Sustainable electronics at VTT

31/03/2021 VTT – beyond the obvious

Sustainable development

“ Sustainable development aims to meet the **needs of present generations without jeopardising the ability of future generations to meet their own needs**.

It provides a comprehensive approach bringing together economic, social and environ-mental considerations in ways that mutually reinforce each other.

https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-approach-sustainable-development_en

EU committed to implementing the 2030 Agenda for Sustainable Development and the SDGs.

Motivation for sustainability in flexible electronics

Global electrical and electronic **waste production increasing with 6.5 CAGR%**[1] with only **20% collected/recycled** properly[2].

Global consumption of material resources expected to **more than double** between 2015 and 2050[3].

[1]Sullivan, M. Printed Electronics: Global Markets to 2022, BCC Research LLC. 2018
[2]Ellen MacArthur Foundation. Circular consumer electronics: an initial exploration. 2017
[3]European Union reflection paper. Towards a Sustainable Europe by 2030. January 2019

Drivers and tools for sustainable flexible electronics

- New functional properties
- Improved performance
- Need for end-of-life solutions (cradle-to-cradle)
- Need for reduction of carbon footprint
- Limited availability of raw materials
- Possibility to use abundant and cost-compatible materials

Energy and material efficient manufacturing

Materials from renewable resources

Bio-degradable / compostable materials

Eco-design, circular design

Recycle, reuse, repair

VTT tackles sustainable development through multidisciplinary competences in **biomaterial development and printed and hybrid electronic**

- **Additive manufacturing process – low emissions and losses**
- **Possibility to use wide selection of substrate materials including biobased, compostable and recyclable materials**
- **New functionalities through bio-materials**

Our goal − Implementation of bio-based materials as a new normal in electronics.

Research topics towards sustainable solutions for flexible electronics

- **Renewable, biobased and biodegradable** substrates and overmolding materials
- **Abundant materials** for conductors
- **Functional components** and **materials** based on intrinsic material properties
- **Sustainable** powering **solutions**

Pioneering work in printed paper based hybrid electronics

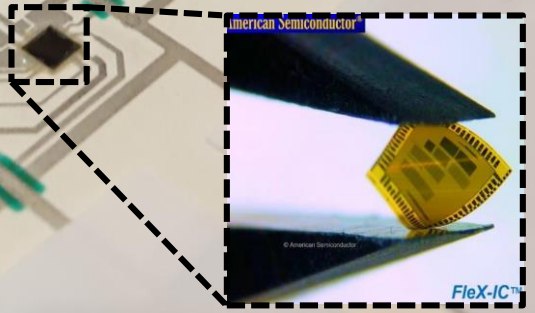
Wireless sensor devices on a paper surface which are manufactured by using **high-end and low-cost printing techniques**.

- Open/close detection in shipping of valuable goods
- Humidity and temperature sensing in shipping of precious goods (paper-based humidity sensors)
- Tracking and tracing of registered post

EU FP7 ROPAS (2011-2015)

Silicon on paper

- Paper based hybrid electronics
- Sustainable temperature logger tag
- Paper + bare-die ultra-thin RFID temperature sensor chip



Courtesy of American Semiconductor

https://www.youtube.com/watch?v=CbMFWoooLcQ

ECOtronics

Funded by Business Finland

ecotronics

Sustainable Electronics & Optics

Sustainability through

- Selecting highly recyclable and compostable materials
- Promoting environmentally friendly manufacturing technologies to reduce use of materials
- Developing the methodology to recover the materials
- Quantifying the environmental impact of the developed solutions

ECOtronics

Material development

- Sustainable substrates: cellulose based, paper coatings, bio-plastics, bio-composites
- Inks: e.g. metal replacement
- Adhesives: e.g. low temperature alternatives

Printed components development for energy module with innovative product design

- Super-capacitor, OPV, diodes

Sustainable R2R processing

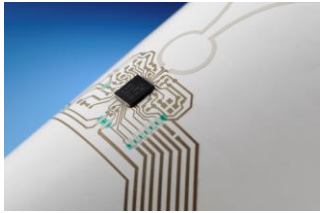
- Printing, hot embossing, over moulding, assembly, converting

Life-cycle

- Assessment, repulpability, deinking

PCB design and testing on sustainable substrates

https://www.ecotronics.fi

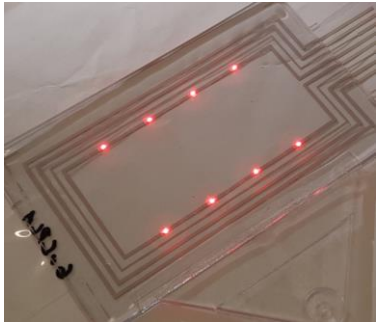


Application of bio-based materials for printed, hybrid and structural electronics

Benchmarking of several bio-based materials

- Film processing
- Mechanical and thermal properties
- Stability (temperature)
- Performance in printed and hybrid electronic applications (resistance of printed test patterns)
- Printing, hybrid-integration overmolding

Bio-based electronics applicable as lightweight, functional structures e.g. in automotive industry.



