



How to foster innovation
the past and the future ?



the future

The background of the slide is a close-up photograph of several green leaves, likely from a tree or shrub, with prominent veins. The leaves are in various shades of green, from light to dark, and are slightly out of focus, creating a soft, naturalistic backdrop.

Green electronics: ***a technology for a sustainable future***

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project vision success development management ideas teamwork
STRATEGY invent
team motivation leadership planning
action innovation

Green Materials:

**Abundant (non toxic)
materials**

Green Technologies:

**Simple and low energy
processes**

The background of the image is a close-up of green leaves, likely from a tree or shrub, with a soft, out-of-focus effect. The leaves are various shades of green, from light to dark, and their veins are visible. The overall tone is bright and natural.

**Alternative
electronics is needed
because ...**



What we are generating?

HIGH-TECH TRASH

This is recycling?



This is waste selection?



Can we change this?



International e-waste shipments

Export of e-waste



Source: Greenpeace, Basel Action Network

Is this the future?



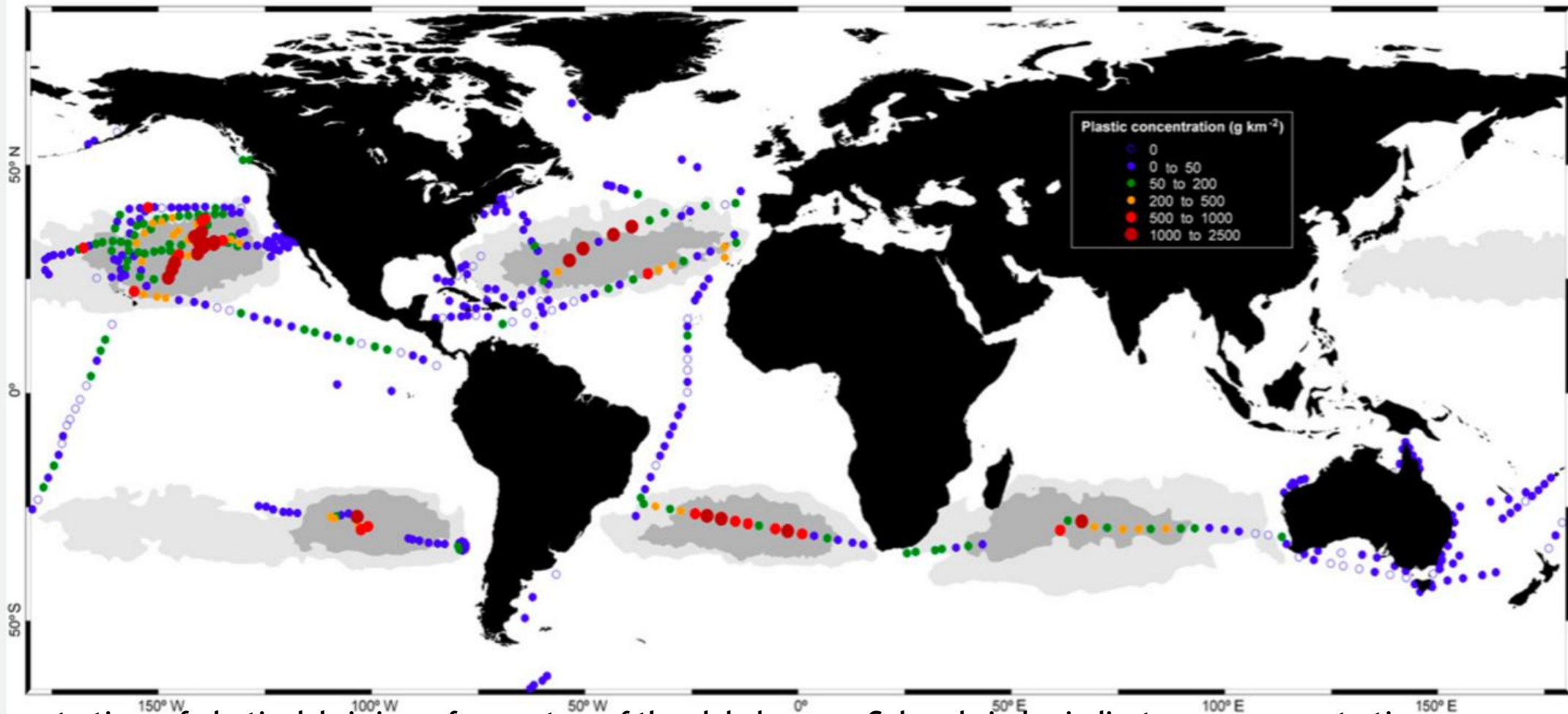
5 countries dump more plastic into the oceans than the rest of the world



