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SURFACE INSULATION RESISTANCE

In Pursuit of Large Data Sets

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J. Elliott Fowler

16th World Congress on Computational Mechanics

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Vancouver, BC, CA

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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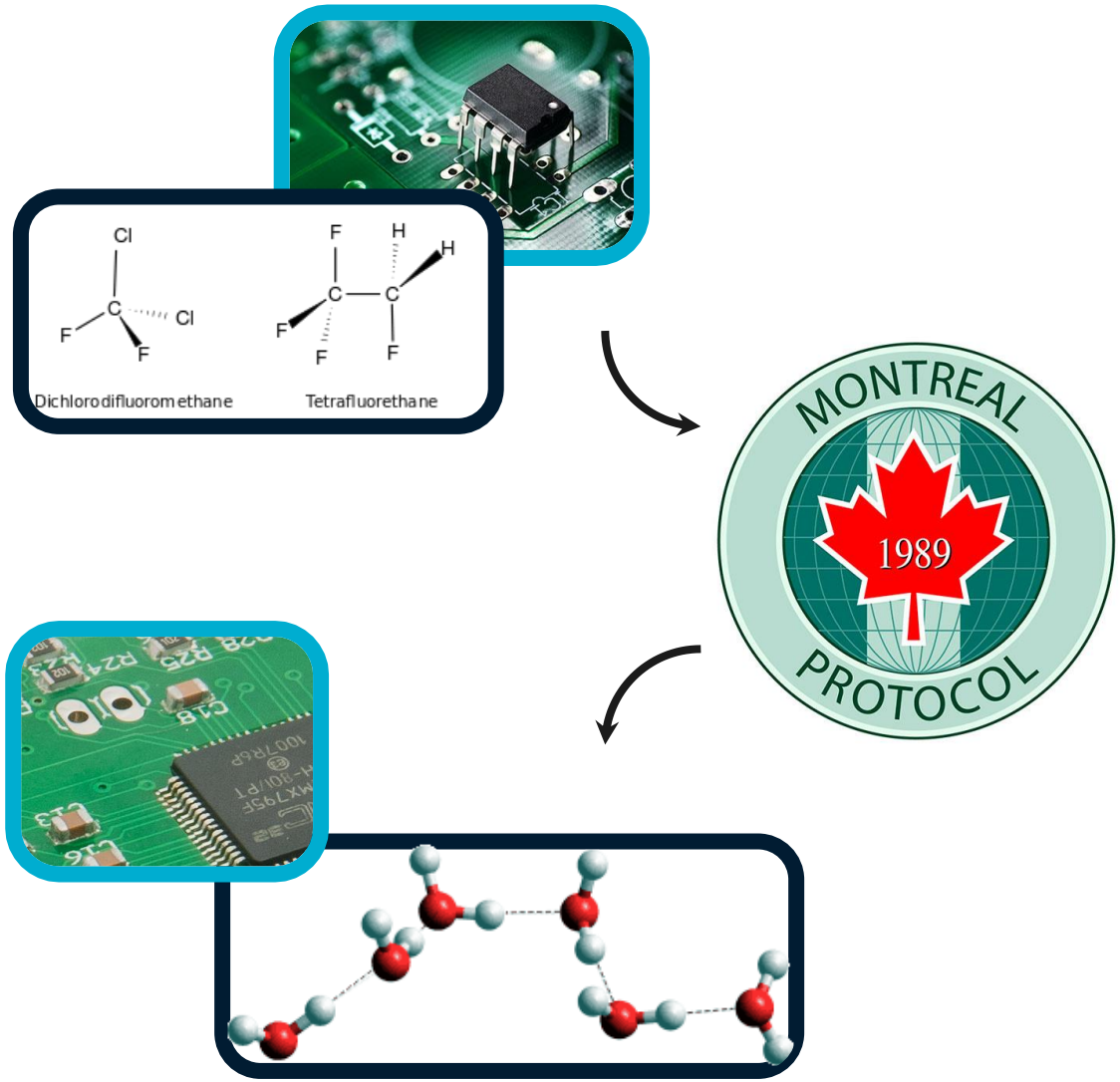
IPC J-STD-001H → HOW DID WE GET HERE?



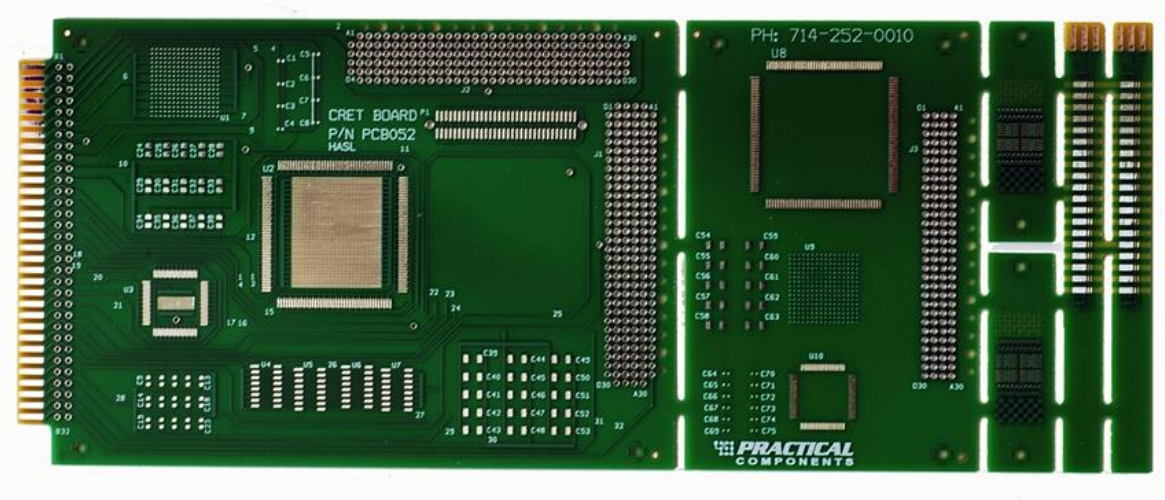
8.1 Qualified Manufacturing Process

…the Manufacturer shall qualify soldering and/or cleaning processes that result in acceptable levels of flux and other residues. Objective evidence shall be available for review…

…This may include

1. *Surface insulation resistance (SIR)*, possibly in combination with ion chromatography…
2. Historical evidence…
3. Electrical testing results… during extremes of temperature and humidity

FROM IPC-B-52 TO SNAP-OFF COUPONS



IPC-B-52

- "…manufactured using the same manufacturing process and surface finish intended for the end-product."
- Multiple test coupons assembled together (Main, IC, Solder Mask Adhesion, SIR mini,…)

