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Green Materials and Fabrication Approaches for Sustainable IoT

Daniela Iacopino
Tyndall National Institute, Cork
IoT Week
Dublin, June 2022

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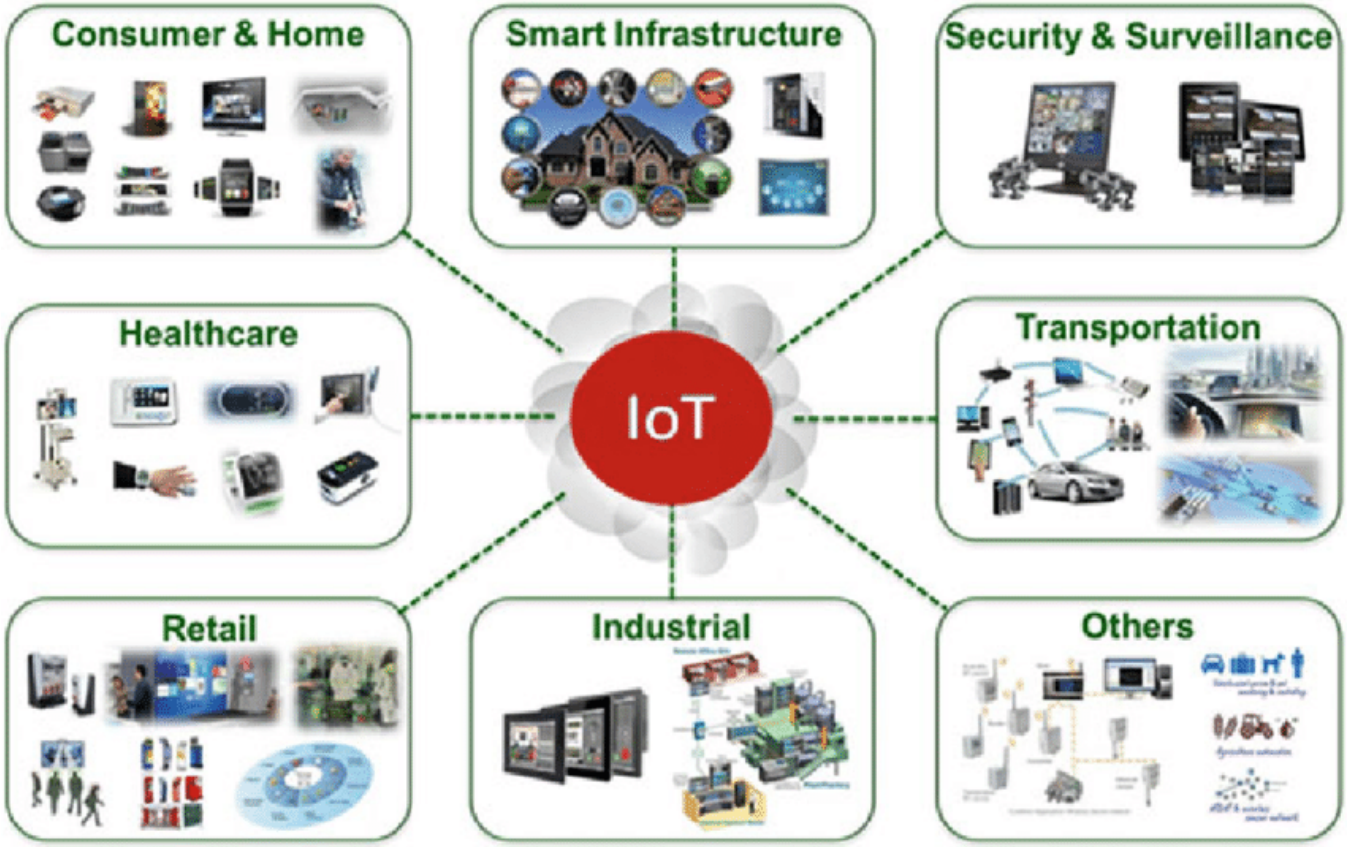
IoT Sensors Revolution

