

INTEGRATED PRINTED MOISTURE SENSORS IN COMPOSITE STRUCTURES

Karen Bermes
September 5, 2012

Clarification

- Integrated sensor
 - Inside composite structures
- Printed electronics
 - Prints conductive inks to form circuit

High Performance Materials Institute

“Improve the performance and affordability of advanced composite materials and structures.” [1]

Multifunctional composite structure

- Prosthetics
- Thermal management
- EMI shielding

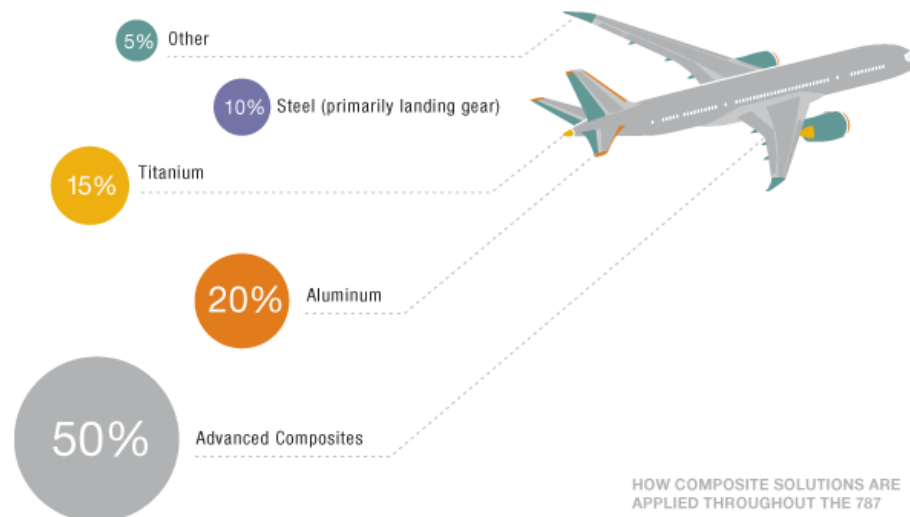


Images retrieved from [1]

Why do we need moisture sensors?

Boeing 787

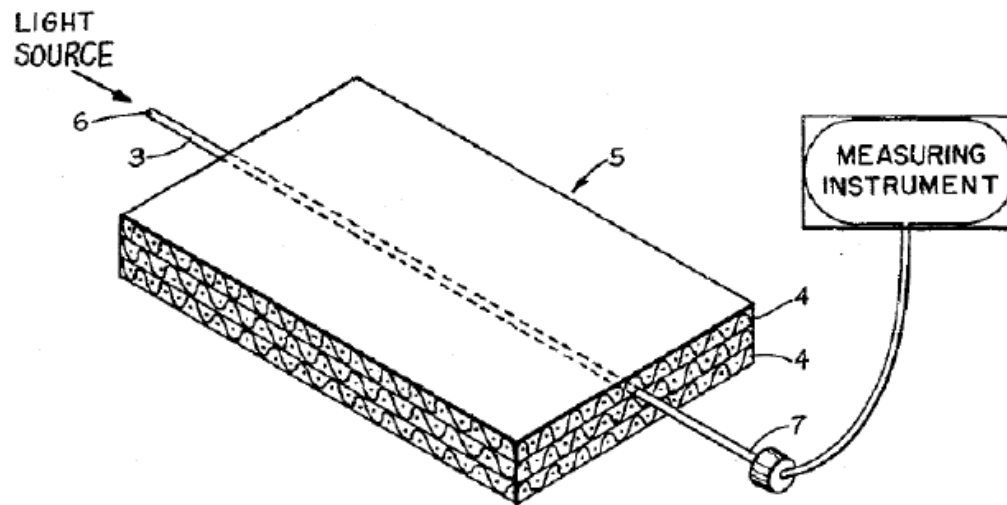
- Comprised 50% by weight
- Moisture can permeate through structure
 - Integrate sensor into structure for detection
 - Thin



Retrieved from [2]

