



FAIRE LA LUMIÈRE
SHEDDING LIGHT

GREEN SENSORS BY PRINTED PHOTONICS

Charles Trudeau

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Presentation Outline



- INO – Who are we?
- Printed Photonics at INO
- NSERC Green Electronics Network
- Green sensors
 - What do we mean by “Green” ?
 - How to make Greener Sensors
- Examples of green sensors at INO

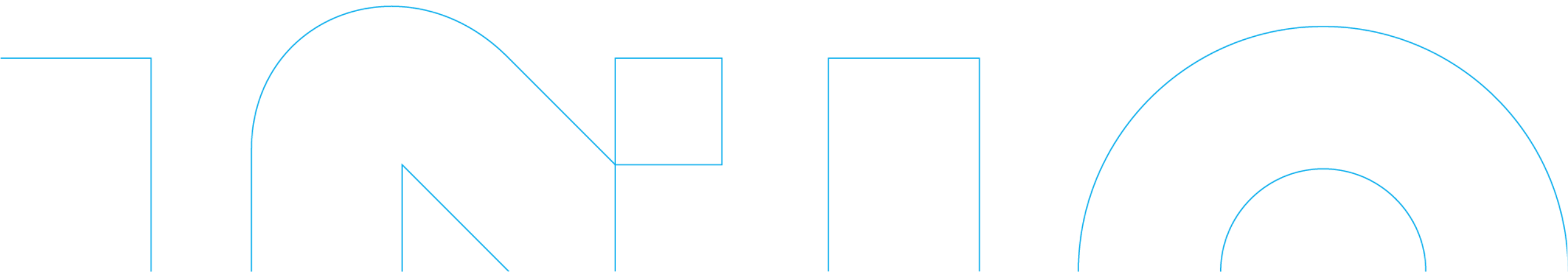
About Us

- INO is a private institute of translational **applied research** (NPO)
- **Founded in 1988**
- **200** employees
- Annual budget ~**\$35 M**
- **ISO 9001** and **13485**
- Offices in Québec, Montréal, and Hamilton



OUR MISSION

Bring to life innovations that enable Canadian industry to be more productive and competitive.



Our role



Industrial world

Obstacles

Challenges



Solutions

Knowledge



Academic world

In 30 years...



325 *
Patents



More than
6,500
solutions



35
Spin-offs



75
Technological
transfers

* As of February 2019

Our business units



**Defense,
Security and
Aerospace**



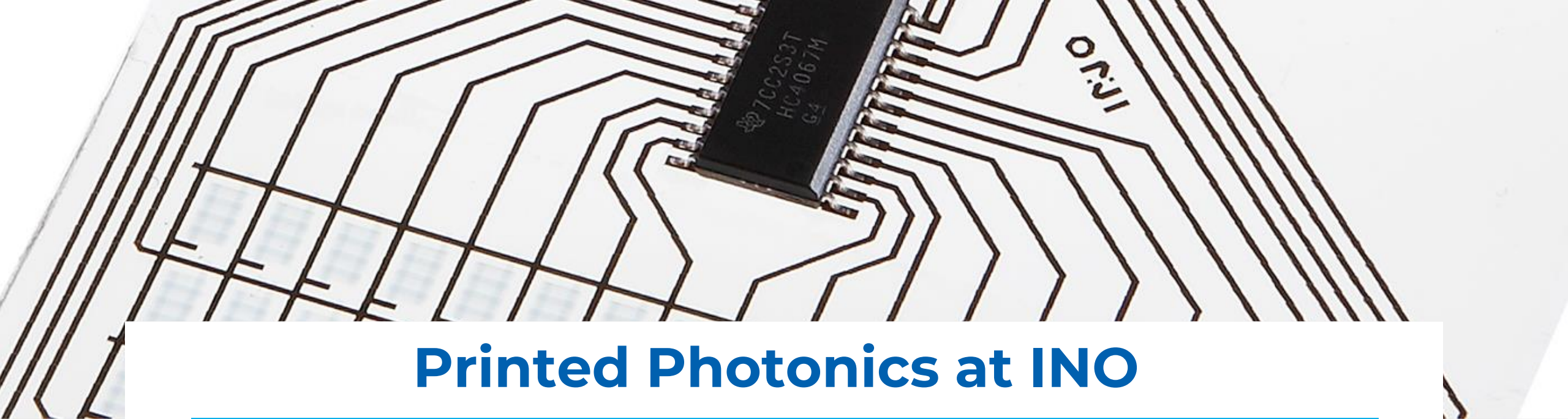
**Advanced
Manufacturing**



**Sustainable
Resources,
Agriculture and
Infrastructures**



Biomedtech



Printed Photonics at INO

- The team and the lab
- Capabilities
- Electrodes and Printed Circuits
- Sensors and Devices
- Other Applications