Towards "snap-off" coupons

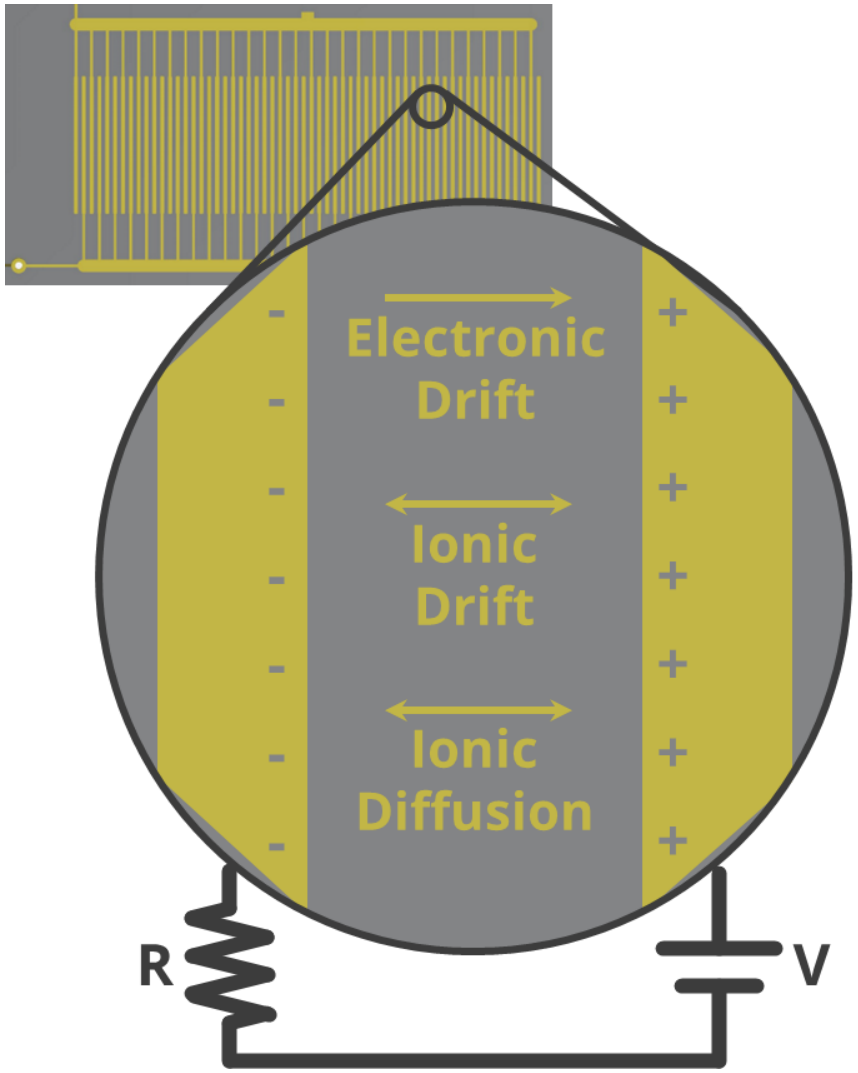
- Manufactured *concurrently with* the end-product
- Per panel qualification of cleanliness & reliability

In either case…

- Need for paradigm shift: Qualitative (Binary) → Quantitative
- *Mechanistic understanding of SIR*

IPC-B52 from Practical Components, Inc.
IPC-9203A

BASICS OF SIR



- Test cards composed of interdigitated comb (IDC) or other (i.e., BGA, LGA, etc.) patterns
- Elevated temperature/humidity chamber, DC bias (5 V), resistor (1 MΩ)
- Current measured periodically
- Underlying physical phenomena:

  Electronic drift
  Ionic drift/diffusion

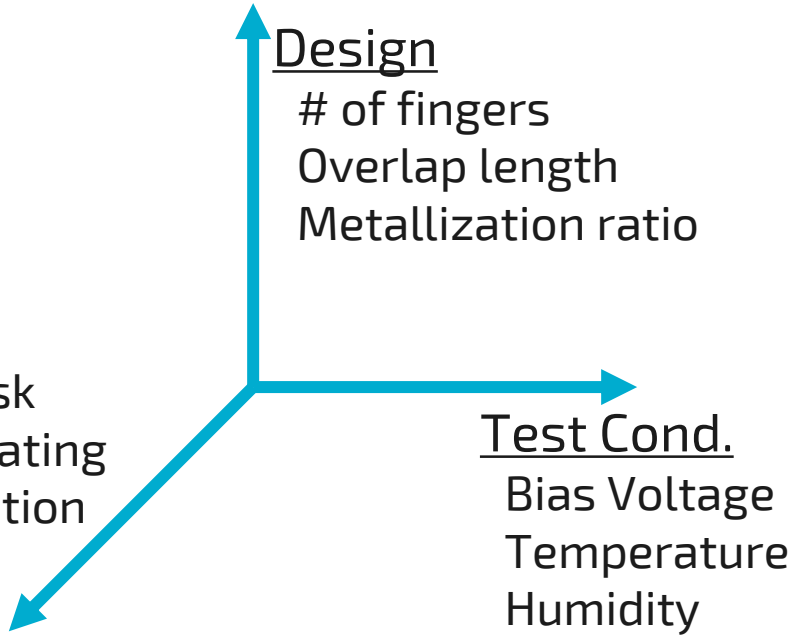
- Affected by:

  Pattern design
  Materials
  Test conditions

SYSTEMATIC EXPLORATION

SIR Total Parameter Space

$$I = f(a, b, c, d, e, \dots)$$

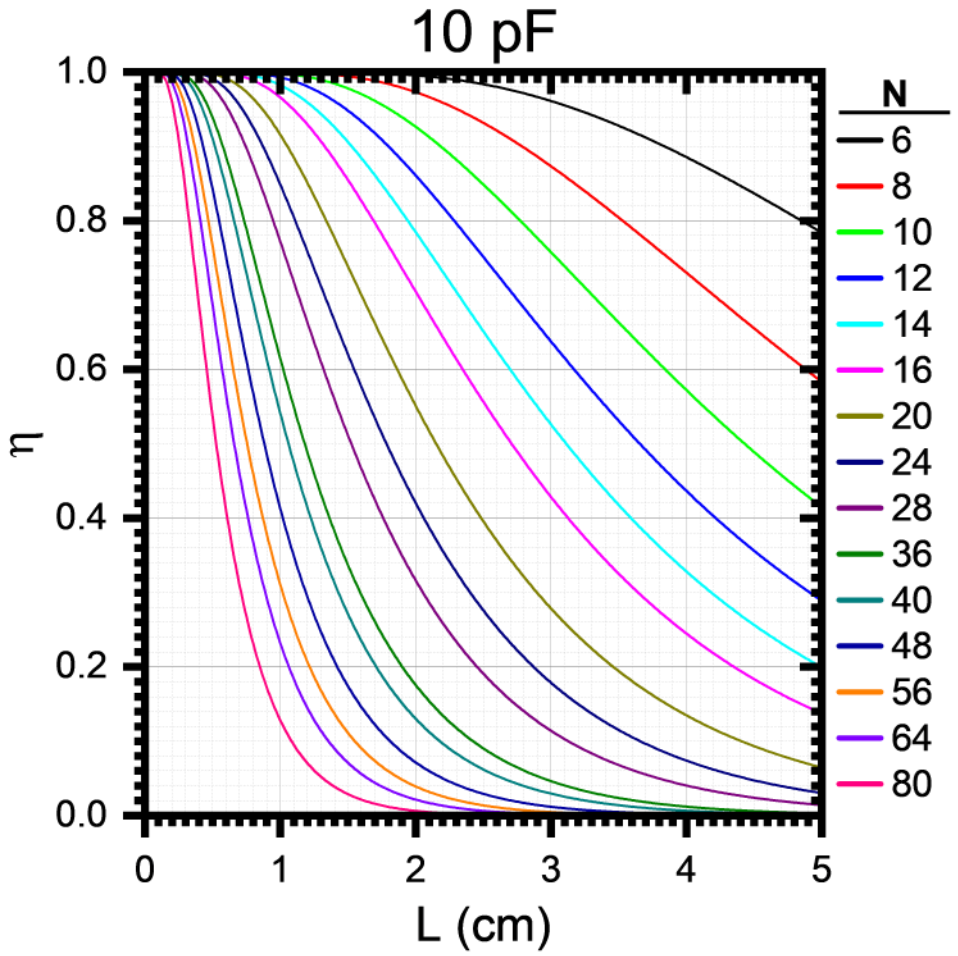


Campaigns

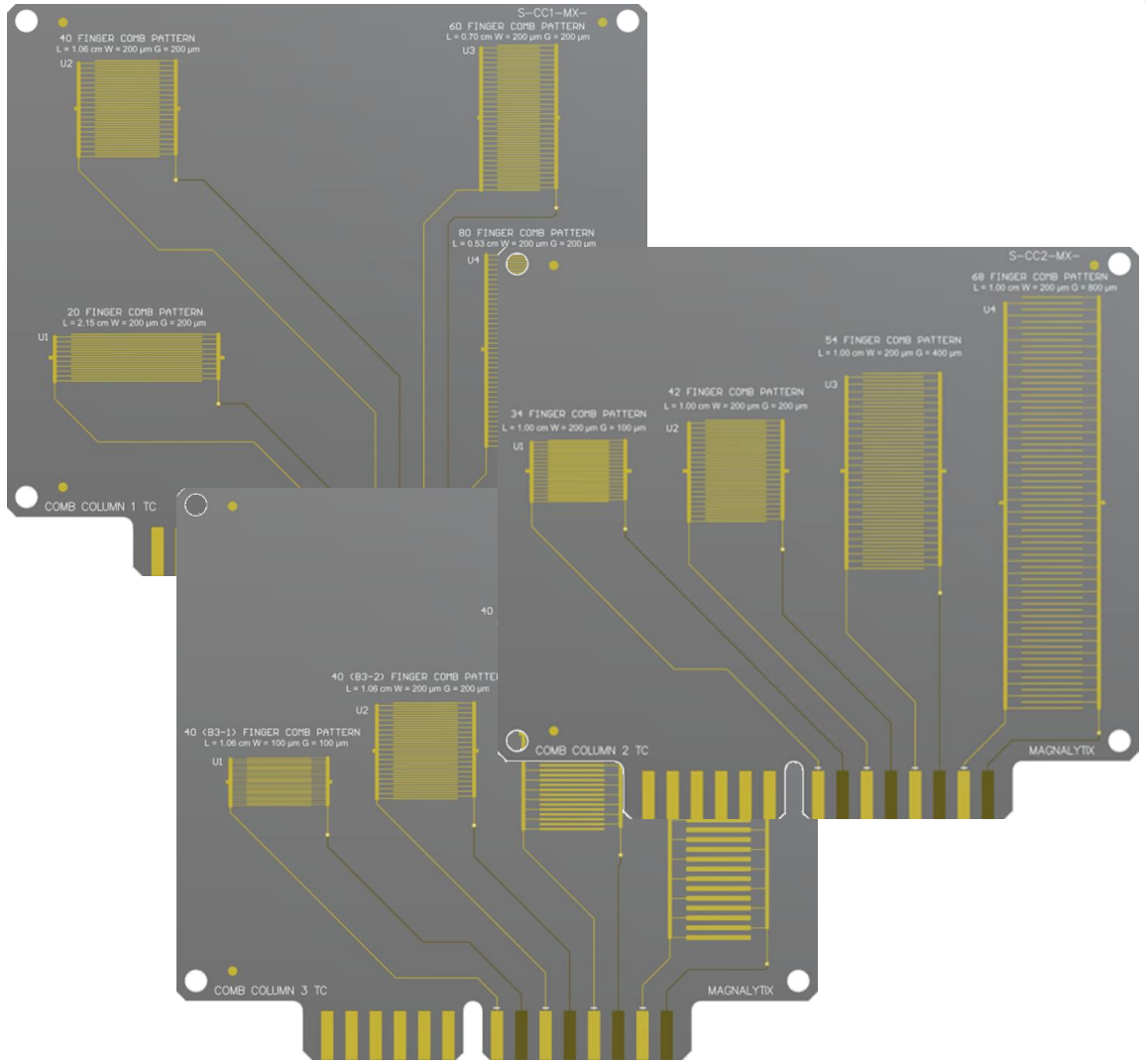
1. Vary design w/ constant capacitance
   Clean boards, benign environment
2. Vary design w/ constant capacitance
   Clean boards, varied environment
3. Vary design w/ “constant” capacitance
   Vary material construction
   Vary contamination

1
CLEAN BOARDS, BENIGN ENVIRONMENT

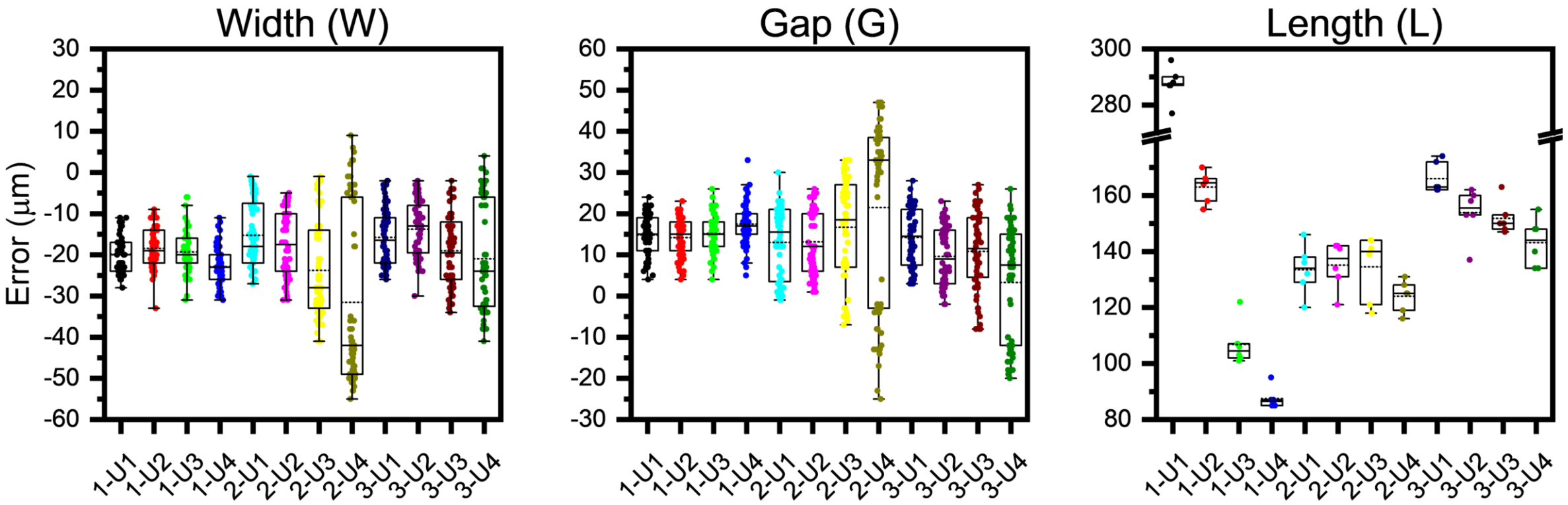
CAPACITANCE COMPUTATION & BOARD DESIGNS



Sensors and Actuators A: Physical 2004, 112, 291

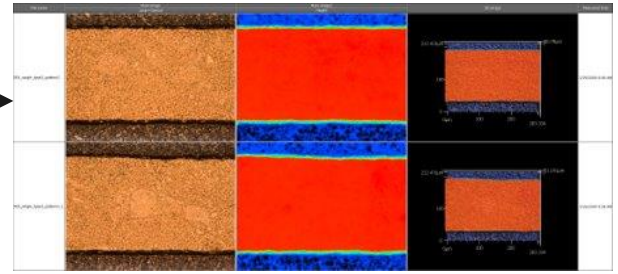


HOW WELL DID THE FAB SHOP DO?