Fiber Optic Moisture Sensor

- Index of refraction
- Acts as a defect along path
- Converting light to electrical signal can be expensive



US Patent No. 4,221,962

Technology

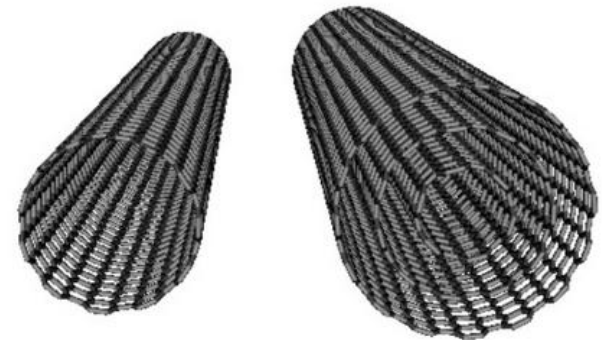
- Nanotechnology
 - Buckypaper
- Printed Electronics
 - OPTOMECH M³D Printer
- Controlled Environment Chamber
 - Vary humidity

Buckypaper (BP)

- 250x stronger and 10x lighter than steel_[1]
- Electrically conductive
- 25 μm thick
- Randomly aligned carbon nanotubes (CNTs)
 - SW and MW
 - Large surface area



Retrieved from [1]