- IoT sensors are increasingly becoming ubiquitous and essential part of our lives
- IoT will become a technological milestone with an impact similar to the one caused by the advent of the Internet itself



The Role of Internet of Things and Smart Grid for the Development of a Smart City DOI: 10.1007/978-981-10-5523-2_

Monitoring of Goods

- The monitoring of precious and/or perishable goods' (food, pharmaceutical, vaccines, artworks) local environment during **transport and storage** is of critical importance for business, freight owners and transporters
- It ensures traceability and quality of manufacturing. Prevents unnecessary losses.
- Cost often prevents the effective monitoring of goods.
- Low cost RF sensor tags are ideal for this application.

Monitoring of goods: Environmental Impact

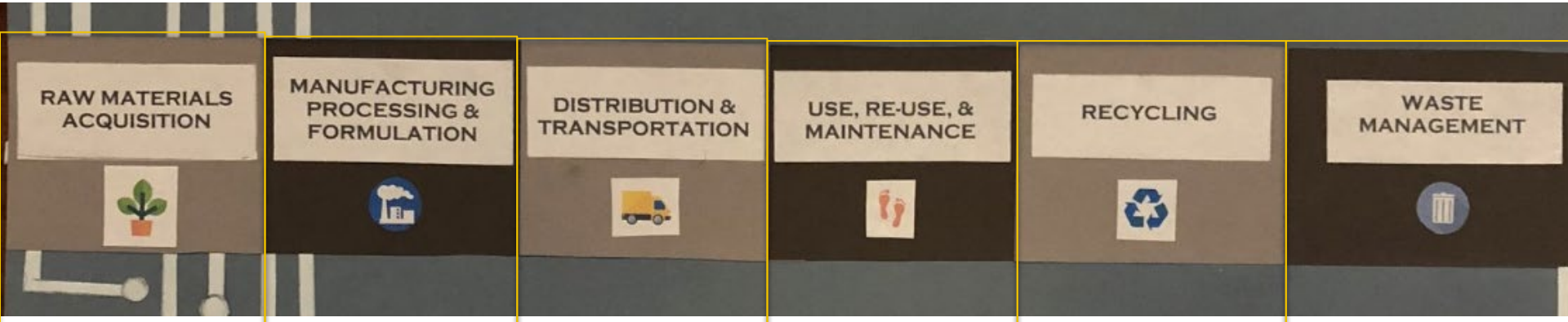
However, the environmental impact of deploying large number of IoT sensors needs to be taken in consideration

- The number of tags produced and disposed will grow to > one tag per person per day. Global tag consumption could approach 2 trillion tags per year
- By 2025 METI supermarket (Japan) will attach electronic tags to all products sold (estimated 100 billion products/year).
- 9 million tonnes CO_2 eq just to make the microchips!
- Plastic packaging?

?

Sustainable RFID - Fairfield (fairfieldgroup.com)