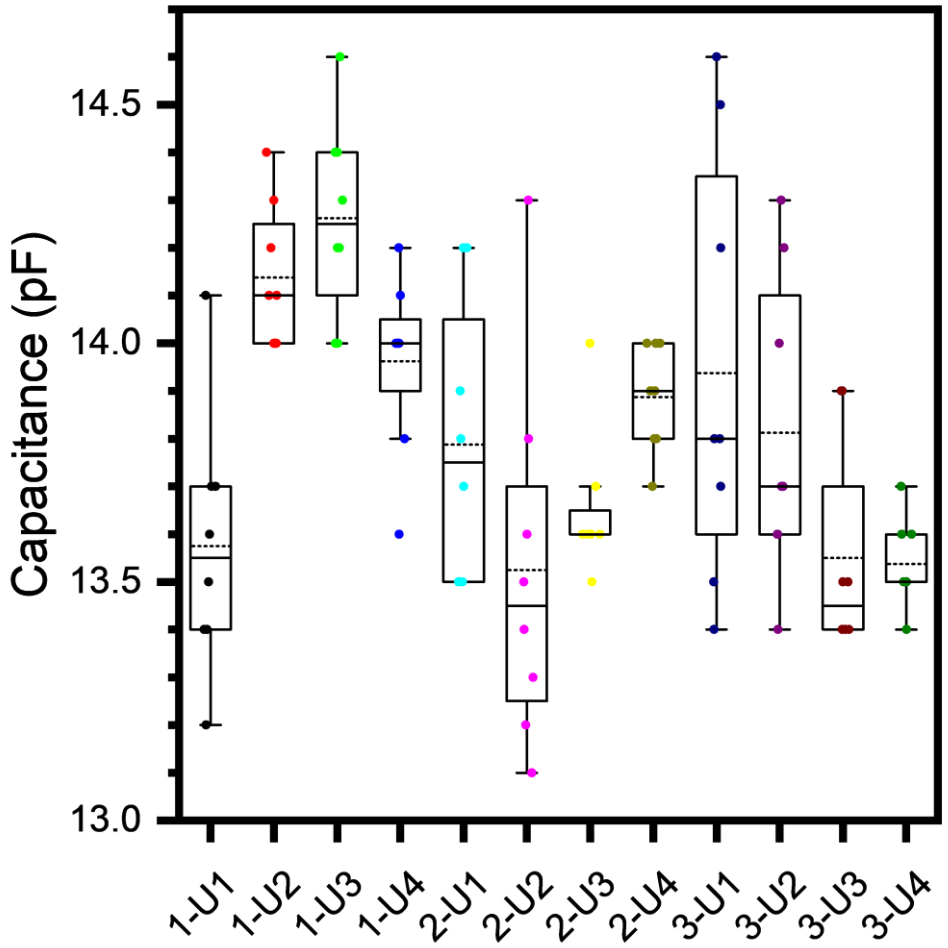


Revision to measurement scheme in progress

- Minimum confocal microscopy for statistical significance
- Incorporate geometry micro-variances into behavior modeling



CAPACITANCE DISCREPANCY



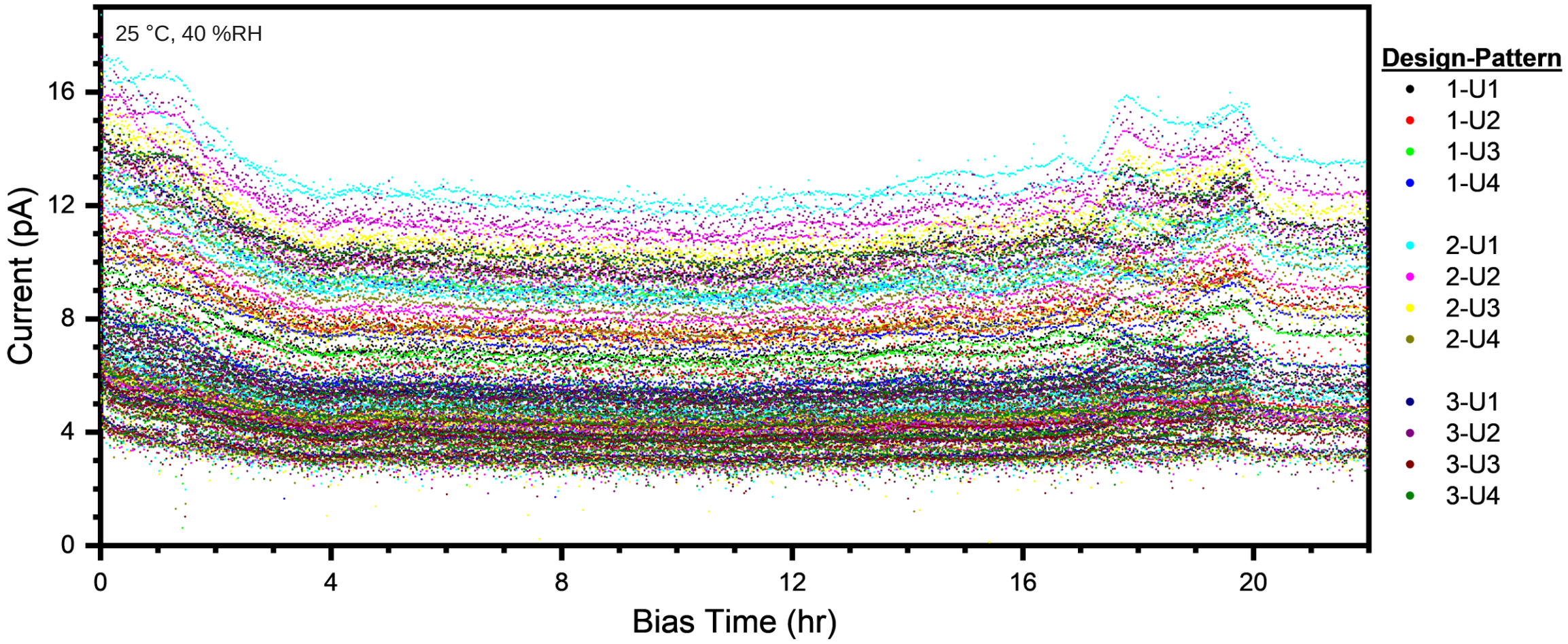
Measured with Agilent E4980A Precision LCR Meter at 1 kHz

Possible causes:

- Single frequency vs sweep measurement
- Room conditions
- Cu traces thicker than model assumption
- FR-4 substrate relative permittivity

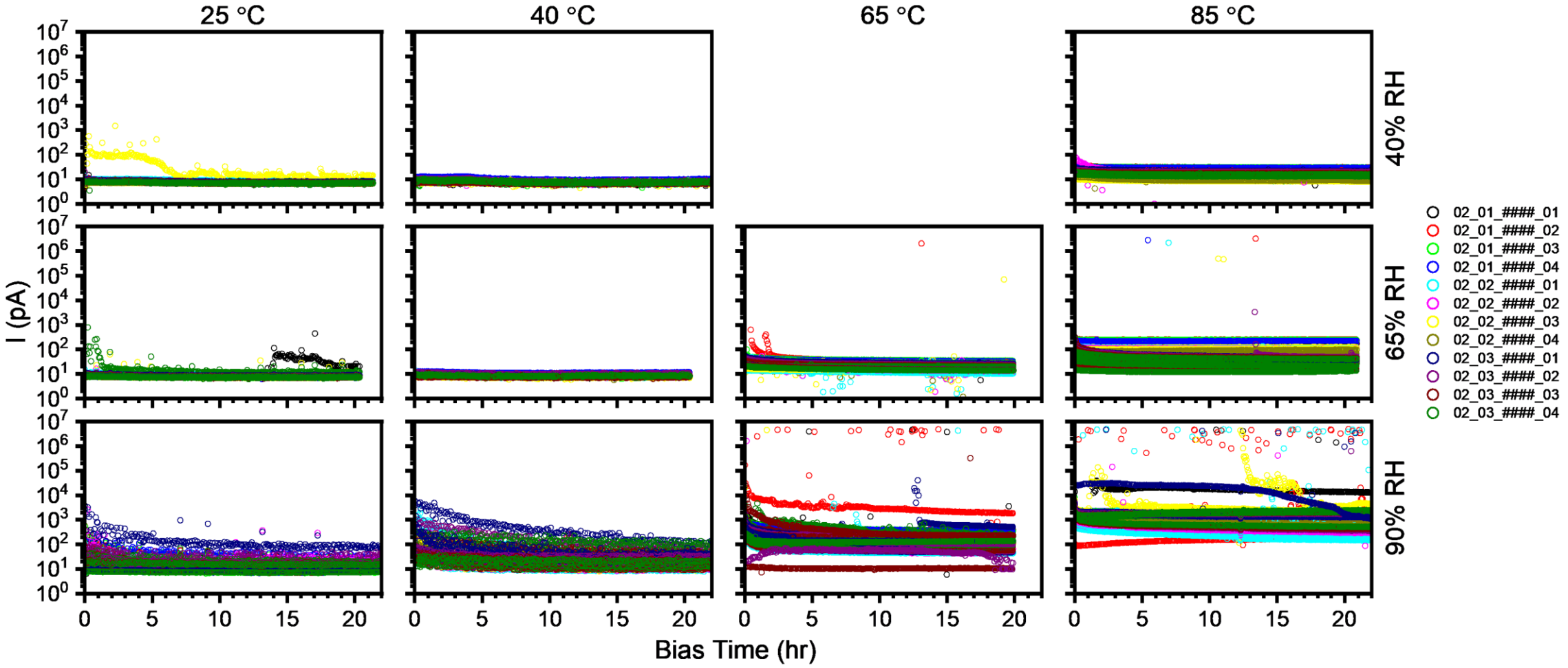
Inclusion of solder mask will further increase capacitance