SWNT

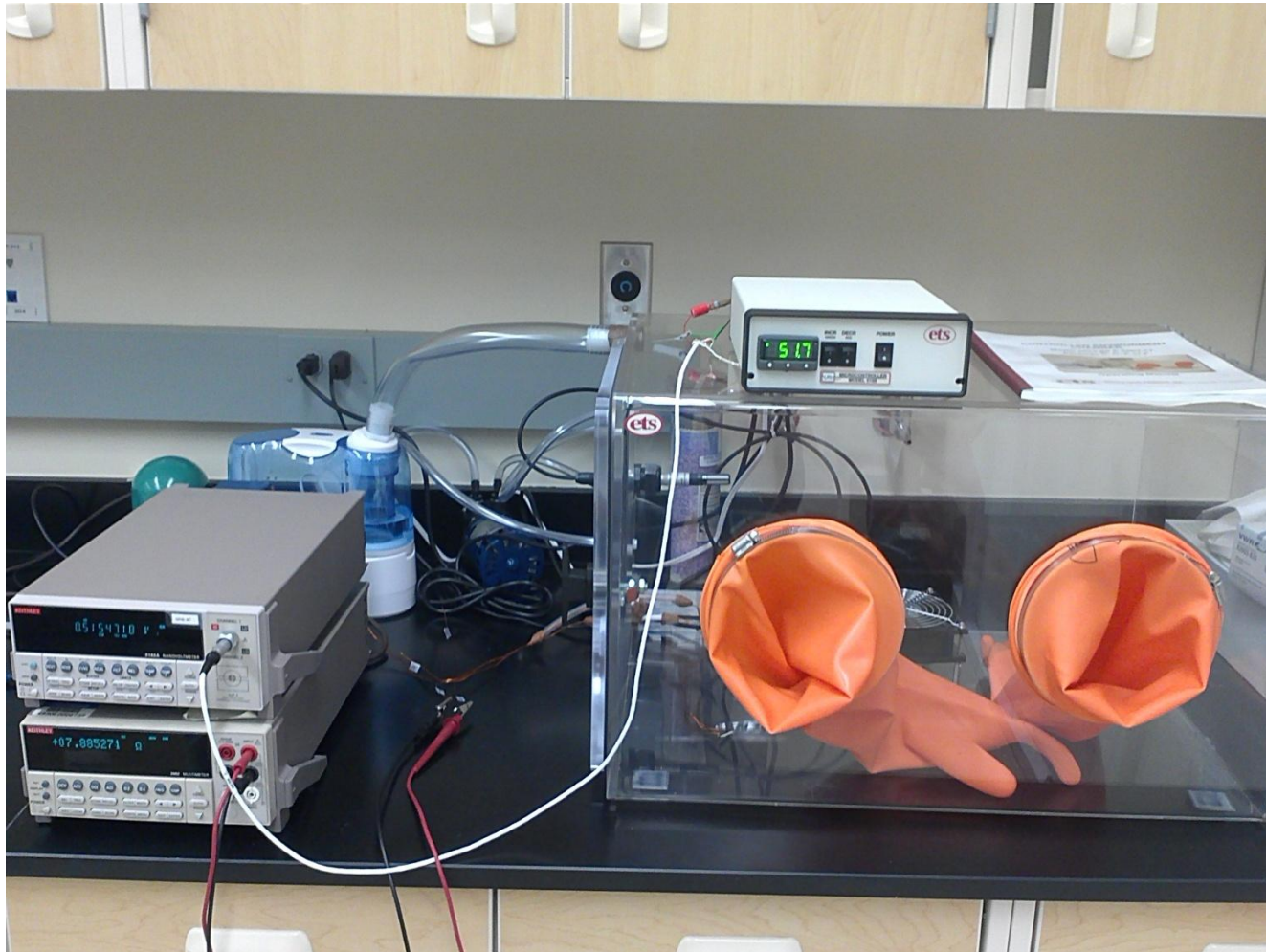
MWNT

Retrieved from [3]

OPTPMEC M³D Printer

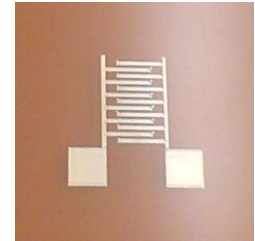


Controlled Environment Chamber



Procedure

- Printed open circuit on polyimide
- Sinter
- Attach BP or print CNT ink