Life Cycle of RFID Tags

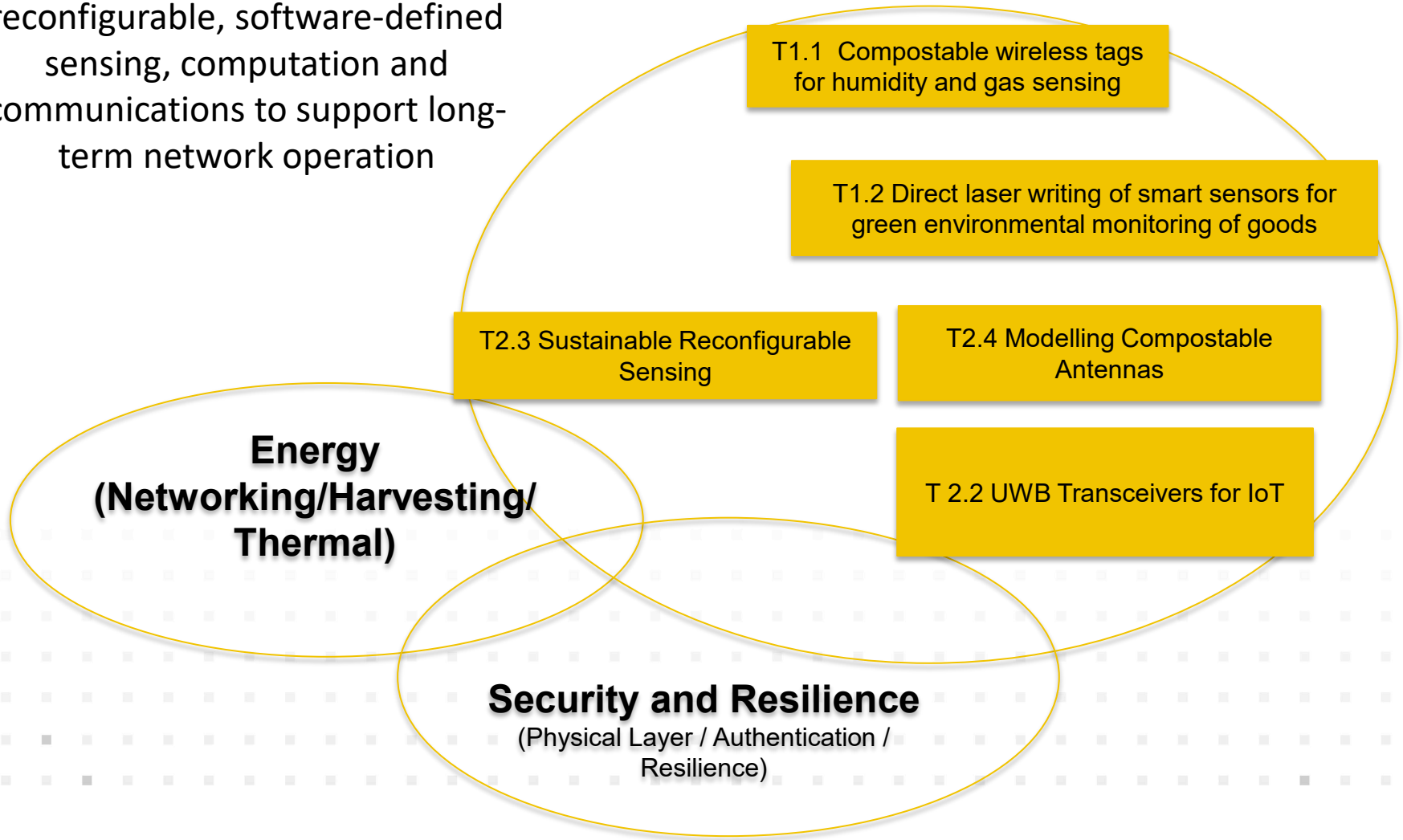


RAW MATERIALS ACQUISITION	MANUFACTURING PROCESSING & FORMULATION	DISTRIBUTION & TRANSPORTATION	USE, RE-USE, & MAINTENANCE	RECYCLING	WASTE MANAGEMENT
Extraction of metals (Cu, Al, Ag). Battery materials extraction	Microchip production. Greenhouse gases released from electrical generation	Greenhouse gases emitted from transportation vehicles	Reusability low = most RFID tags on go into municipal solid waste or recycling stream once package is received	Most materials can be recycled. Cost?	Most tags end up in the recycle. Breakdown of manmade materials leaches into the environment

