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An Instrumented Getter for Hermetically Sealed Packages

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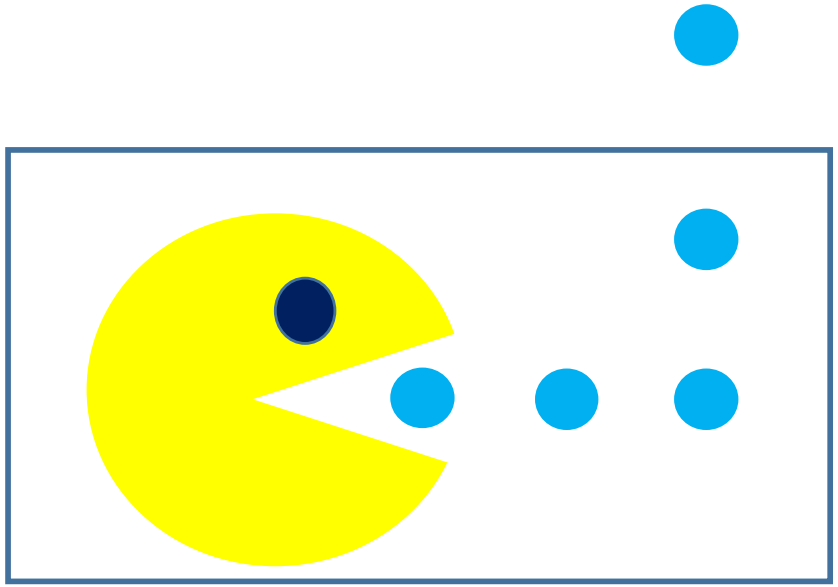
MacDermid Alpha ELECTRONICS SOLUTIONS

Introduction

- Getters are used to chemically bond and trap certain gases that leak into hermetically sealed packages
  - Can extend useful life of the packaged device
- A getter is sealed in the package and you hope it works…
  - Open loop system
  - Catastrophic failure may reveal a problem
  - Any problem!



Historical Use of Getters

- Getters have been used since at least the 1930s
  - 1937 patent, “Gettering Vacuum Tubes”
  - Used to maintain a suitable vacuum in vacuum tubes
- Various getter chemistries are used to trap different gases
- Examples of gases that can be gettered
  - Water vapor
  - Carbon dioxide
  - Hydrogen
  - Nitrogen
  - Oxygen

Courtesy www.pixfeeds.com

Improving the Use of Getters

- What if you could instrument a getter to determine its working state at any time after package sealing?
  - An augmented BIST function for the component
  - Problem parts could be identified and replaced before a catastrophic failure occurs
  - Problems in a hermetic sealing process line could be identified and corrected
  - Parts in long term storage could be checked for acceptable hermeticity prior to use

Architecture for an Instrumented Getter

- Use a chemical sensor architecture
  - An analyte
  - A chemically sensitive layer
  - A sensing transducer
- Analyte: moisture in the hermetic package
- The chemically sensitive layer: the getter
- The sensing transducer: a sensing structure that produces an electrical signal or impedance change from interacting with the getter