- Attach measurement materials/instruments
 - Silver paste
 - Gold and copper wire
- Measure resistance in CEC while varying humidity

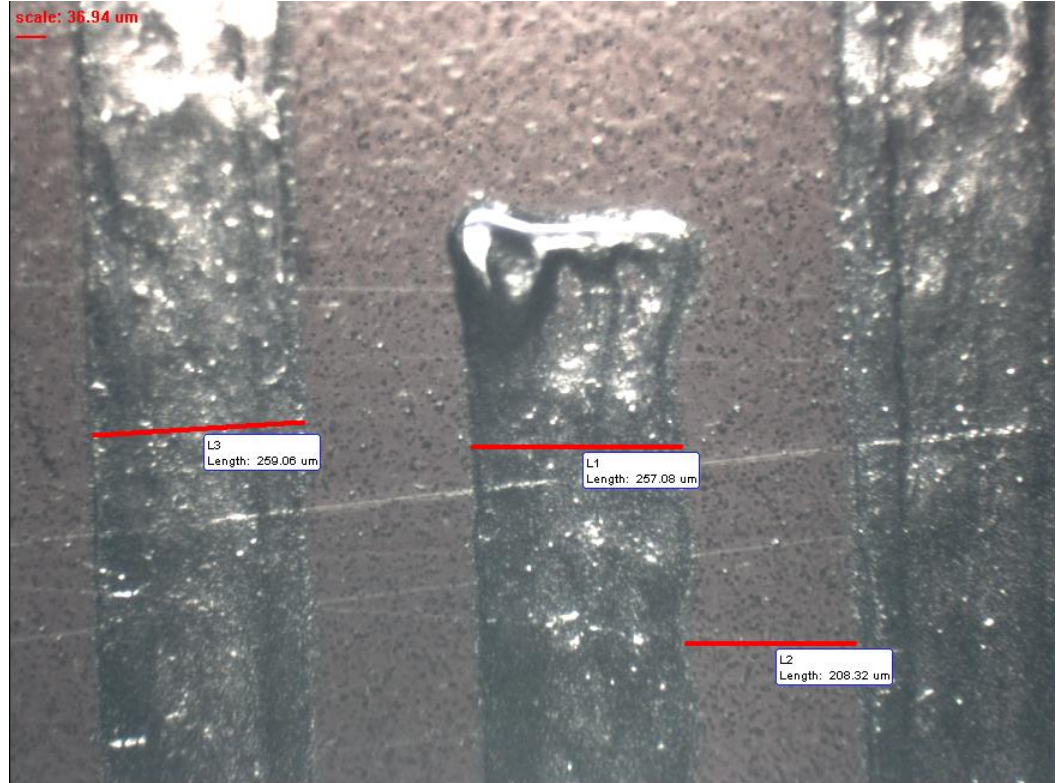
Parameters

- Spacing between silver electrodes
- Printing multiple passes
- Dry samples before testing