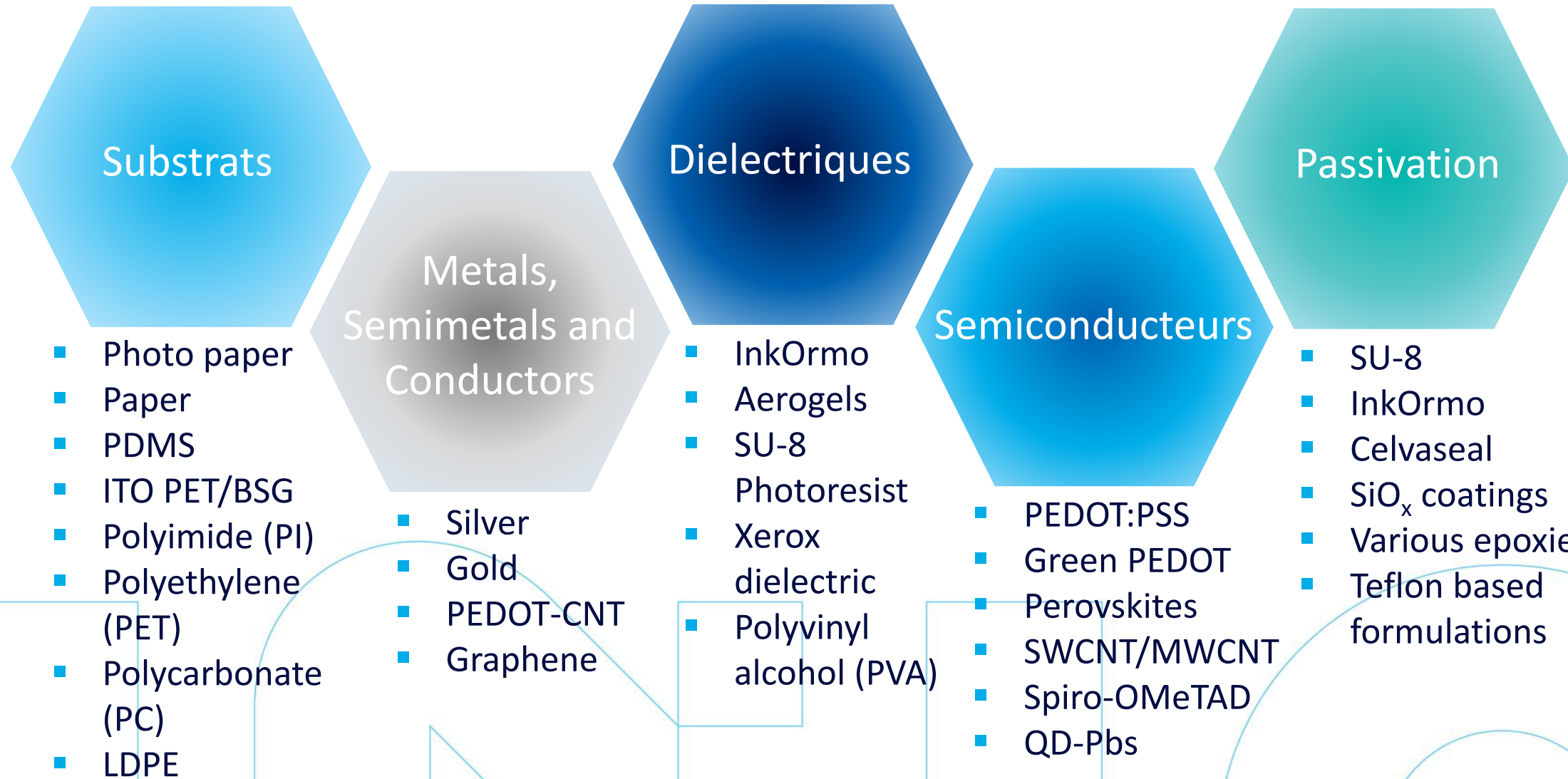
Our Team and Laboratory



Technical Team

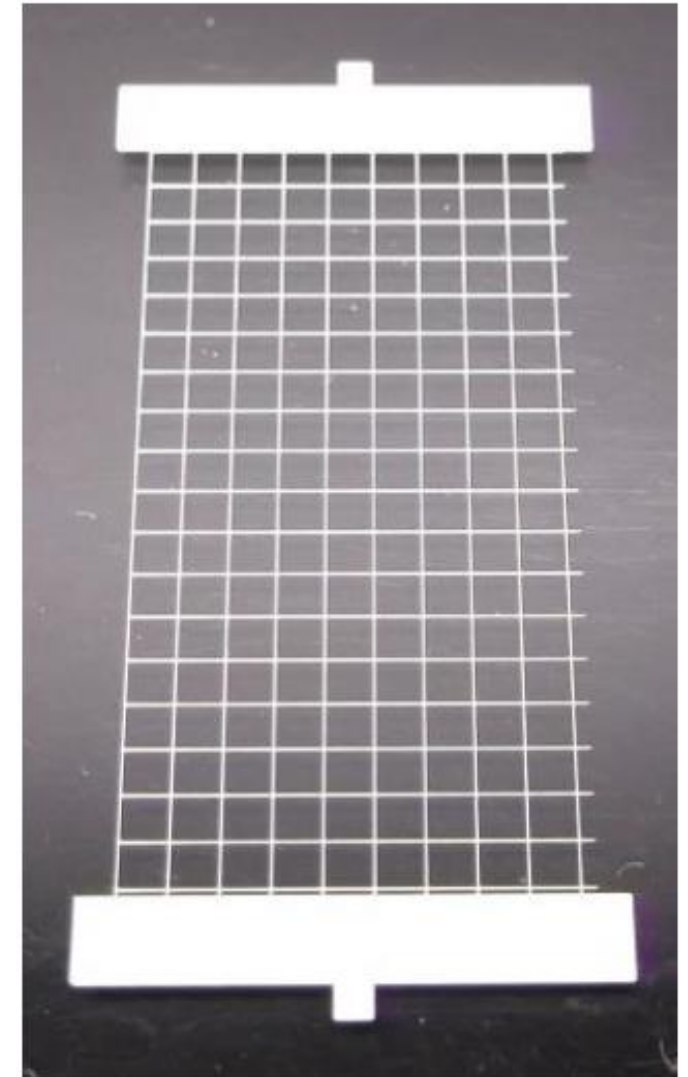
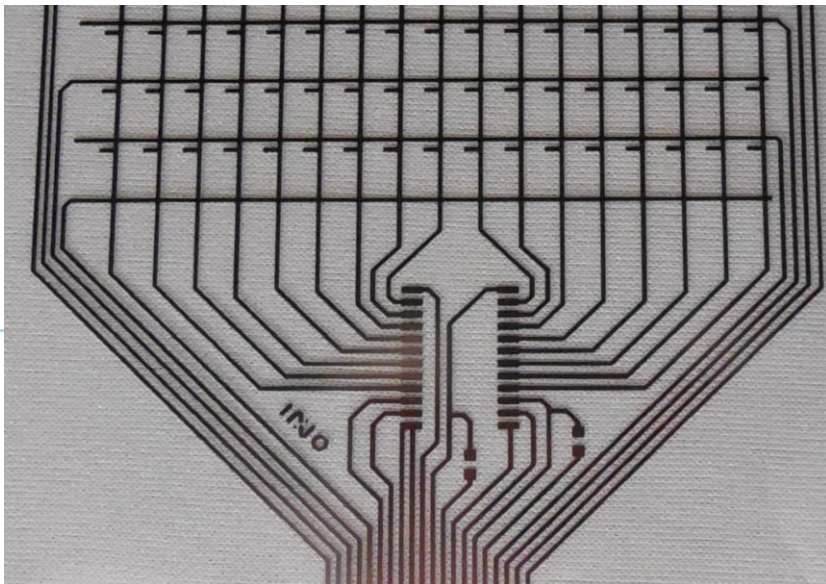
- Inkjet Printing
- Aerosol Jet Printing
- Spray Coating
- Lamination
- Hybrid Assembly

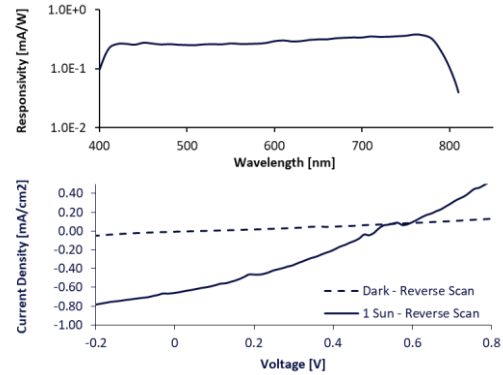
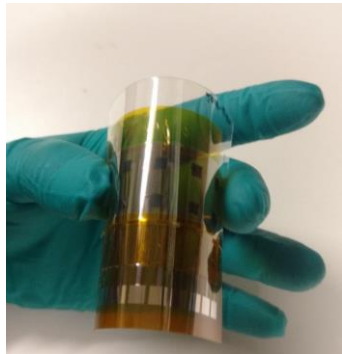