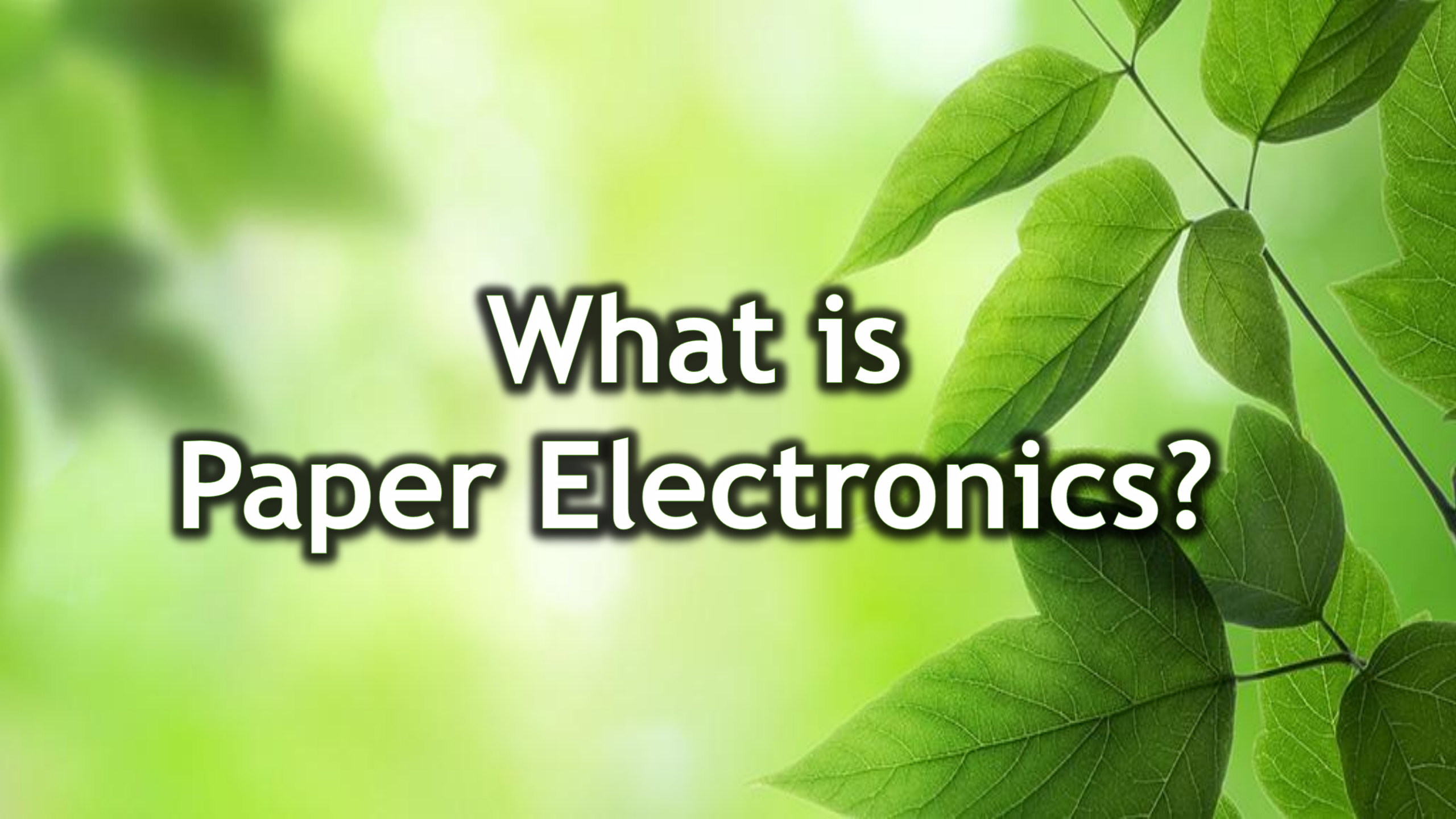
At this rate, we would expect nearly one ton of plastic for every three tons of fish in our oceans by 2025 – an unthinkable number with drastic economic and environmental consequences.

We dump 8 million tons of plastic into the ocean each year. Where does it all go?

Every ocean now has a massive plastic garbage patch



Concentrations of plastic debris in surface waters of the global ocean. Colored circles indicate mass concentrations

The background of the image is a close-up, slightly out-of-focus photograph of green leaves. The leaves are vibrant green and have a clear vein structure. They are arranged in a way that creates a sense of depth, with some leaves in the foreground and others blurred in the background. The lighting is bright, suggesting a sunny day, which gives the leaves a fresh and lively appearance.

What is Paper Electronics?

Sometimes we are inspired by science fiction ...