Prediction

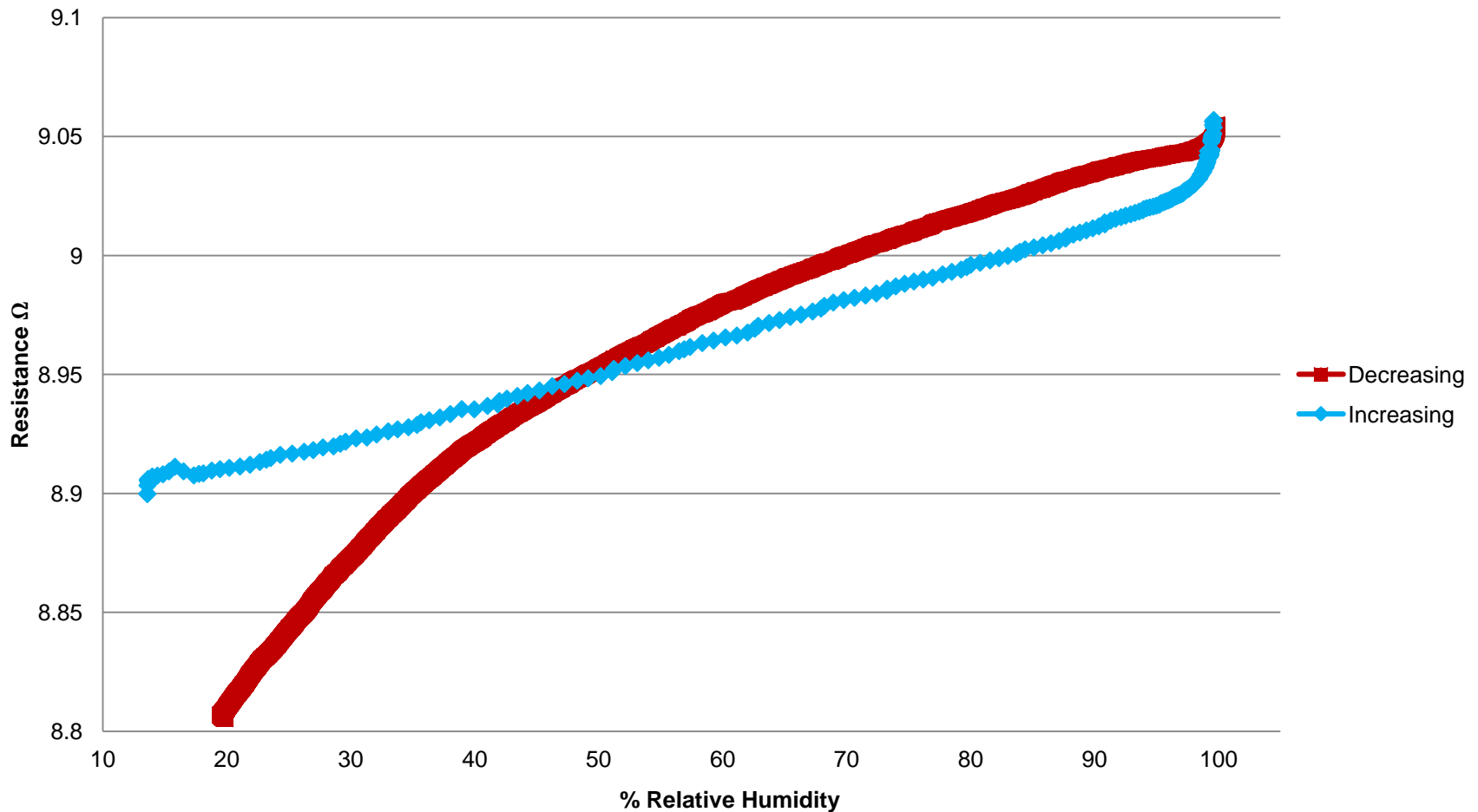
- CNTs are electrically conductive
- Pure water
- Resistance will increase with increasing humidity