Luoma et al. (2021) J. Plastic Film & Sheeting 0(0) 1- 34
Välimäki et al. (2020) Int. J Adv. Manuf. Technol. 111 (1) 325-339

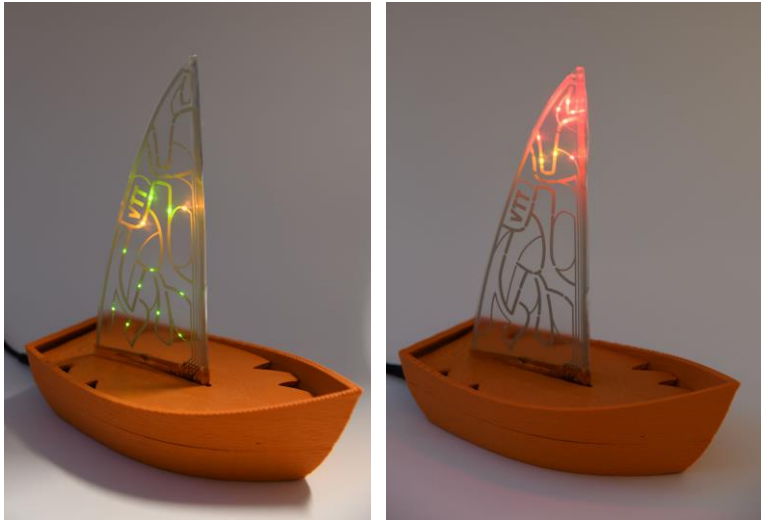
BIOBOAT – A sensor for clean indoor air built using bio-based materials

Article under preparation

Biopolymer-based sail

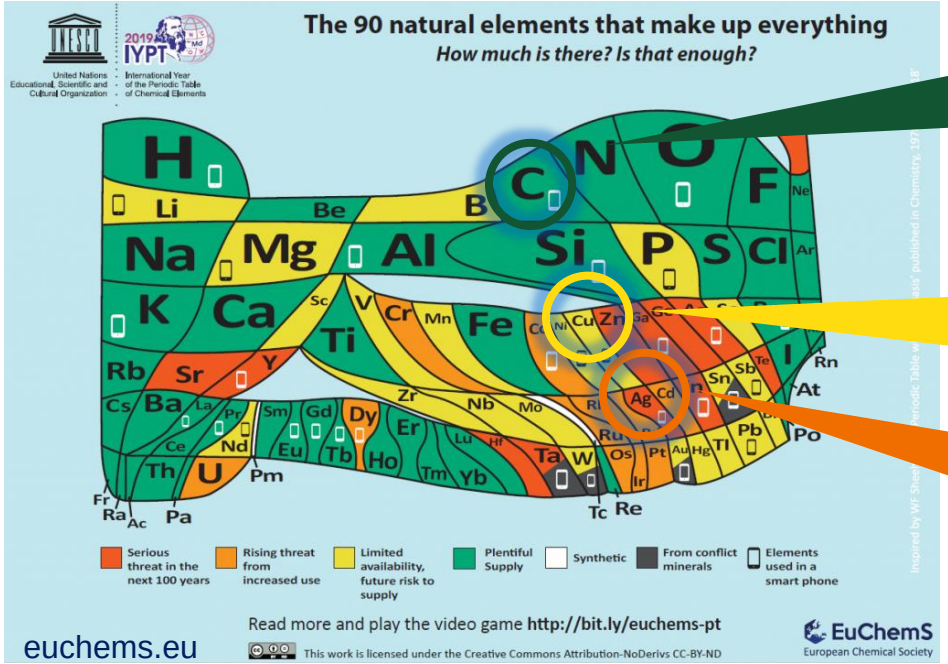
- Printed, hybrid integrated and overmoulded
- LED indicators for informing of air quality (CO2)
- Electrical performance improved in comparison to reference polymers

3D-printed, cellulose-based and recyclable boat housing the electronic module.



Lights turn from GREEN to RED with increasing CO2 levels due to insufficient indoor ventilation or crowded space.