Staydry® Hicap™ 2000 Getter

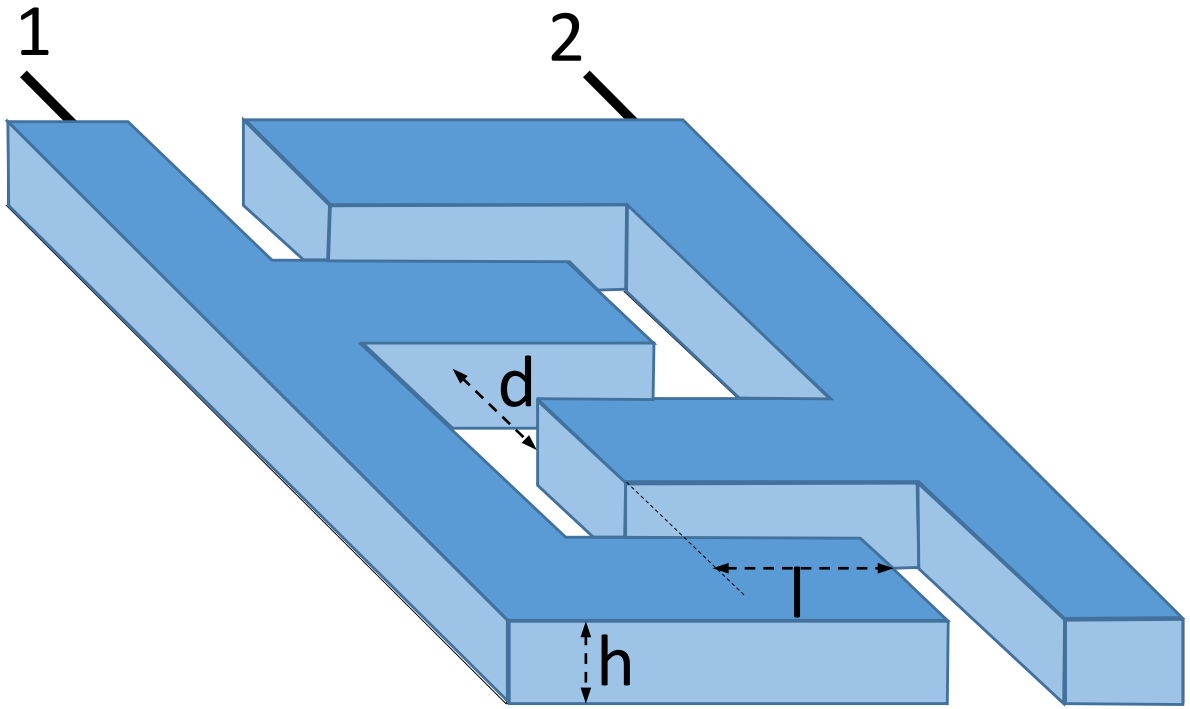
- Alpha Advanced Materials high capacity moisture getter
- Irreversible getter material for absorbing H_20 and CO_2
  - H_20 absorption investigated here
- Low curing/activation temperature: 150°-200°C
- Can be dispensed by stencil printing
  - Also by screen printing and direct dispense
  - 76.2 µm (3 mil) typical thickness

The Getter as the Chemically Sensitive Layer

- Hycap 2000 water absorption chemical reaction:
  - $CaO + H_2O \rightarrow Ca(OH)_2$
- CaO: Calcium Oxide
  - ε_r = ~11.8
- $Ca(OH)_2$: Calcium Hydroxide
  - ε_r = ~1.8-3.5
- Therefore, a capacitive transducer with this getter as the dielectric material should be able to produce a signal proportional to the getter's status
  - As absorbed H_2O increases: sensor capacitance decreases

A Sensing Transducer Structure

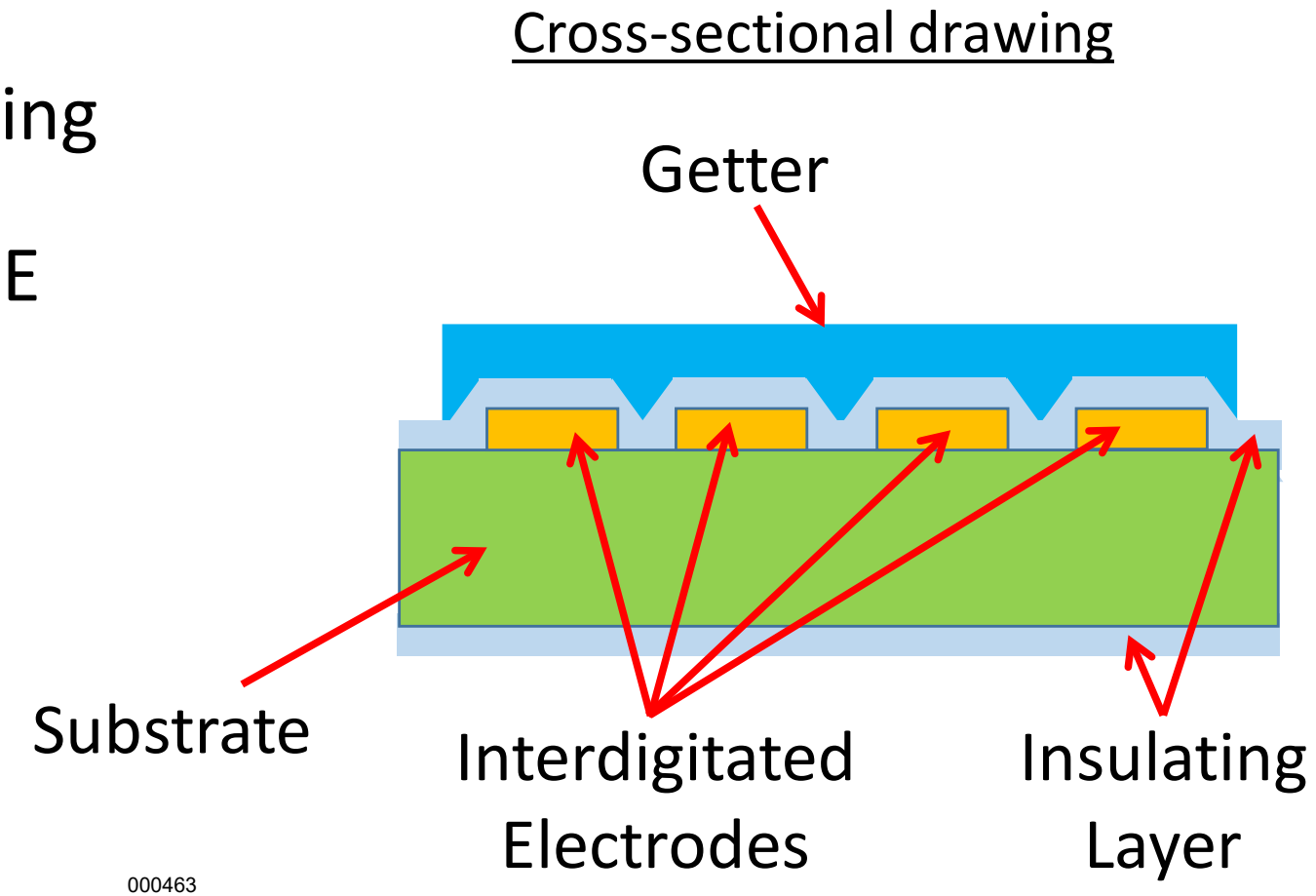
- Planar interdigitated electrode (IDE) structure
- Capacitance is measured in the 3D volume surrounding the electrodes
- Locating a dielectric material inside the sensing volume changes the measurable capacitance accordingly