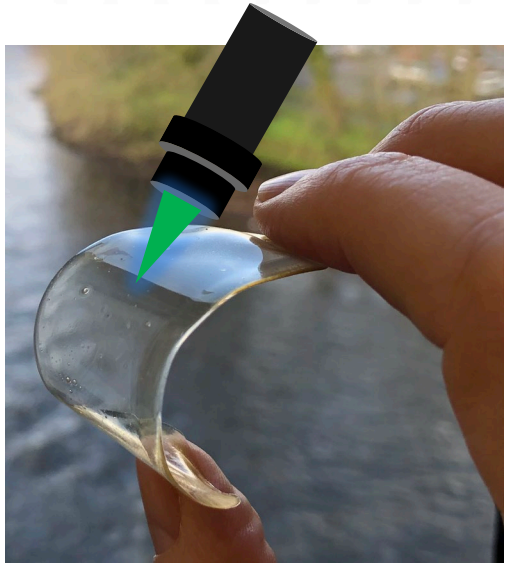
RFID Tag — Design Life-Cycle

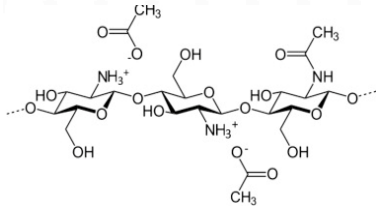
CONNECT Funded Projects in Sustainable IoT

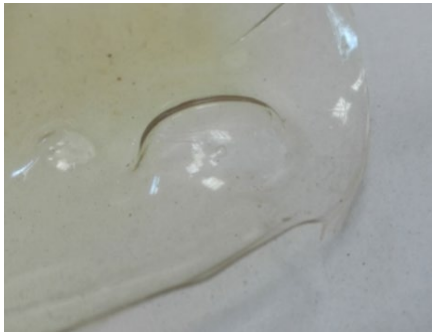
AIM:
To design sustainable, low-power IoT platforms based on compostable, reconfigurable, software-defined sensing, computation and communications to support long-term network operation