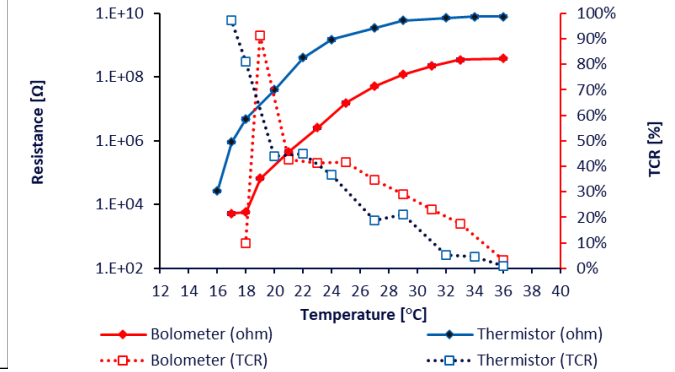
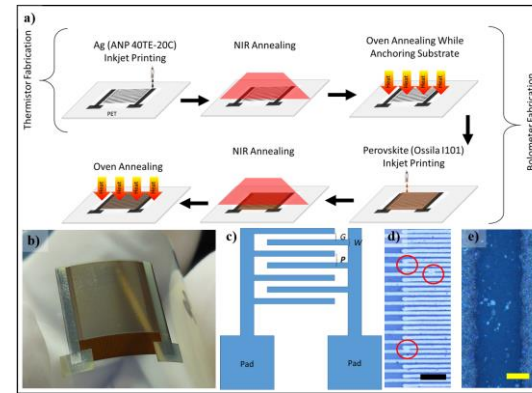
Electrodes and printed circuits

- Bio-electrodes
- Transparent electrodes
- Organic Electrodes
- Heating Elements
- Multilayered Circuits



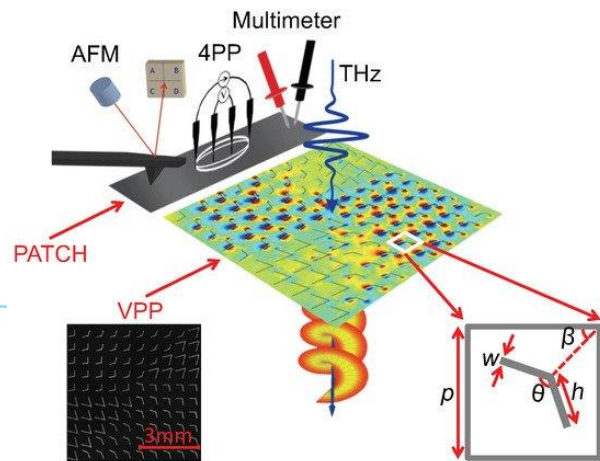


Solar Cells and Photodiodes



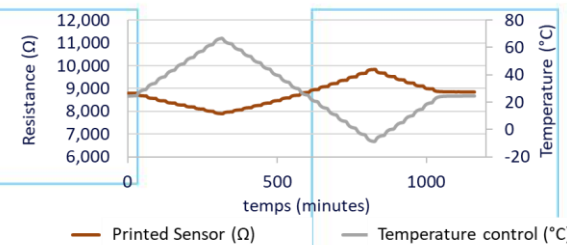
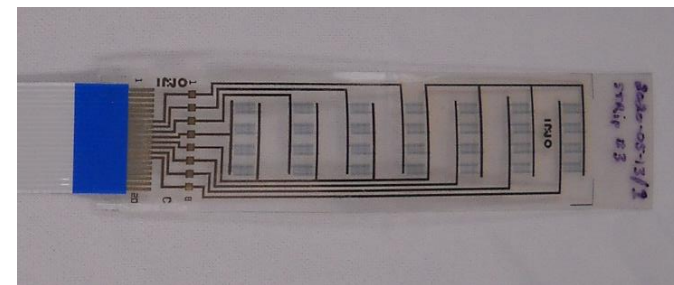
Primitive Bolometers