$$C \cong \frac{(n-1)\varepsilon_o \epsilon_r \gamma h l}{d}$$

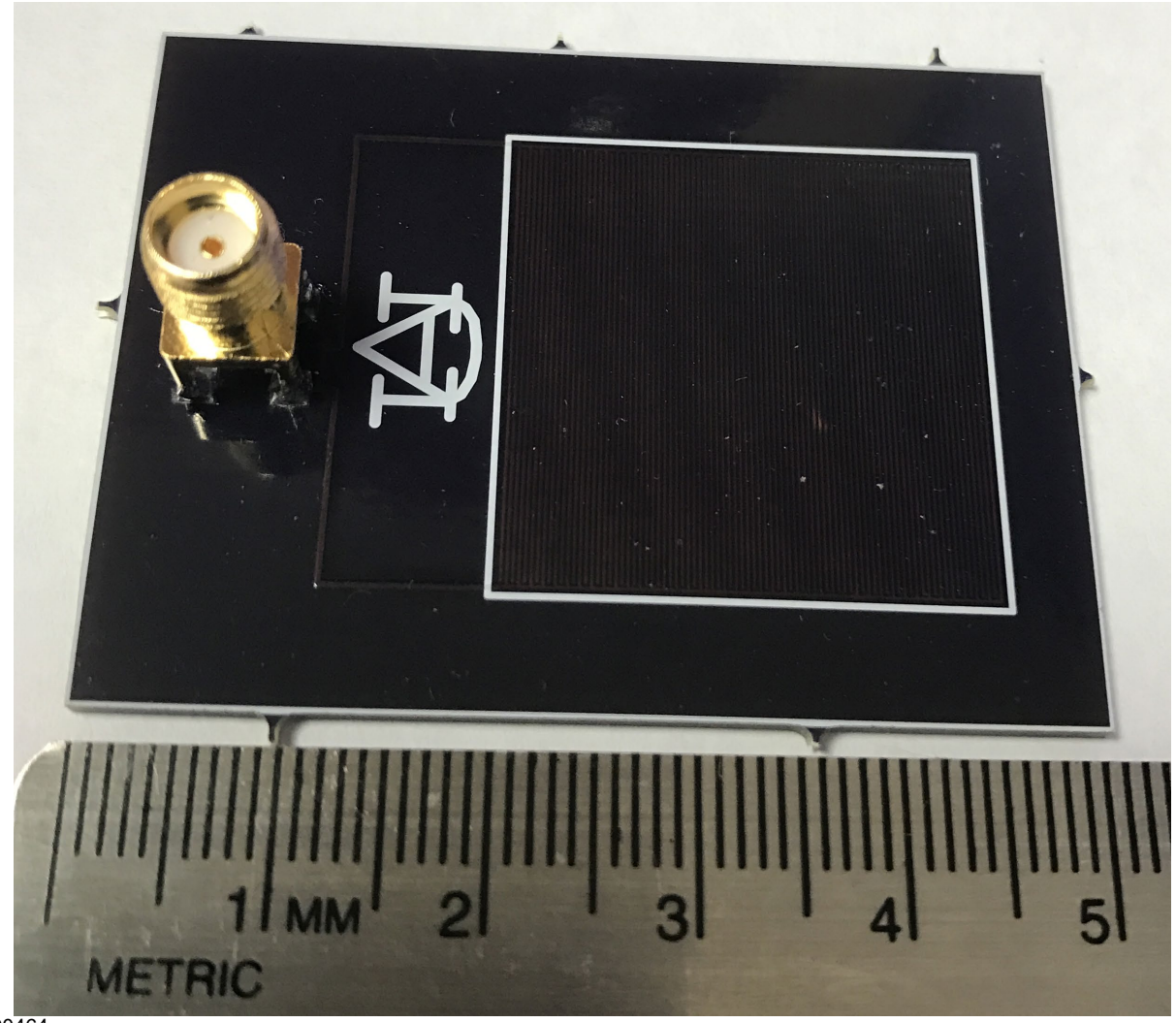
Implementing the Sensing Transducer

- IDE fabricated onto a substrate
- IDE coated with an insulating layer
- Getter applied over the IDE structure
- Realizable in various technologies:
  - MEMS
  - PCB
  - Ceramics



Prototype Sensor in PCB Technology

- Interdigitated electrode array in top Cu layer of a 2-layer PCB
  - 2.61 cm x 2.61 cm
  - 83 electrode pairs (152.5 µm width and gap, 2.49 cm overlap)