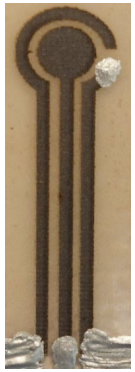


Alternative Approaches: Fabrication



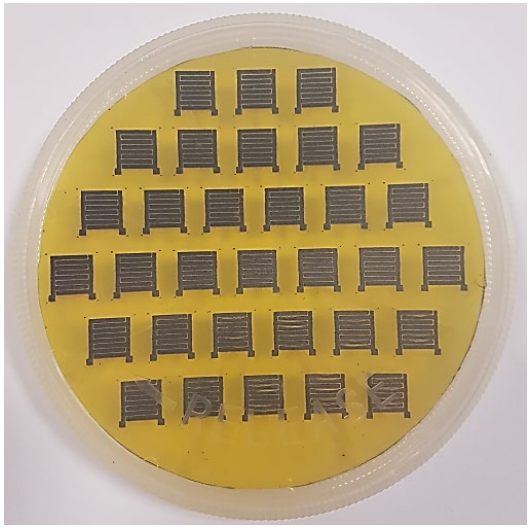




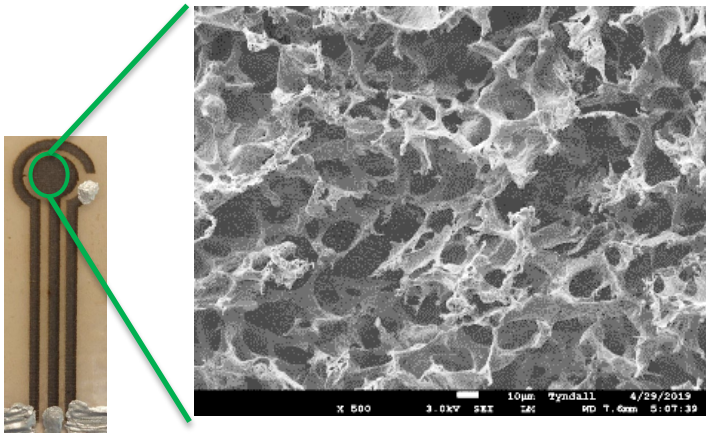


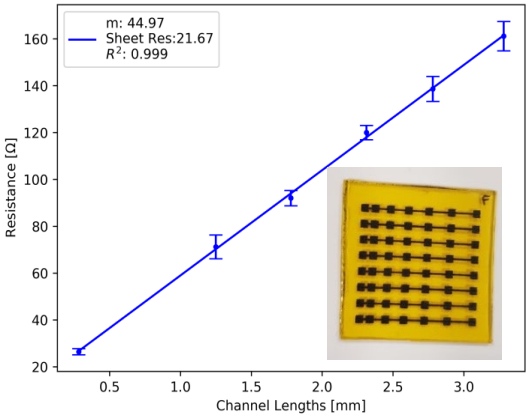
Biodegradable, self-healing, flexible natural precursors

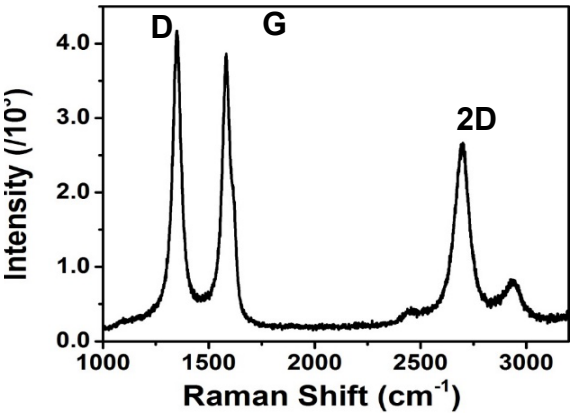
- Versatility of design
- Suitable for scaling up (wafer scale and above)
- Direct patterning (no waste material, no chemicals)
- Low cost equipment (hobbyist lasers are used)
- Mild fabrication conditions (room temperature and ambient conditions)