ALL DATA – CAMPAIGN 1

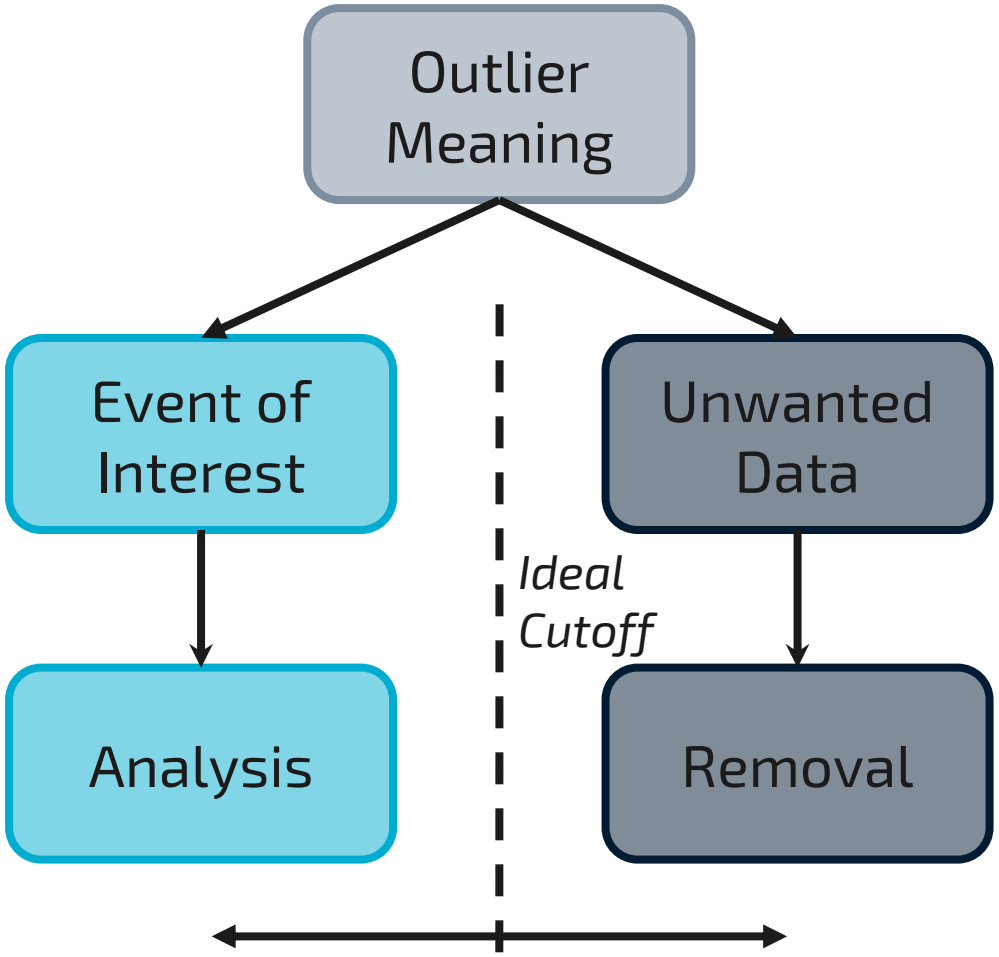


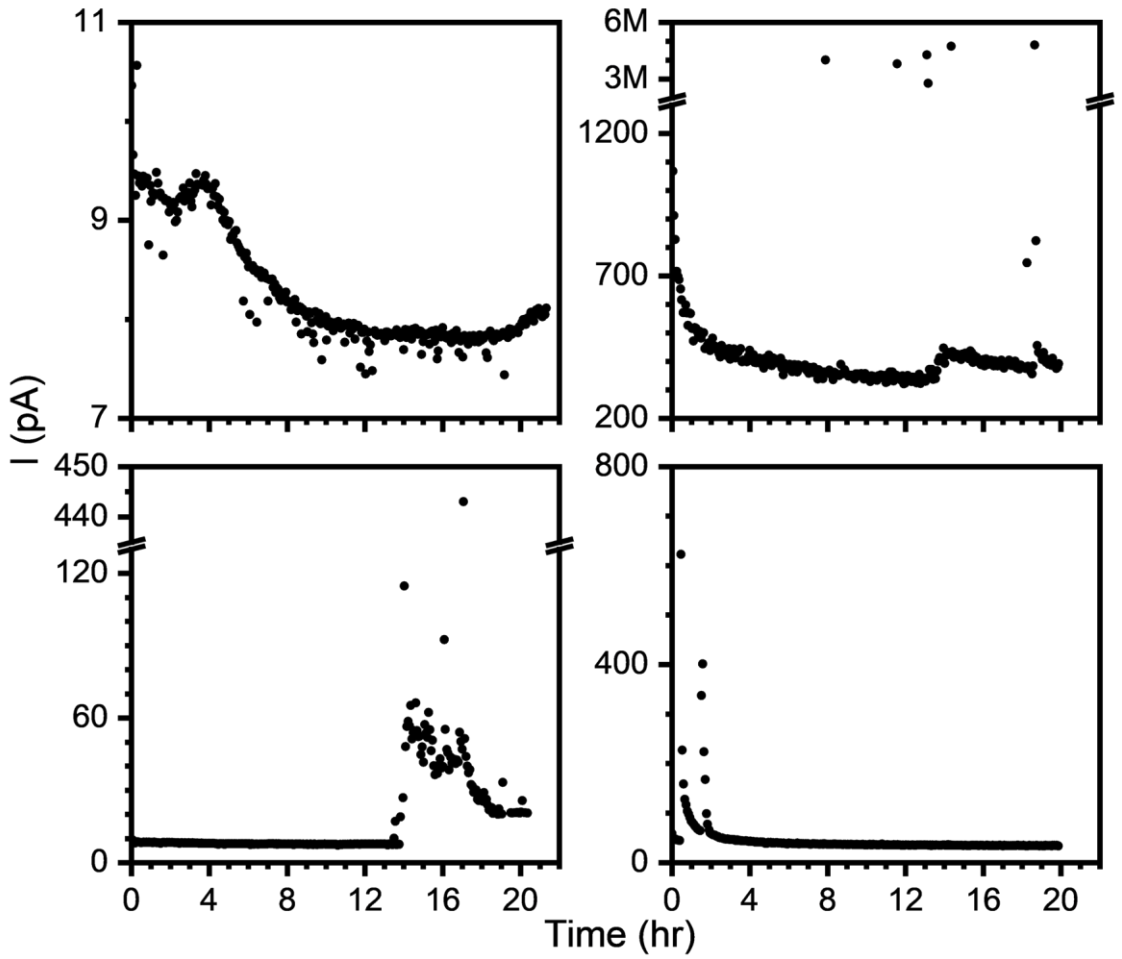
2
CLEAN BOARDS, VARIED ENVIRONMENT

ALL DATA, RAW – CAMPAIGN 2



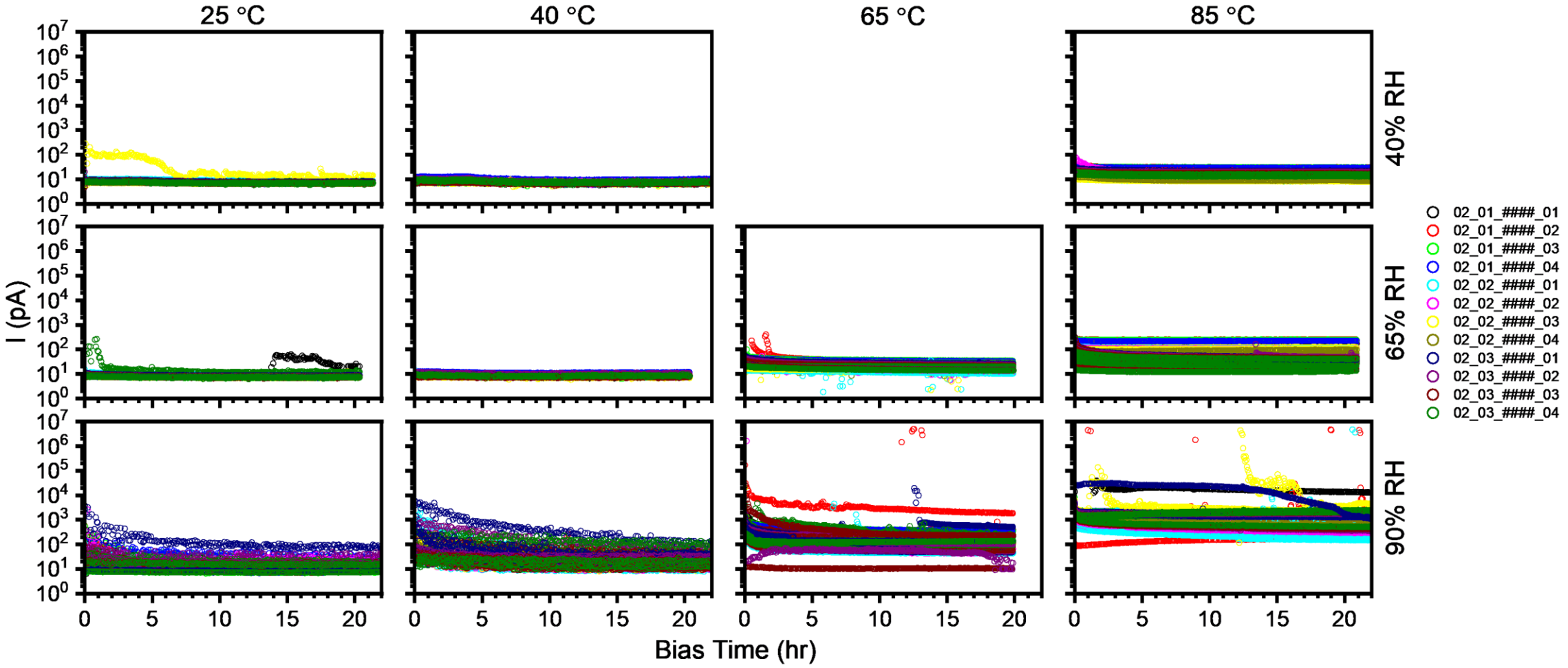
TIME SERIES ANOMALY DETECTION



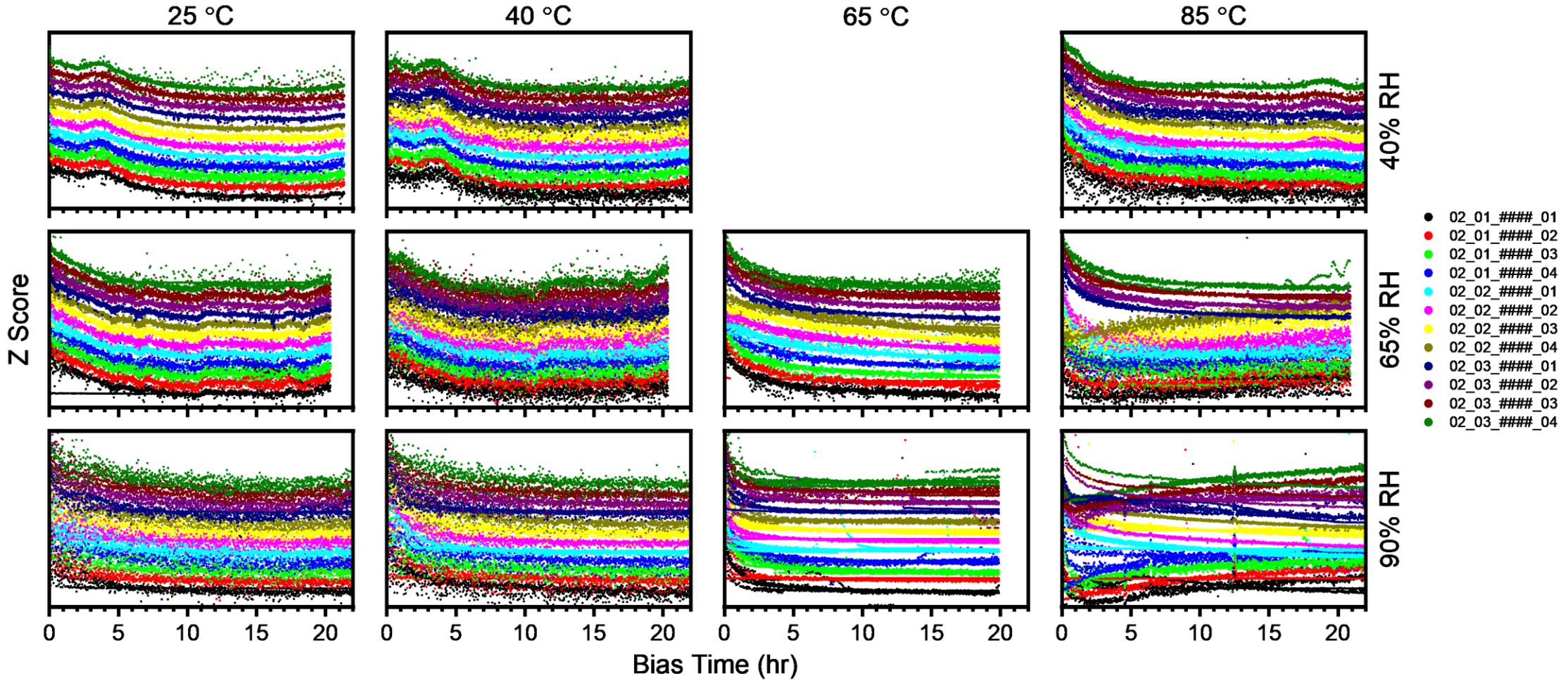


Adapted from neptune.ai/blog/anomaly-detection-in-time-series

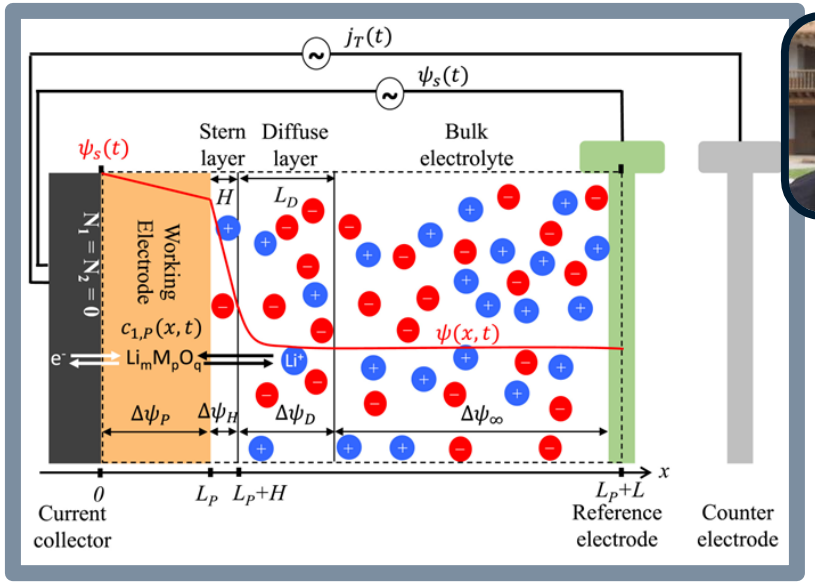
ALL DATA, CLEANED – CAMPAIGN 2

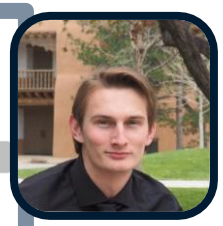


ALL DATA, CLEANED & NORMALIZED – CAMPAIGN 2



MODELING & STATISTICAL ANALYSIS

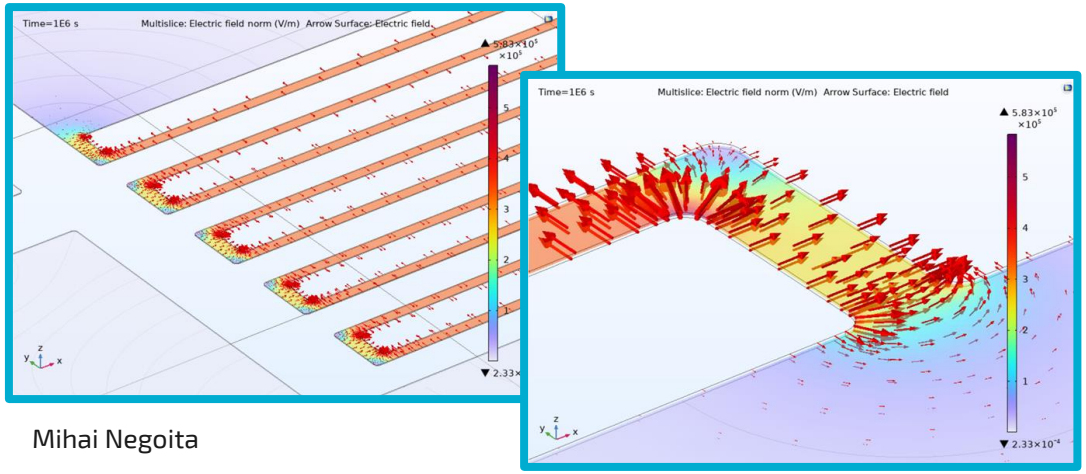




Sam Grosso
(Prof. Fernando Garzon)