Replacement of silver based conductors with more abundant and inexpensive substitutes



C
Est. 1 – 10 €/kg
1-10 Ω/□*, **

Cu
6 €/ kg
0.01-0.05 Ω/□ *

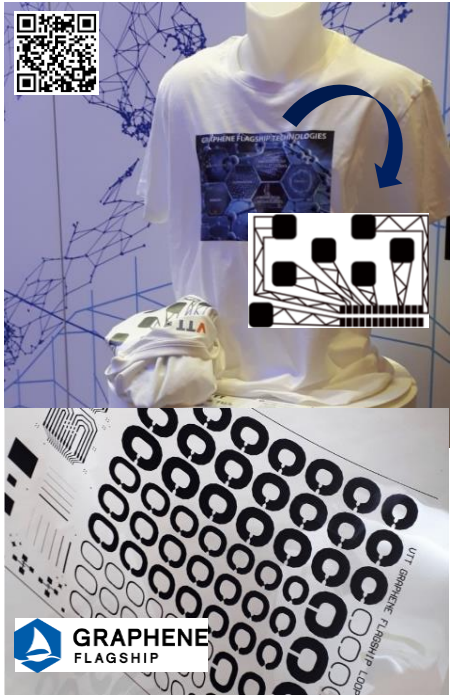
Ag
680 €/kg
0.005-0.01 Ω/□*

* Typical values for printed layer
** As graphene ink

Flexible and textile integrated electronics based on graphene

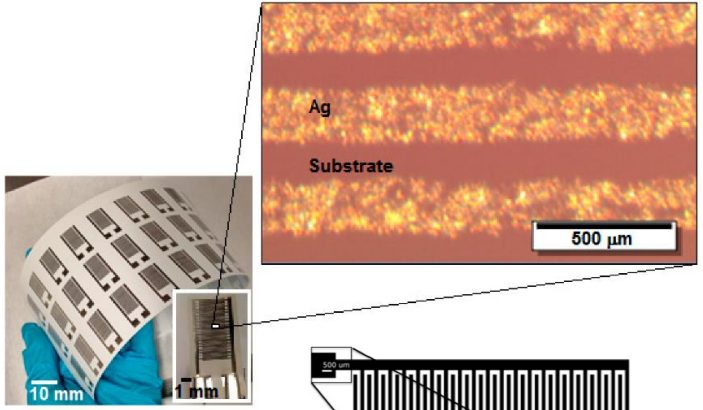
- **Capacitive touch sensitive electrodes on fabric** based on screen-printed conductive areas
  - Graphene pattern printed on polyurethane thin film laminated inside a t-shirt
  - 10% stretching of conductive wires without significant loss in conductivity demonstrated
- **Low-cost screen-printed graphene antennas** for near-field UHF RFID transponders

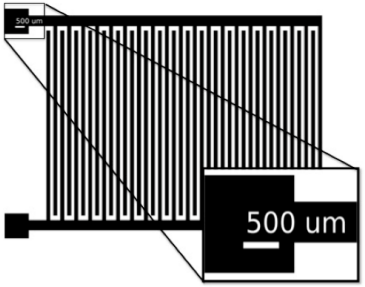
Jaakkola et al. (2020) 2D Materials 7(1) 9 p. 015019

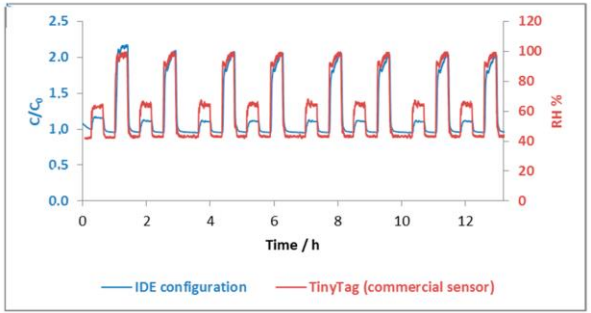


Paper based humidity sensors

- An inkjet-printed relative humidity sensor based on capacitive changes responding to **different humidity levels in the environment**
- Interdigitated silver electrodes on the paper substrate - **paper itself as a sensing material**