Buckypaper Sensor



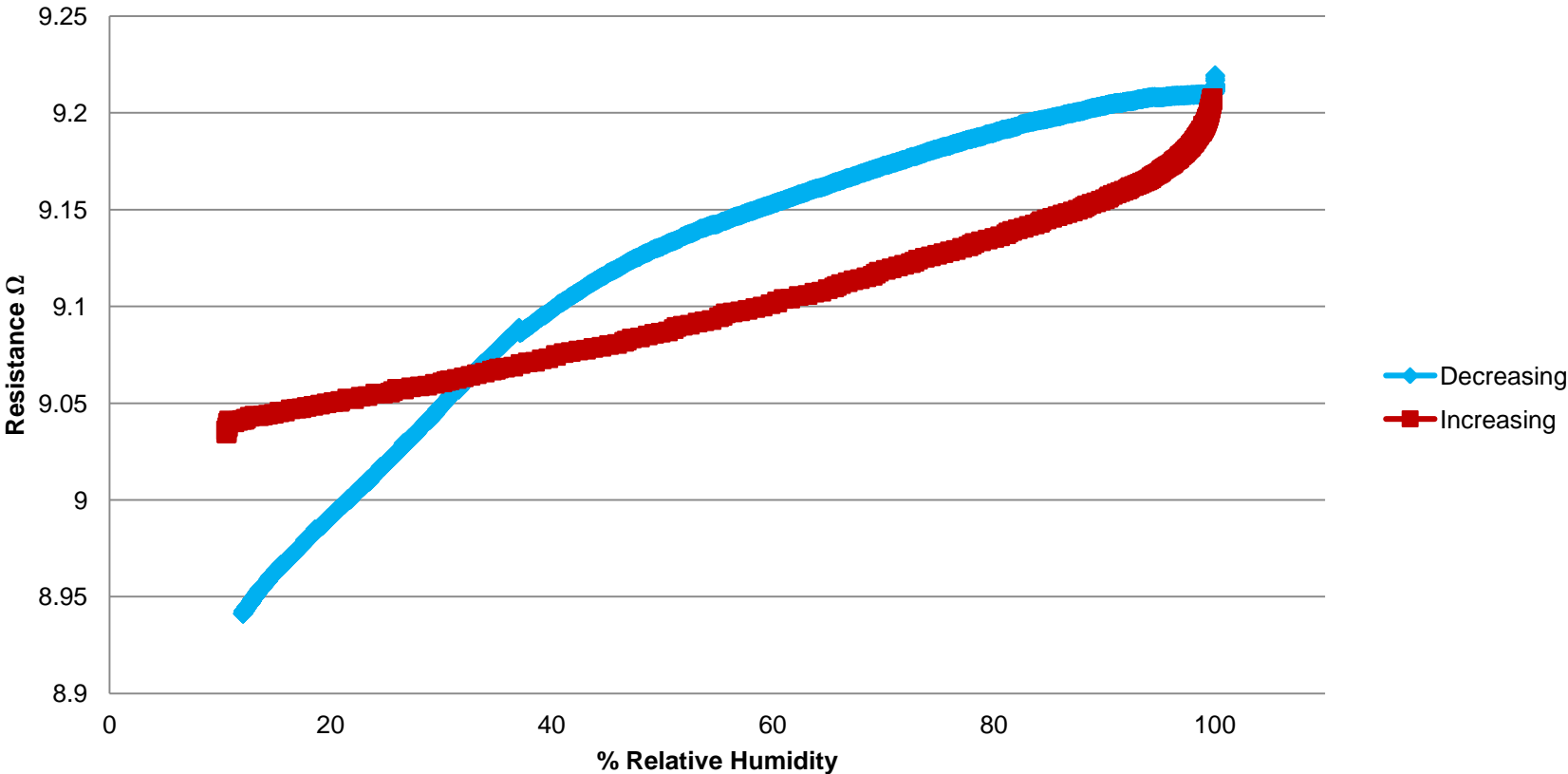
Resistance vs. Relative Humidity BP

200 μ m NC BP Sensor

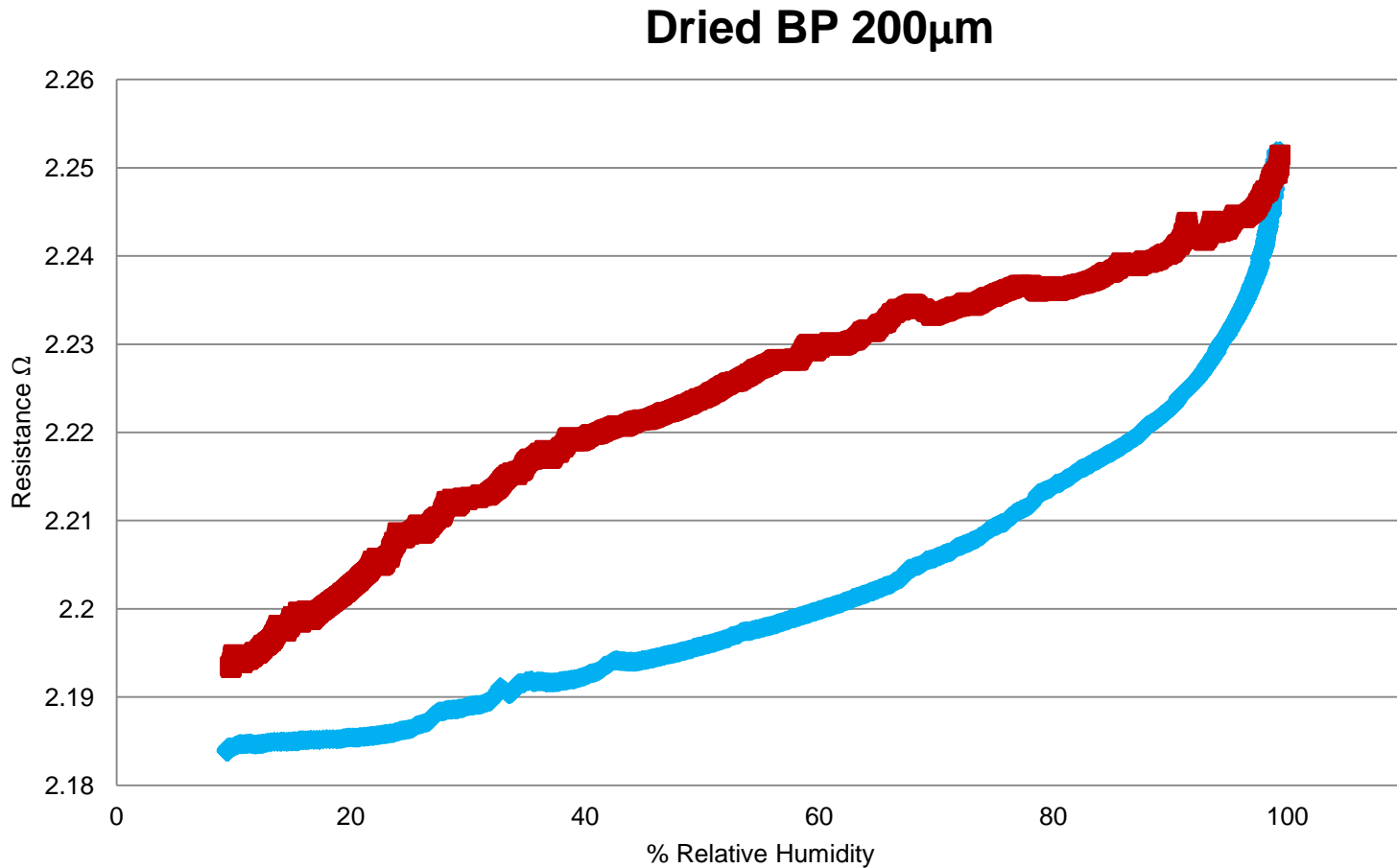


