structuring diamond using transition metals under designed chemo-thermo-mechanical conditions.

Chemo-Thermo Control

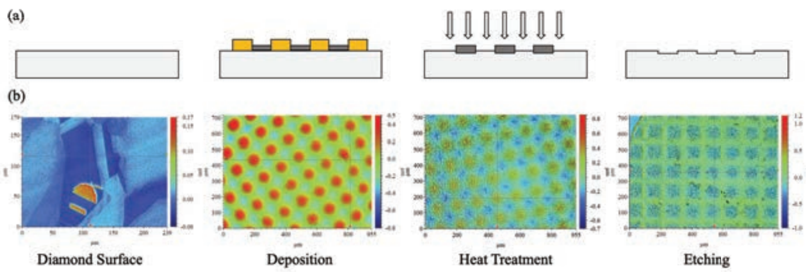

Fig. 2 (a) Schematic sketch (cross-section view) showing the process to create patterns on polycrystalline diamond substrate. (b) Surface topography (top view) of the substrate surface corresponding to each step in (a). Note the formation of a stepped topography on diamond after etching.

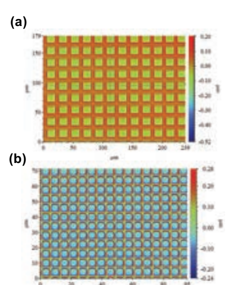

Fig. 3 Surface topography (top view) of patterns with grate periods of (a) 20μm, and (b) 6μm via photolithography.

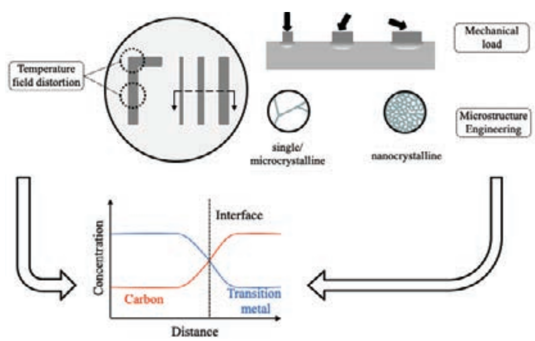

Fig. 4 Schematic sketch of design patterns via chemo-thermo-mechanical control.

Mechanical Control

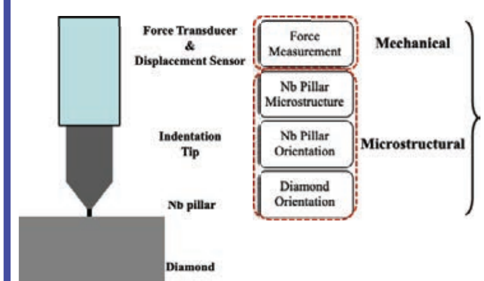

Fig. 5 Revealing the critical mechanical condition for diffusion interaction at the interface.

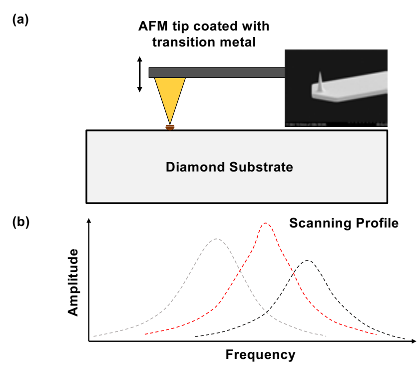

Fig. 6 (a) Sketch of scanning process across diamond thin film to structure pattern. (b) Illustration of designing scanning profiles for different patterns.

Summary

- Patterns with different scale and morphology are successfully manufactured on diamond surfaces via chemo-thermo control.
- Effects of transition metal, temperature, hold time, and crystal direction of metal and diamond on pattern topography will be investigated.
- Mechanical control processes will be tested via AFM and nanoindentation. Effects of transition metal, normal and sliding force, and crystal direction of metal and diamond on pattern topography will be investigated.
- Special patterns with different applications will be manufactured, and their performance will be tested.

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Department of Industrial Engineering