<https://doi.org/10.1038/s41528-020-00097-2>



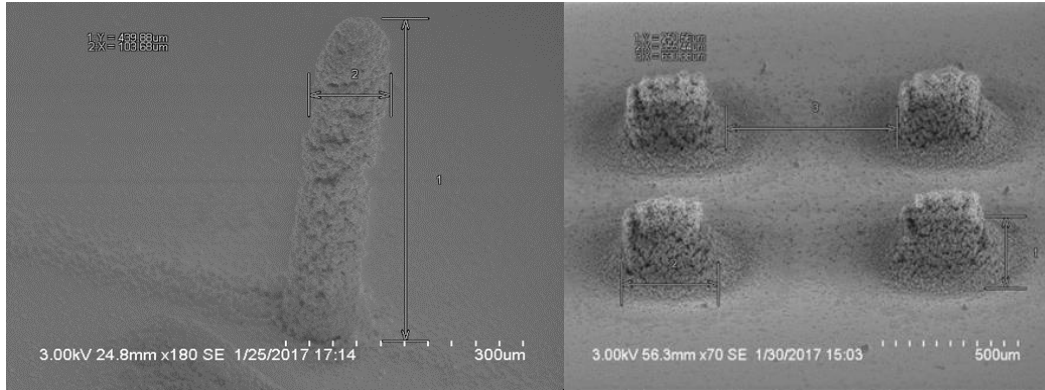
Vortex Phase Plates

<https://doi.org/10.3390/s19030444>

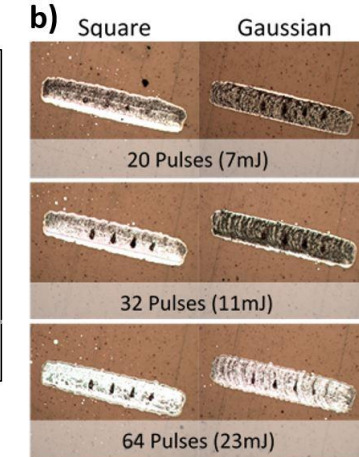
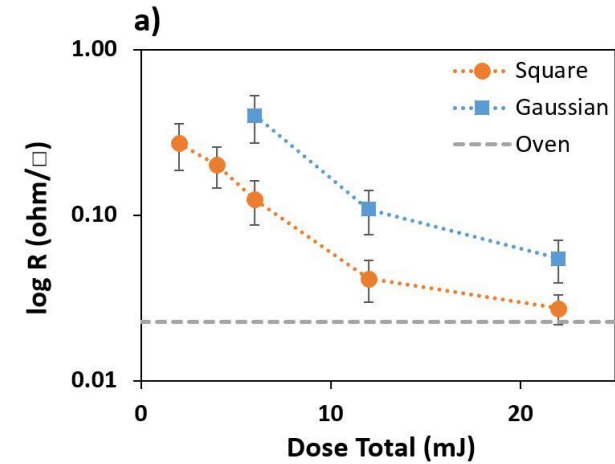


Temperature and Humidity Sensors

Other Applications

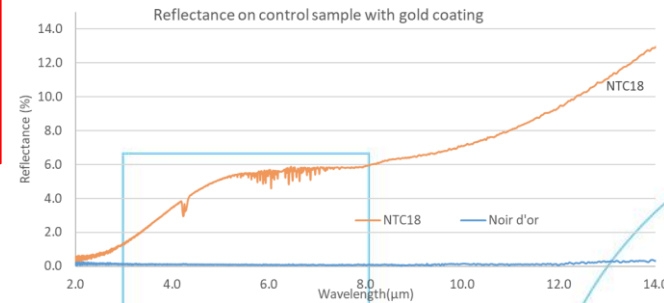
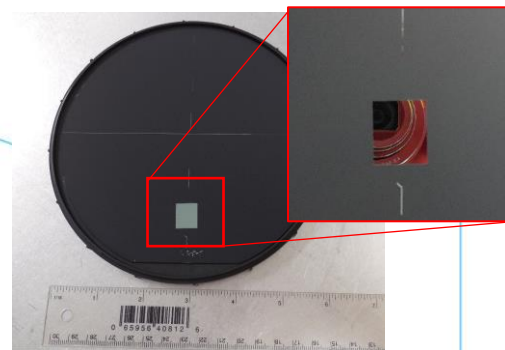


Aerogel Thermal Insulator Printing



Temporal Modulated Laser Sintering

<https://doi.org/10.1038/s41598-018-19801-4>



Anti-reflection Coatings



N SERC Green Electronics Network



Theme 1

Green Materials and Processes for Printed Electronic Devices

Theme 2

Printing Processes and Device Fabrication

NSERC Green Electronics Network



Industrial Partners



Institutional Partners



International Partners





Green Sensors

- What do we mean by “Green” ?
- How to make Greener Sensors

What do we mean by “Green”?



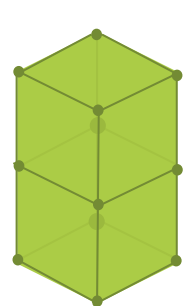
What do we mean by “Green”?



Reduce Waste
Materials & Energy

Improve Safety
People & Environment

What do we mean by “Green”?



① Waste Prevention

② Chemical Economy

③ Less Hazardous Chemical Syntheses

④ Safer Chemicals Products

⑤ Safer Solvents & Auxiliaries

⑥ Energy Efficient

⑦ Renewable Feedstocks

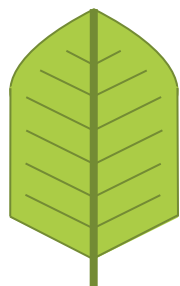
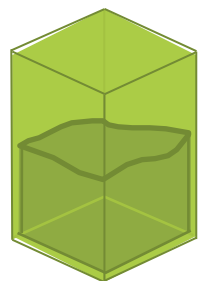
⑧ Streamlined Processes

⑨ Efficient Processes

⑩ Innocuous Degradation

⑪ Eco-Friendly (Pollution Prevention)

⑫ Safe (Accident Prevention)



12 PRINCIPLES OF GREEN CHEMISTRY & MANUFACTURING

Based on the work of Anastas, P. T.;
Warner, J. C. Green Chemistry: Theory
and Practice, Oxford University Press:
New York, 1998, p.30.