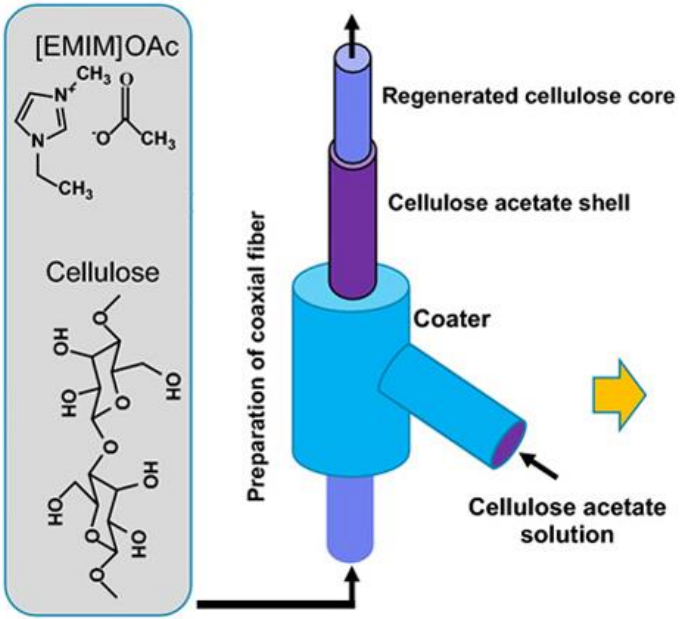


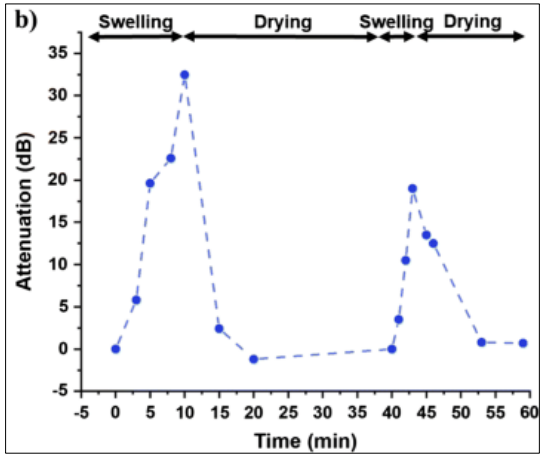




C. Gaspar et al., Sensors 2017, 17, 1464; doi:10.3390/s17071464

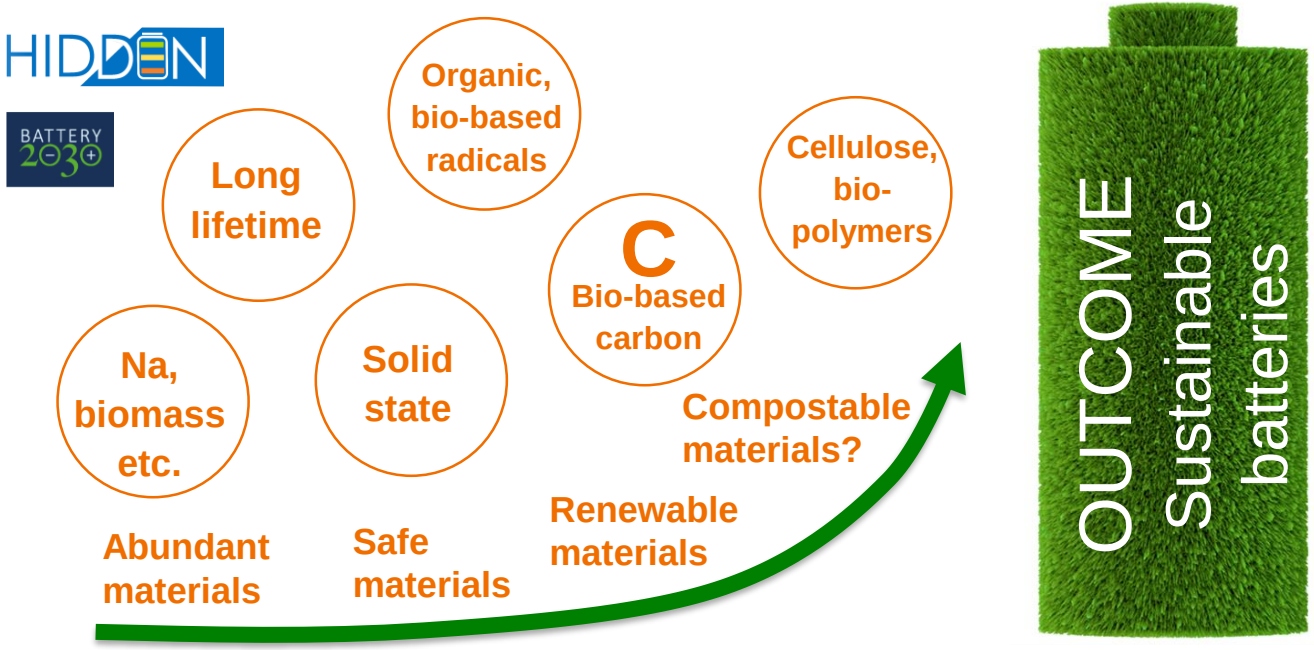
Optical cellulose materials enables new sustainable sensors for multiple application fields