  - Covered with solder mask
- 3 sensors were procured from OSH Park
  - Commercial 2-layer FR-4 process
  - $15.20 for three boards
- Attached SMA connector for connection to laboratory instrumentation

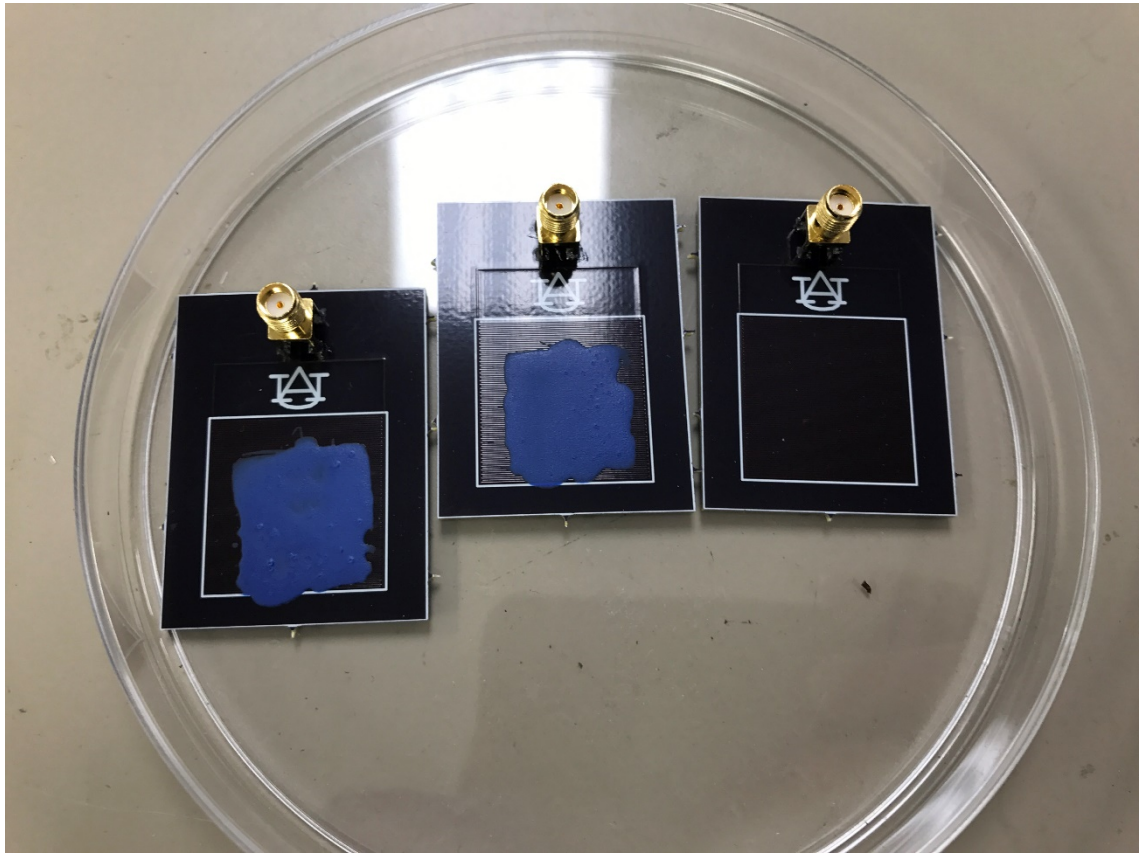


Getter Curing

- 254 µm (10 mil) thick stencil fabricated
  - Stamped out of polyimide
- HiCap 2000 stencil-printed
- Cured at 200°C for two hours
  - Box oven
  - 20 min ramp up
  - 40 min ramp down
- Some popcorning observed after curing
  - Increased getter surface area