How To Make Greener Sensors



12 PRINCIPLES OF GREEN CHEMISTRY & MANUFACTURING



- 1 Waste Prevention
- 2 Chemical Economy
- 3 Less Hazardous



- 4 Safer Chemicals
- 5 Safer Solvents
- 6 Less Energy



- 7 Renewable Feedstocks
- 8 Streamlined Processes
- 9 Efficiency



- 10 Degradation
- 11 Eco-Friendly
- 12 Safe

Materials

Directly functionalize or couple pi-conjugated organic building blocks to improve atom-economy and eliminate wasteful directing groups.

Use light-driven and condensation-type reaction pathways to reduce chemical waste and need for stoichiometric reagents.

Use green solvents for extractions, separations, formulations, and reaction chemistry towards target organic materials.

Strategically design molecules and polymers to enable dissolution in and processing from green solvents.

Use bio-sourced and/or commodity organic building blocks to construct target materials.

Use renewable and/or abundant feedstocks as reactants, reagents, and solvents in chemical synthesis.

Focus on materials that can be mass produced using continuous and/or solvent free methods.

Ensure high carbon content in active materials; reduce use of elements beyond 2nd row.

Incorporate reversible chemical linkages in materials to enable breakdown/biodegradation to low molecular weight components.

Manufacturing

Maximize use of substrate surface.

Manufacturing using one class of "green" materials: recyclable, biodegradable, or compostable.

Formulate easy-to-clean inks to reduce washing solvent on press.

Minimize or eliminate toxic solvent in ink formulations and on press.

Minimize energy requirements of ink mixing, printing, drying, washing and finishing processes.

Reduce manufacturing complexity to reduce supply consumption and waste generation.

Exclude non-additive, non-printing techniques.

Develop high-speed and high-volume manufacturing methods.

Design inks and printed materials for easy sorting at end-of-life by end user without requiring materials separation.

Develop real-time, in-process monitoring and control to prevent pollution.

Develop inherently safe manufacturing steps to minimize potential for chemical accidents.



Examples of Green Sensors at INO

- Myths of green sensors
- Carbon on paper temperature sensor
- Green PEDOT-Like polymer for humidity and/or temperature sensing