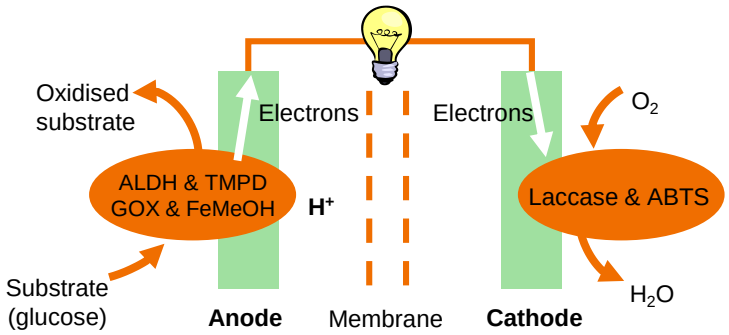
Orelma et al. "Optical cellulose fiber made from regenerated cellulose and cellulose acetate for water sensor applications", Cellulose 27, 1543-1553 (2020)

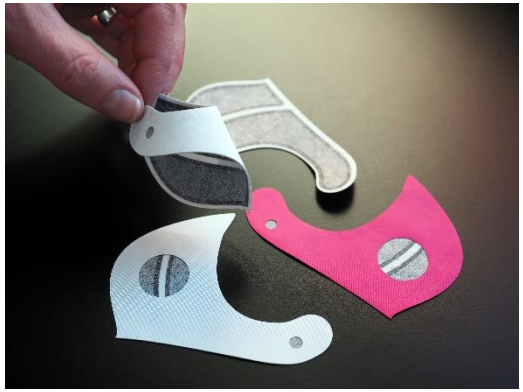
Further possibilities for batteries with high safety and lower environmental impact



Printed biofuel cell – Biobattery

- **Disposable, printed enzyme** based power source convert chemical energy into electricity via mediated enzyme catalysis
  - Open cell voltage: 0.4 V, appr. 1 V with Zn anode)
- Can be **activated with addition of moisture** (e.g. water, buffer, glucose containing drink, body fluids)
- Possible application in **skin care**



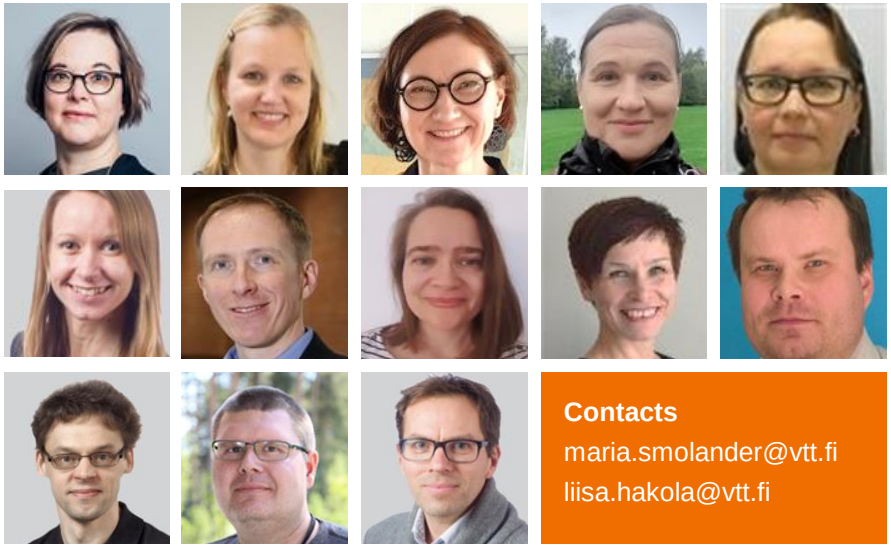


Tuurala et al. Electroanalysis, Vol. 24 (2012) No: 2, 229-238
Smolander et al. EMT43(2008) 2:93-102, WO11073530A, WO07147947

Summary

- **Resource sufficiency** is a global challenge concerning all businesses
- **Sustainability as a business approach** is becoming widely adopted by companies and organisations around the world
- **Greener operations**, **products** and **sustainable materials** are the key!

VTT’s multidisciplinary experts are working together for greener tomorrow!



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and many others!

VTT

beyond

the obvious

Thank you!

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