Instrumented Getter Test Articles

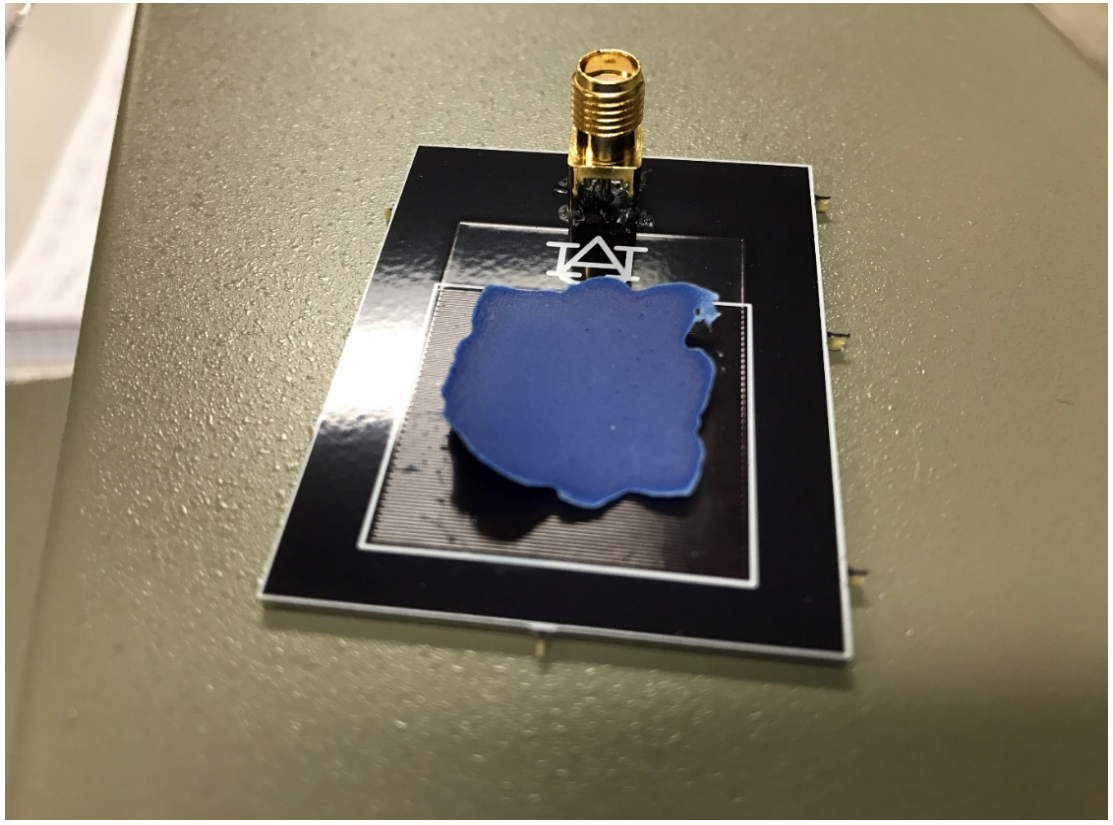
- Three test articles prepared
- One without any getter
- Two with cured getter layers
  - One exposed to saturated air for moisture absorption



Getter Moisture Absorption

- One cured getter PCB exposed to moist air
  - 200 hour soak
  - In saturated air
  - At 99.9 % RH
  - At room temperature
- After moisture soak, the getter was visibly different
  - Color had changed
  - The getter layer had potato chipped due to stress
  - Delaminated from solder mask on PCB