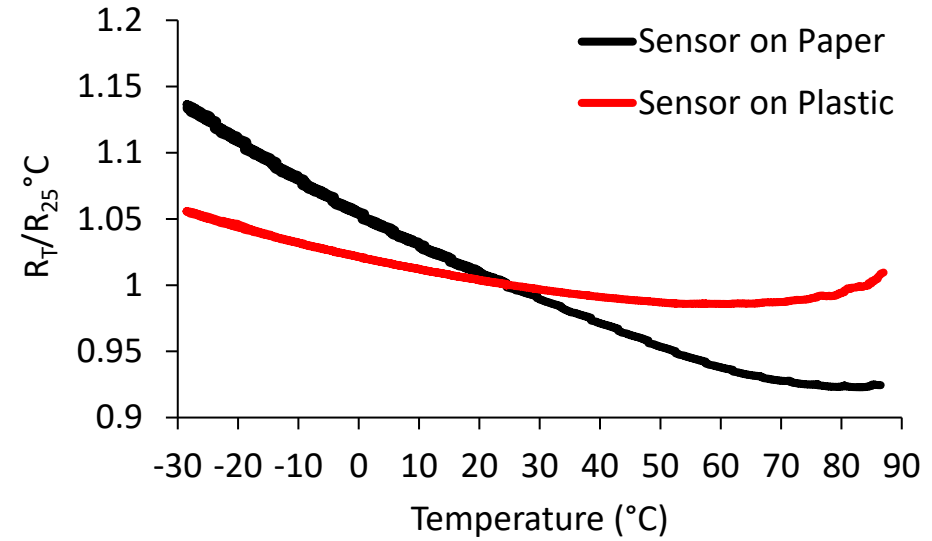
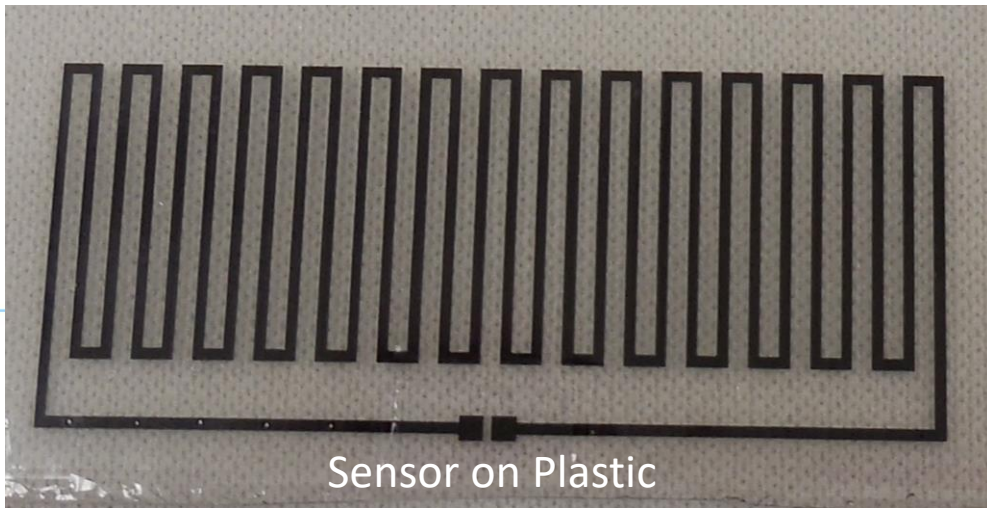
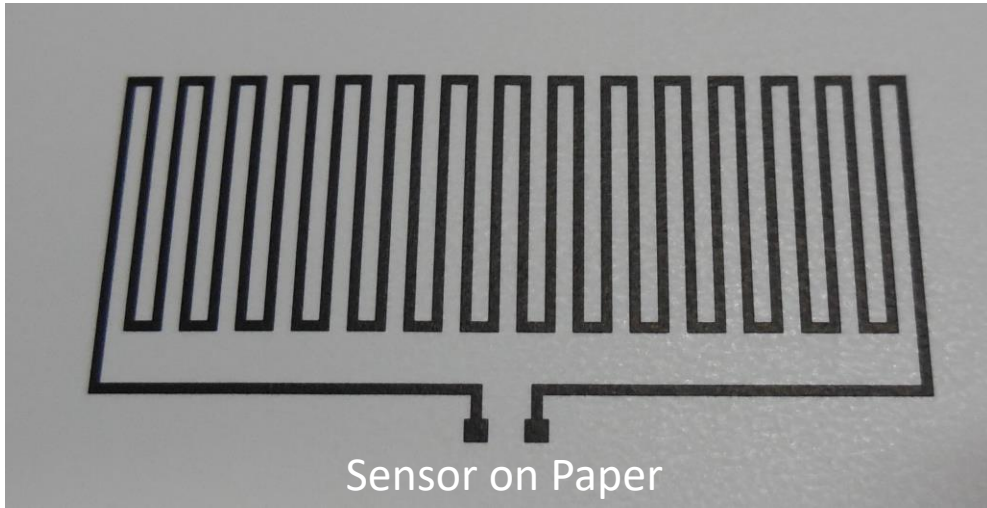
Green sensors are more costly

False – principles of green manufacturing are based on improved efficiency, lowered waste and abundant and renewable feedstocks.