$$i = \frac{nFAc_j^0\sqrt{D_j}}{\sqrt{\pi t}}$$

Electrochimica Acta 2019, 321, 134648



Mihai Negoita

Variable	Importance Score for Predictor to Current
L = 1.06 cm	22.26
L = 2.15 cm	3.08
L = 0.53 cm	18.97
L = 0.7 cm	22.85
G = 200 µm	13.88
G = 400 µm	17.57
G = 800 µm	29.68
W = 200 µm	11.08
W = 400 µm	3.42
W = 800 µm	13.79
Temp.	204.61
Rel. Hum.	297.63

Increased with Contamination?

Ayorinde Olatunde
(Prof. Anirban Mondal)

3
VARIED MATERIALS, CONTAMINATED BOARDS

CREATING [GOOD] PROBLEMS FOR MYSELF

Design of Experiment

- (only) 2 board designs
- (no) ENEPIG plating and/or (no) solder mask
- Adipic acid, succinic acid, or commercial flux x 2 contamination levels (+clean)
- 2 sets of environmental conditions
- 4 chambers across 4 days
- 320 boards x 4 channels
- Before/after EIS (new!)

➢ Approx. 1,500 files or 350,000 data points

A note on contamination

- Mounted spray gun at set distance from horizontal surface, manually actuated
- Tradeoffs vs dip coating & spin coating
- Investigating contamination printing

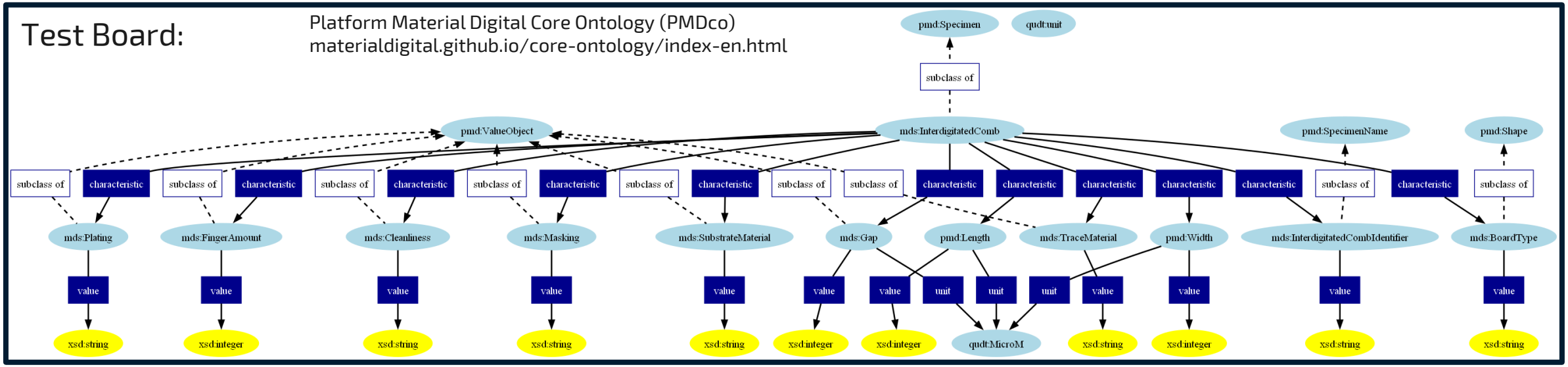
ONTOLOGY DEVELOPMENT

Jarod Kaltenbaugh
(Prof. Kris Davis)

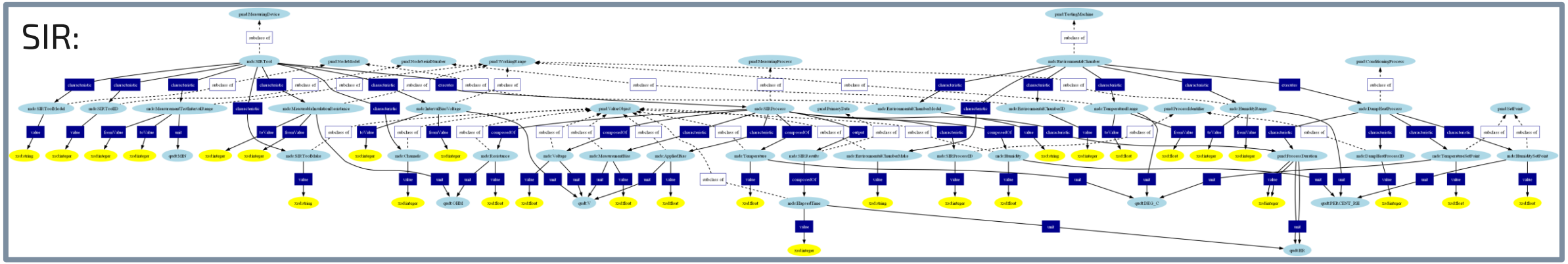
A formal description of knowledge as a set of concepts w/i a domain & the relationships b/w them

Test Board:

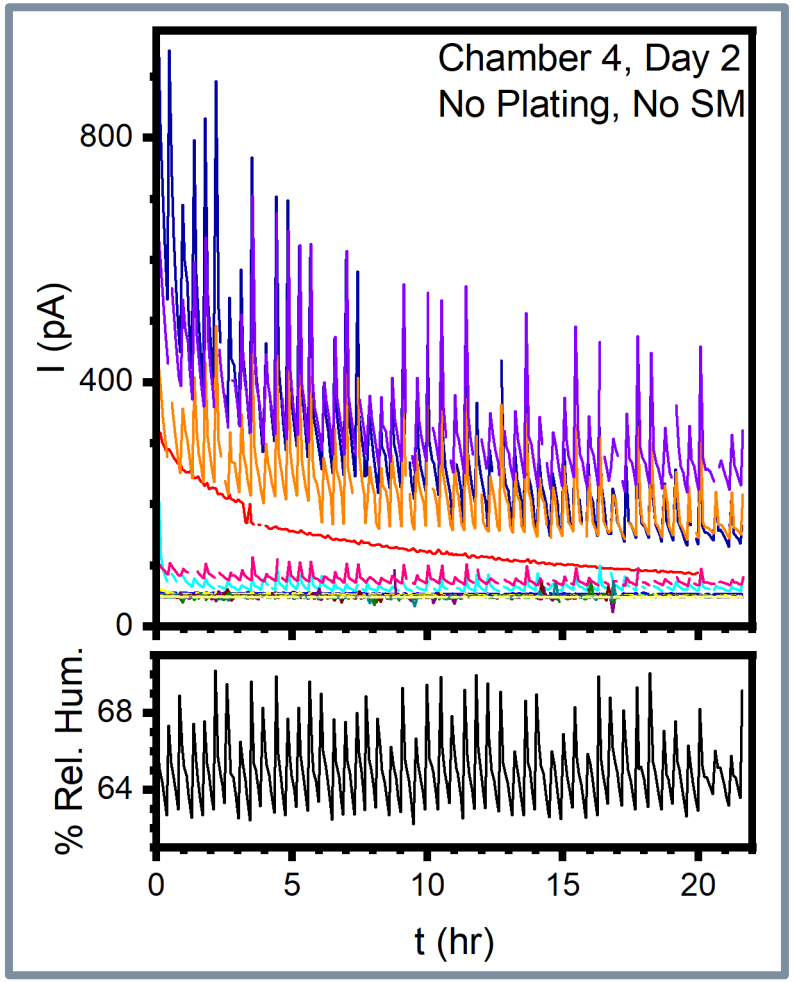
Platform Material Digital Core Ontology (PMDco)
materialdigital.github.io/core-ontology/index-en.html

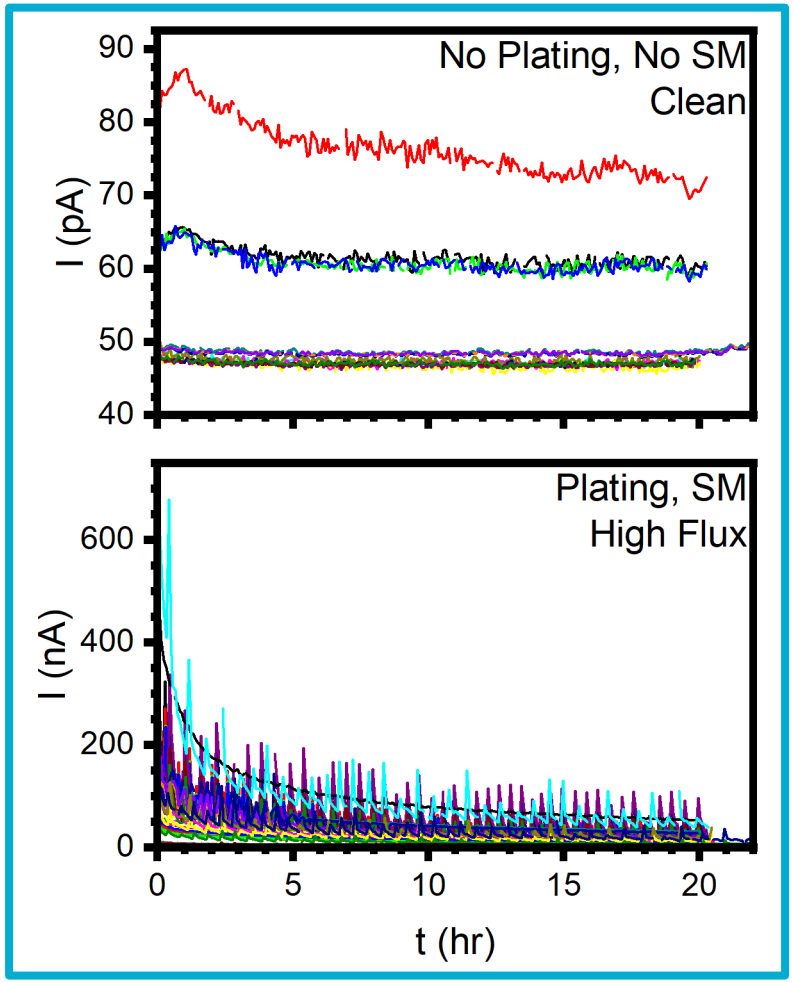


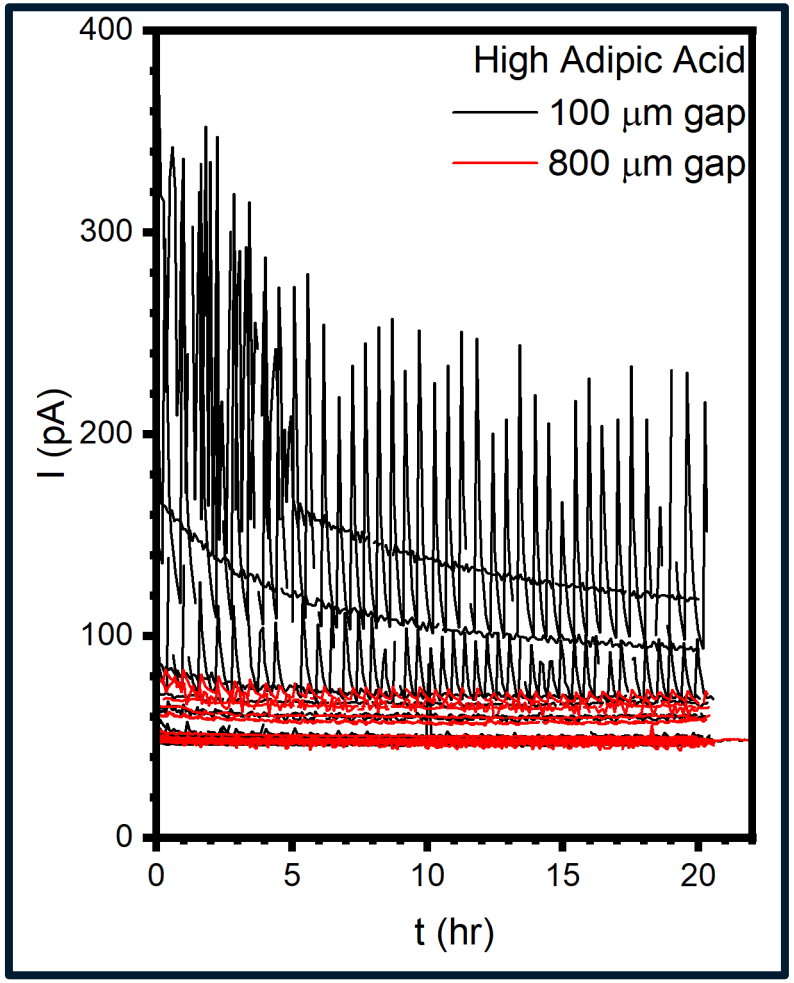
SIR:



LET'S TAKE A PEAK ANYWAY







ANALYSIS ONGOING…
THANK YOU