Soaked Getter Layer on Sensing PCB

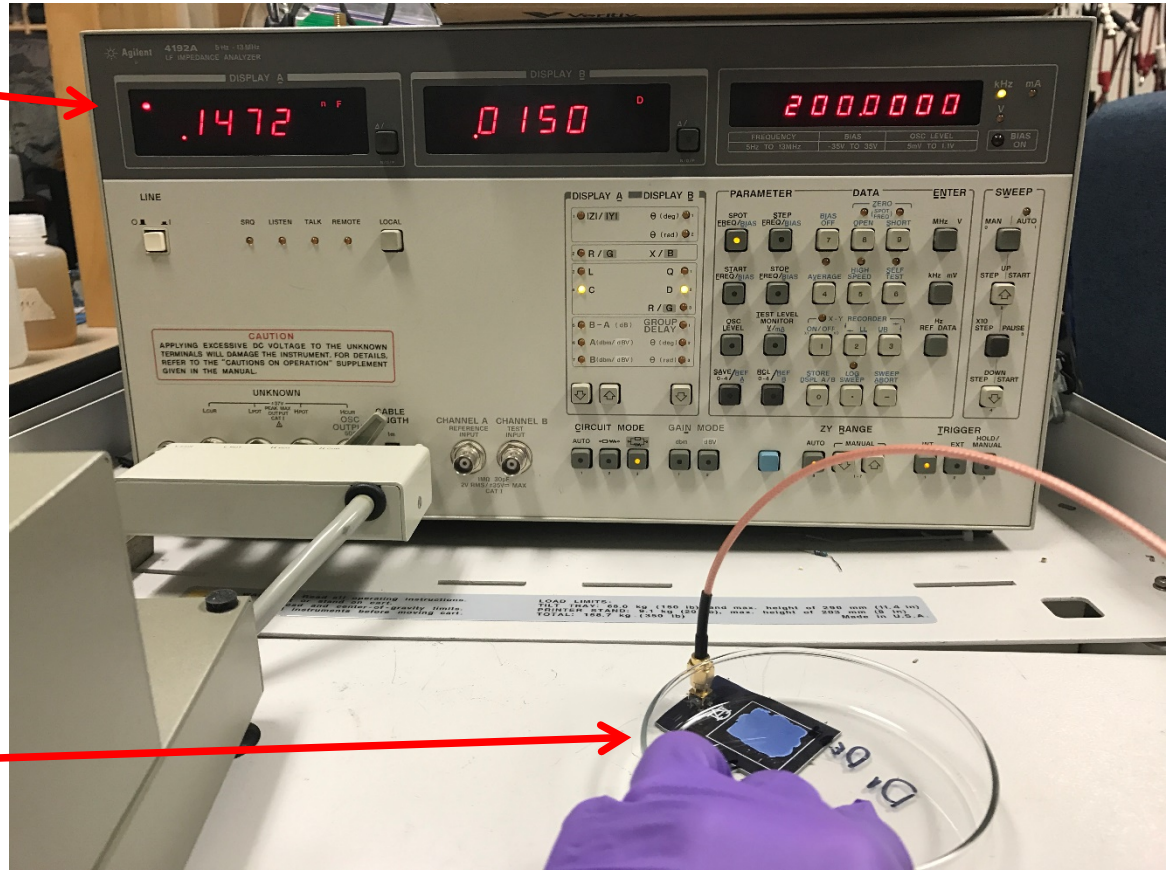


Dehydration after Moisture Absorption Soak

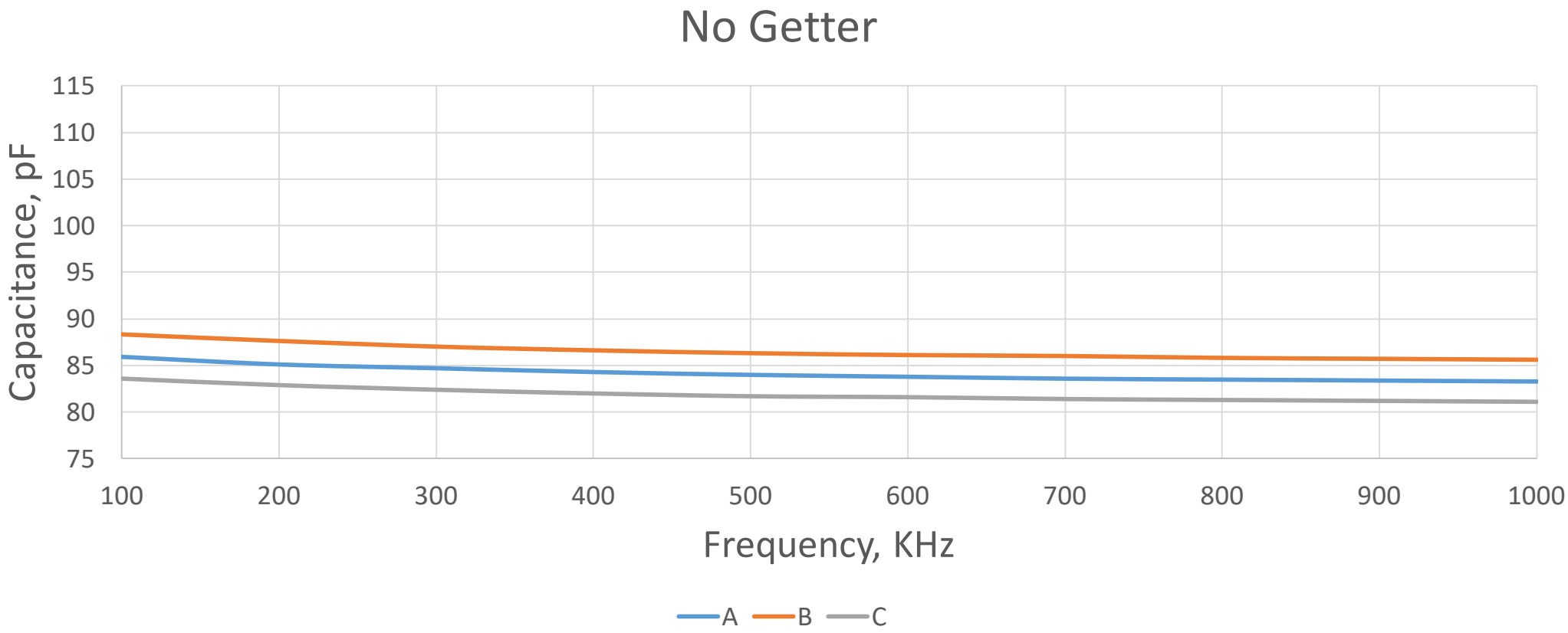
- Soaked test article was dehydrated after soak
  - To remove liquid water on the getter layer
  - Did not reverse chemical reaction from absorbed moisture
  - Performed in a box oven
- Other two PCBs kept in N_2 dry box until evaluated
  - To minimize moisture absorption between fabrication and evaluation events