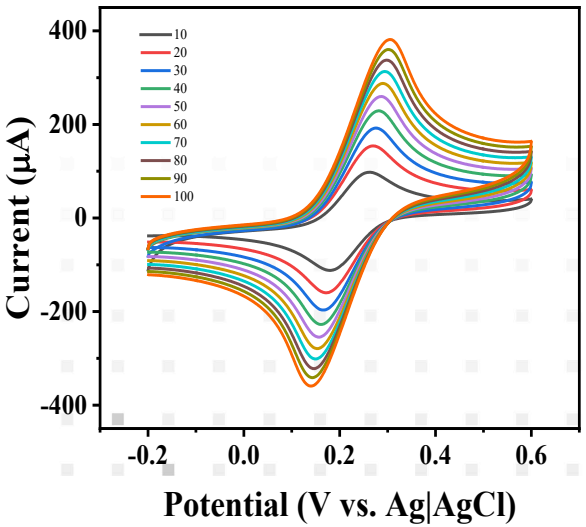
Alternative Approaches: Materials

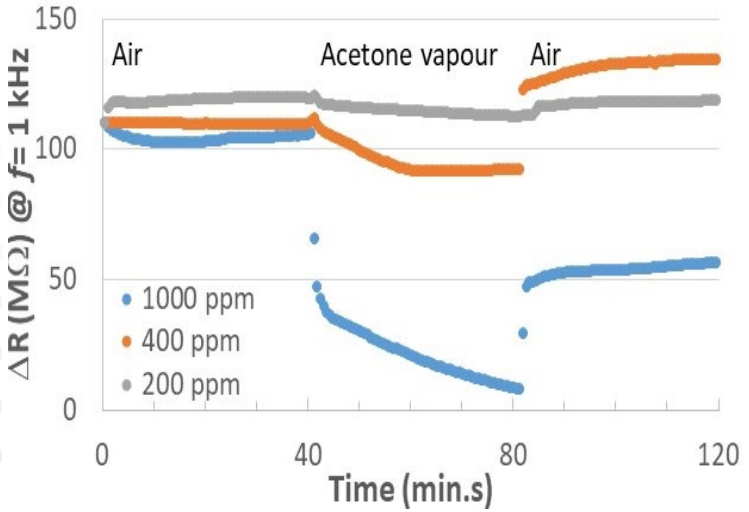






Conductive, high surface graphene-like materials

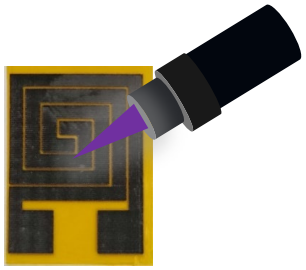




Proposed Solution

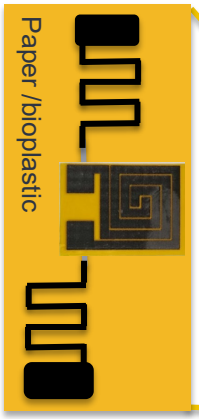
Compostable passive, chipless RF sensor tags for humidity and volatile organic compound (VOC) gas sensing for goods monitoring

Materials and Fabrication

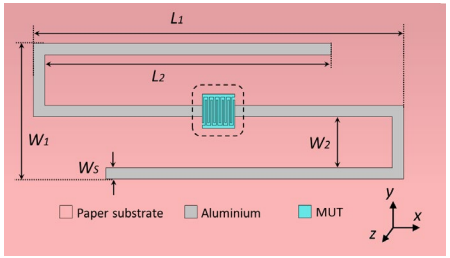


Novel front end sensing materials sourced from natural precursors and obtained by low environmental impact processes

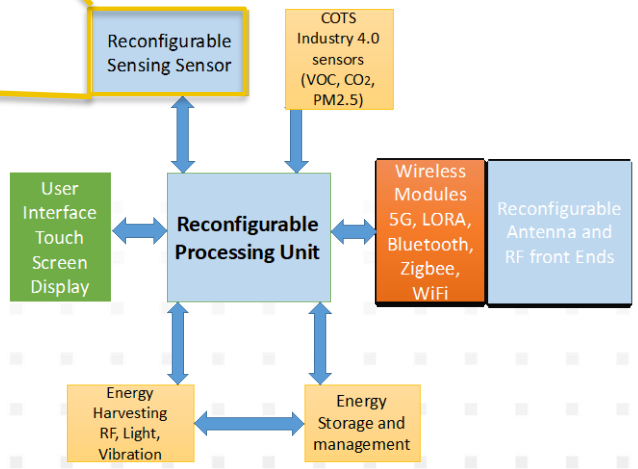
Sensor tag



Modelling



Integration



- Reduce use of high environmental footprint materials
- Simplify sensor fabrication
- Compostable – reduce pollution burden at end of life
- CO2 footprint for chip fabrication is highest footprint (by factor of 10)
- Laser-scribed Al on paper > 5x reduced footprint vs etched Al on PET

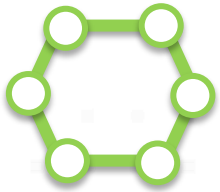
Flexible, reconfigurable energy autonomous sensing platforms for IoT networks

Conclusions

- Solutions for realization of LOW CARBON FOOTPRINT compostable sensor tags for monitoring of goods
- Solutions for low-power IoT platforms based on compostable, reconfigurable, software-defined sensing, computation and communications
- We need a multidisciplinary team to be successful – come join us!

Low impact precursor materials

Low impact fabrication processes



Engineering of material properties

Compostable

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Thank you

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The new chipless RFID technology is a high data-capacity mm-wave barcode system operating at 60 GHz. This means that although it is much smaller than any other commercially available chipless RFID tag it can still contain a relatively large amount of data and information. "The main challenge that we have overcome is to transfer the technology to paper and plastic while retaining the required printing resolution. Uniquely, the 60 GHz mm-wave tag is tolerant to printing errors and surface imperfections. Dr Karmakar also commented that the chipless RFID tag was suitable for use at temperatures above 80 degrees and also at cryogenic temperatures.