Resistance vs. Relative Humidity BP

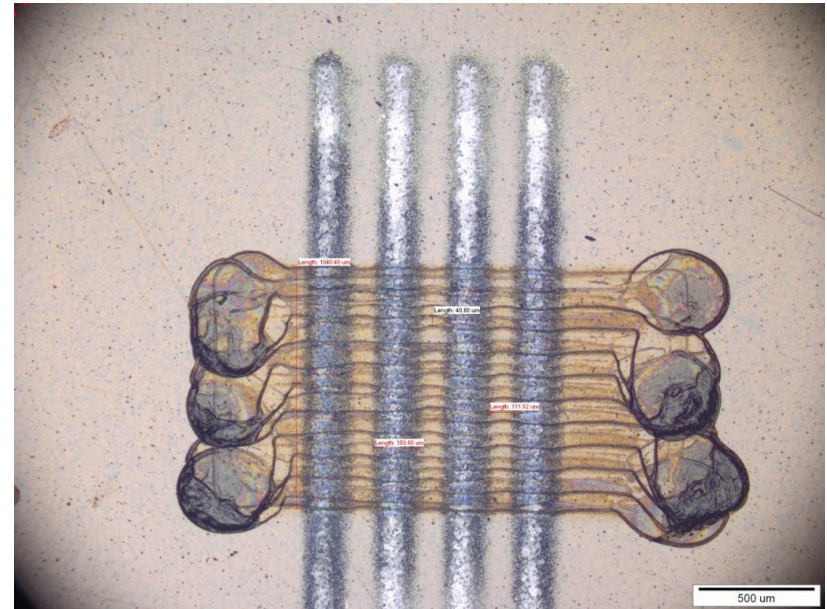
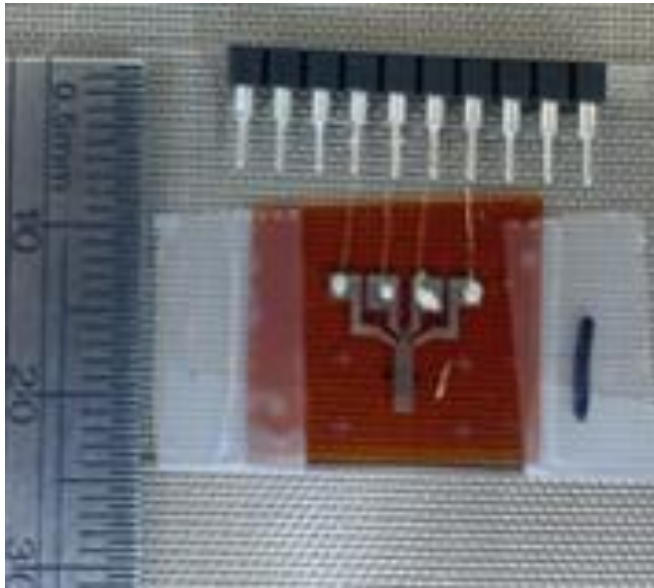
100 μ m NC BP Sensor