Instrumented Getter Evaluation

- Capacitance measured with an Agilent 4192A impedance analyzer
  - 100 KHz - 1 MHz, 100 KHz intervals
  - Coaxial cable capacitance measured and removed from sensor measurements
- PCB tested without getter
- PCB tested with getter (pre-soak)
- PCB tested with getter (post-soak)
- Stressy getter evaluated on the PCB Sensor
  - Held in place with a glass cover
  - Effects of glass were removed by calibration

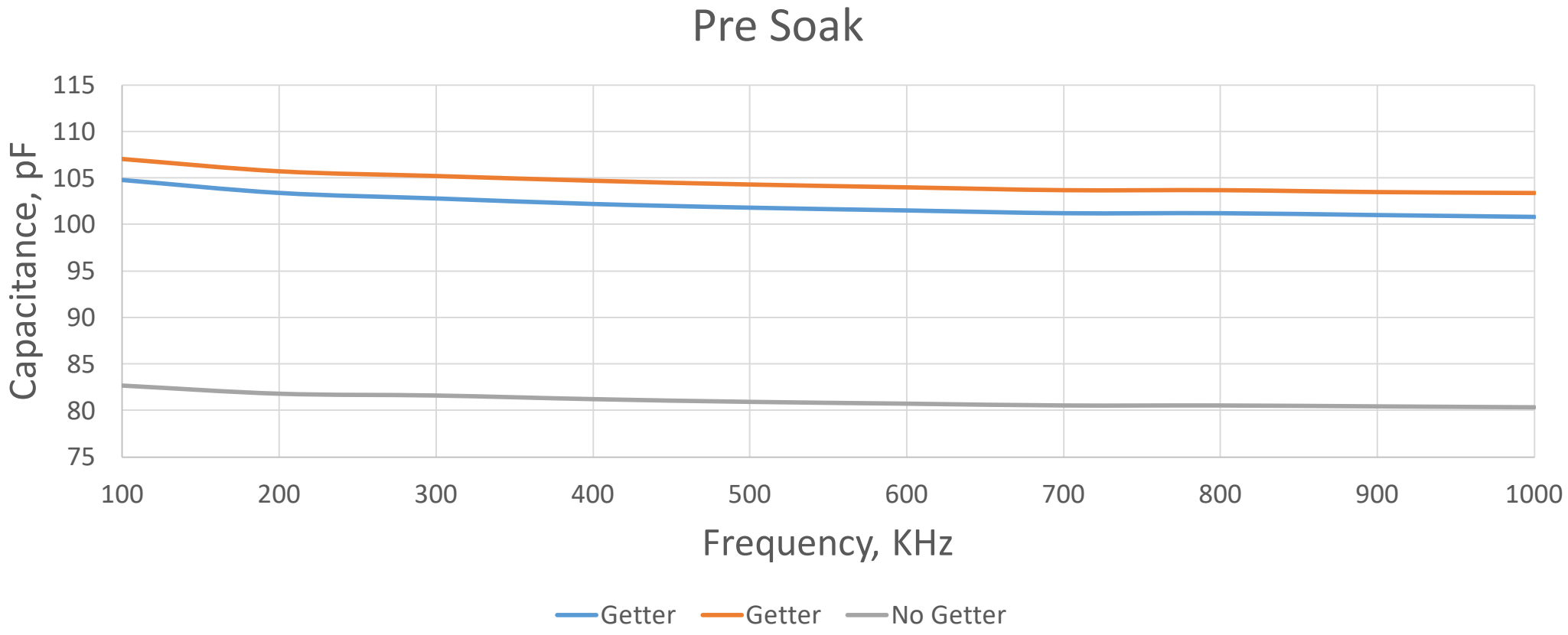


Evaluation of PCB Sensors without Getters



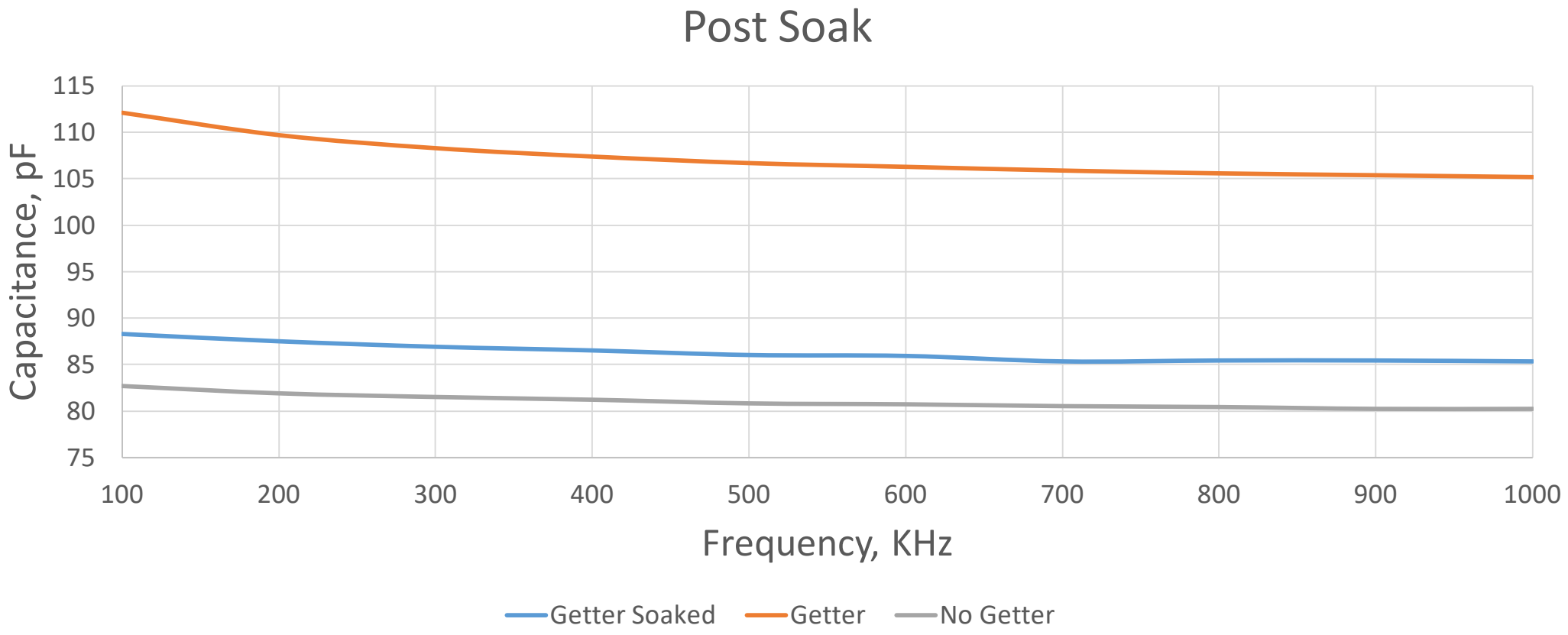
- Some observed variation in “identical” PCB sensors

Evaluation of PCB Sensors with Getters before Soak



- Adding the getter increased the measured capacitance by approximately 20 pF

Evaluation of PCB Sensors with Getters after Soak



- 200 hours of soaking in saturated air resulted in approximately a 15 pF drop

Conclusions

- The chemical change when the Hicap 2000 getter material absorbs moisture results in a measureable change in its dielectric constant
- This change can be measured capacitively as the getter absorbs moisture
  - This was demonstrated using a PCB interdigitated capacitive sensor
  - The sensor only requires power when interrogated
  - Compatible with augmenting BIST functions with the packaged component
- Current plans
  - Retest on a PCB sensor with a solder mask opening over the sensing IDE array
  - To mitigate the delamination issue
- Future plans
  - Implement in MEMS technology

Questions ?