Green sensors have lowered performances

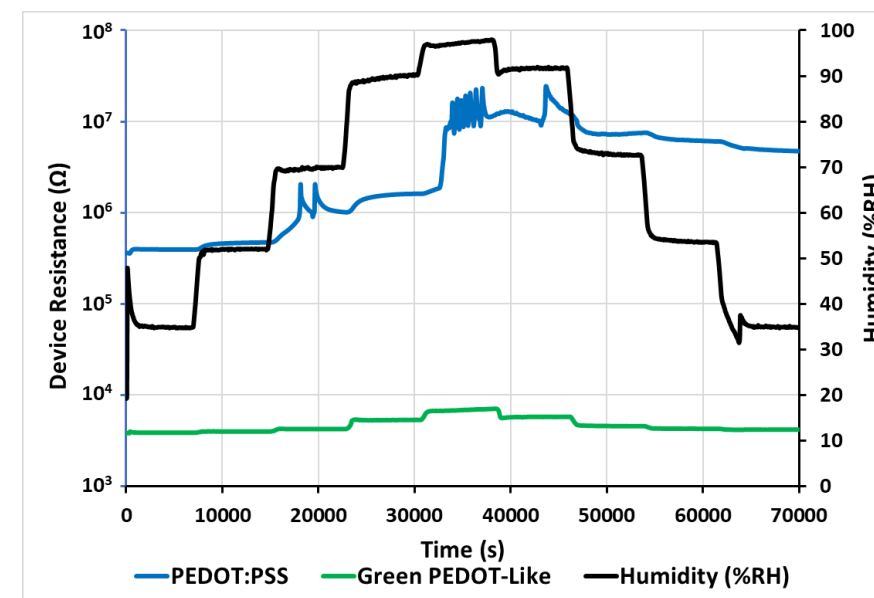
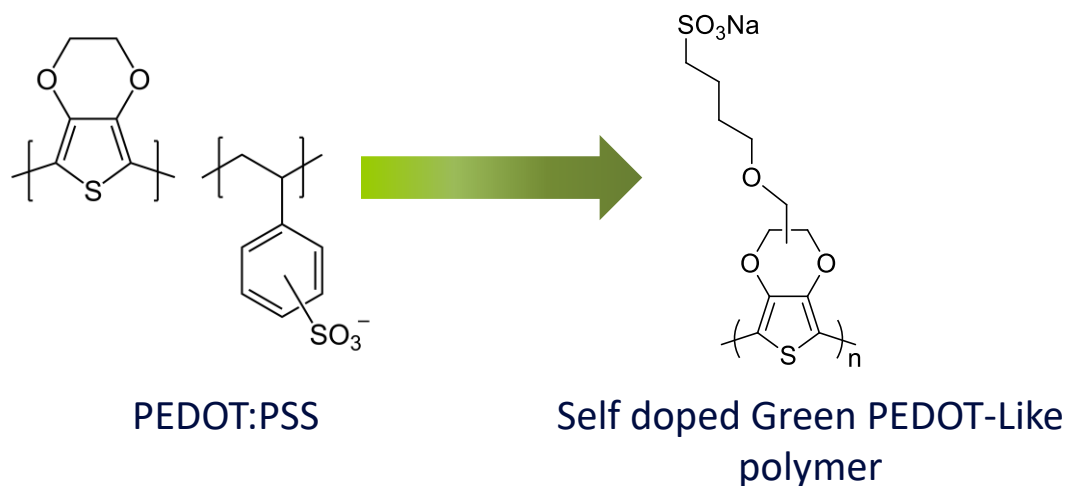
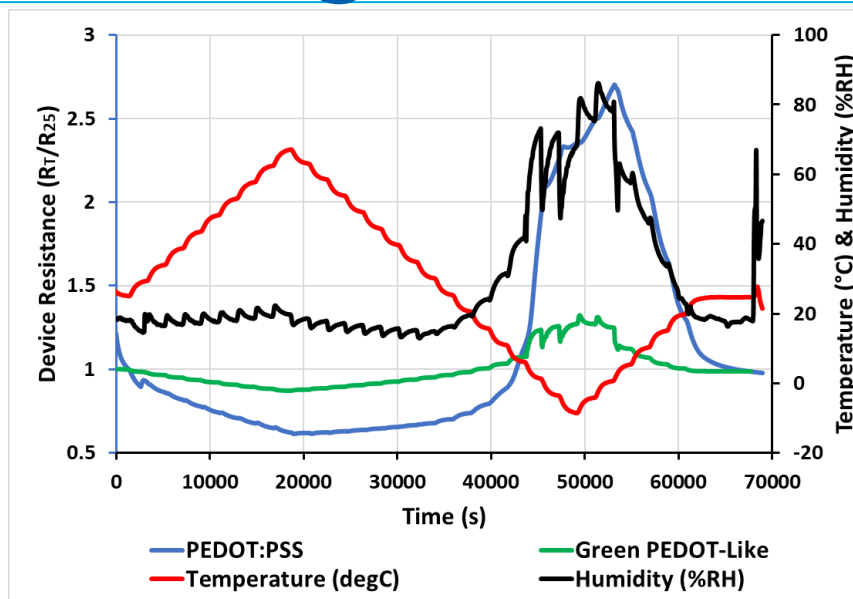
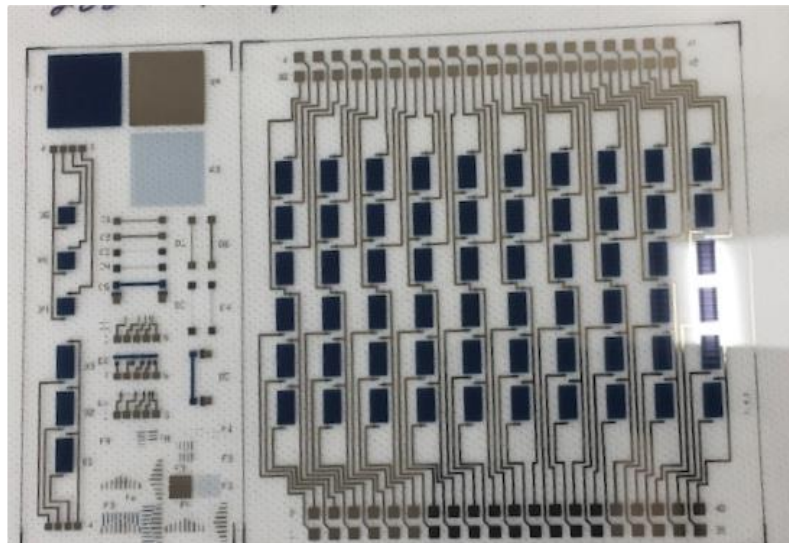
Questionable – Green sensors enable novel market applications

Carbon on Paper Temperature sensor



Fully Biodegradable carbon/paper sensor!

Green PEDOT-Like polymer for humidity and/or temperature sensing



Danke!



Questions?