Resistance vs. RH Dried BP

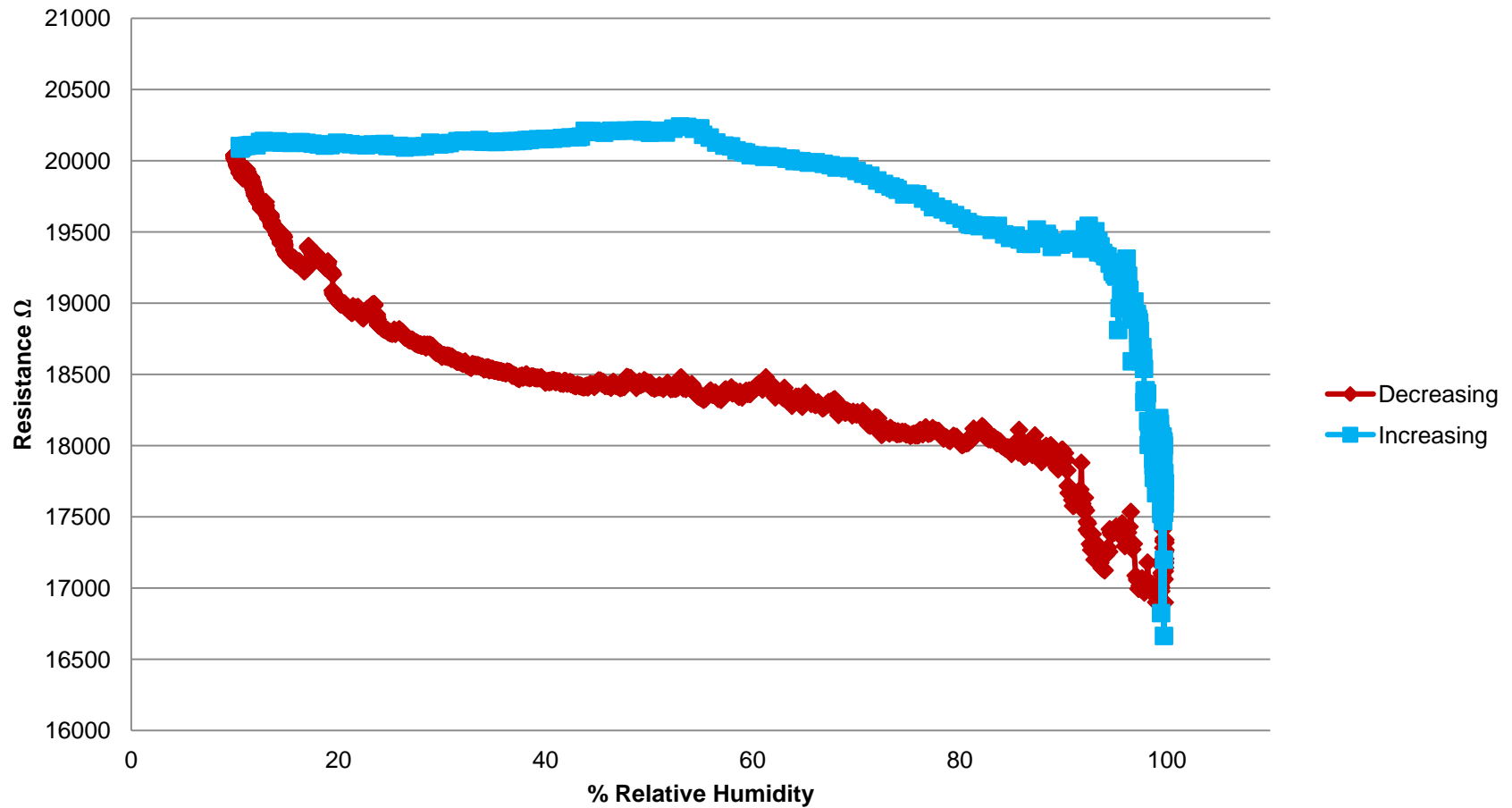


CNT Printed Sensor



Resistance vs. Relative Humidity CNT

Printed CNT Sensor 1



Hysteresis

- Nonlinear, cyclic reaction
- The current state of a system is dependent on its past state, but nondependent on rate [4]
- The goal is to develop a sensor with no hysteretic response.

Future Research Plans

- Embed sensor into composite structure
 - Test effect on structural integrity
- Identify physical properties that cause different responses to changes in humidity
- Improve design to avoid hysteretic responses

References

- [1] <http://www.hpmi.net>
- [2] <http://www.boeing.com>
- [3] <http://www-ibmc.u-strasbg.fr>
- [4] Cruz-Hernandez JM and Hayward V 2001
“Phase control approach to hysteresis
reduction” *Control Systems Technology, IEEE
Transactions on* 9(1) 17-26

Thank you



Questions?