CLICK to watch the video

The background image is a dark, blurry scene from a science fiction movie. It appears to be an interior of a spaceship or a futuristic building. There are some indistinct shapes and colors, including what might be a window or a screen in the background showing some light. The overall tone is mysterious and cinematic.

Why paper?

Cellulose is nature's most common building block.

In a **bio-economy** and **circular-economy** in which **renewable materials** are one of the keys to a more sustainable future, **cellulose** has an active and a crucial role.

and ...



... cellulose is:

Most abundant biopolymer environmentally friendly

Flexible and unbreakable

Low cost material

The lightest known material

Well established production technology (100 km/h)

Good dielectric properties

Paper is ubiquitous

Recyclable



2-3 days

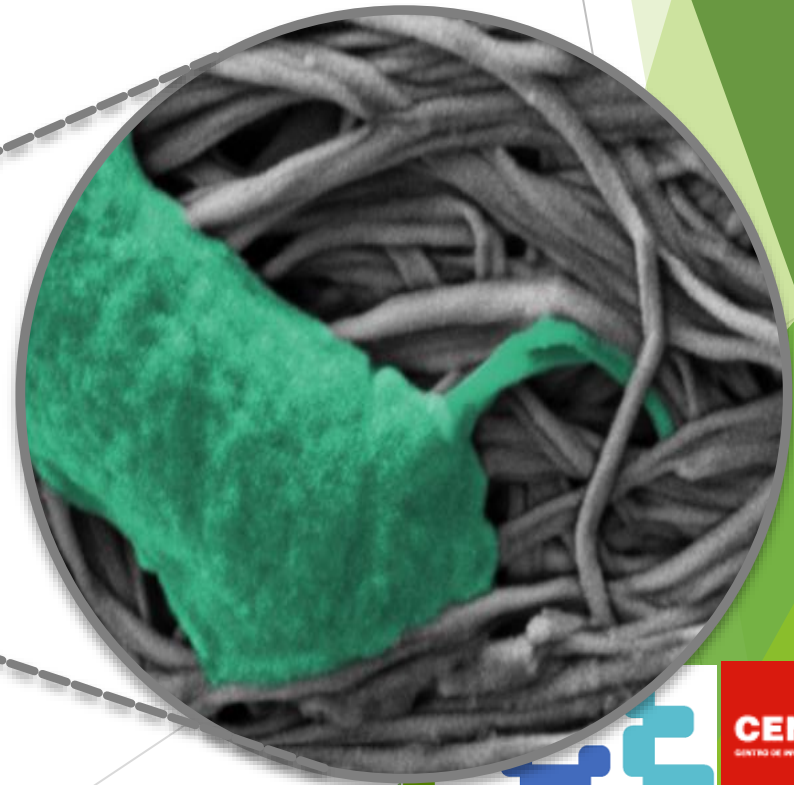
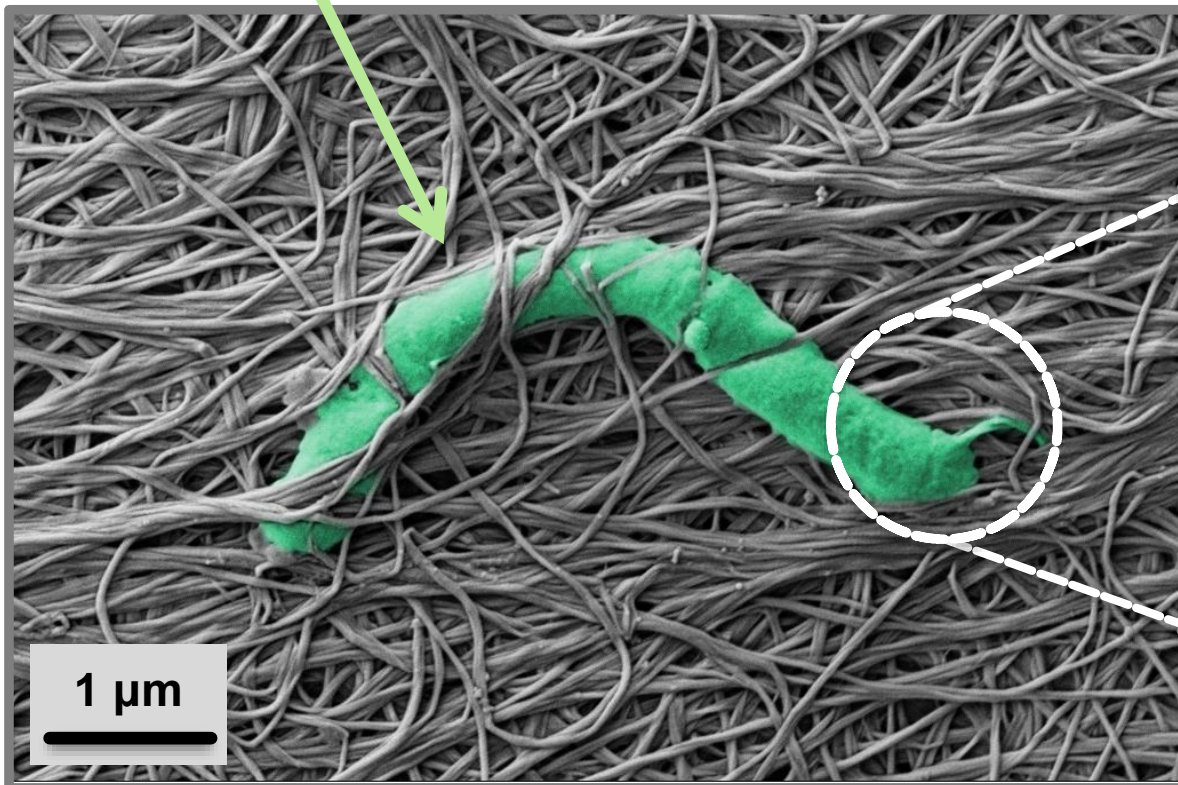
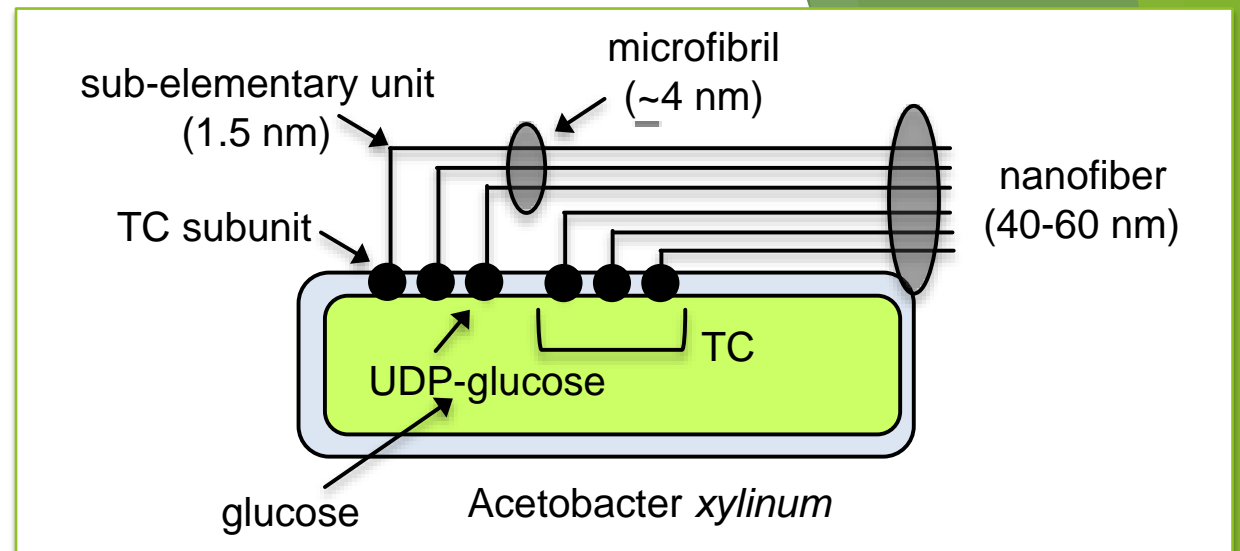


4-5 years

Bacterial cellulose

► Produced by bacteria

Ex: *Acetobacter xylinum*



Bacterial cellulose



Work done @CENIMAT

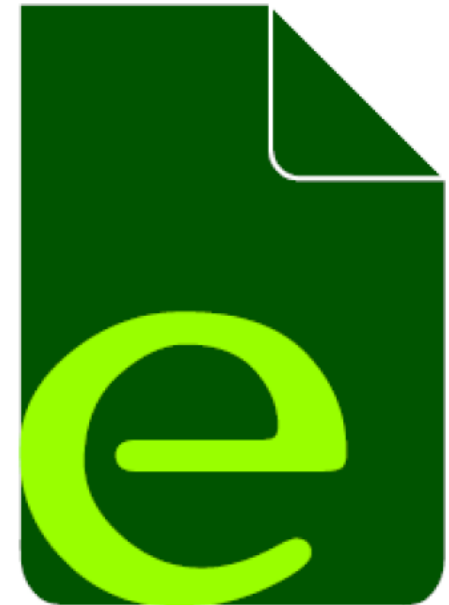
Electronic devices

Thin Film Transistors - *interstrate* structure

In 2008 ...

e-Paper

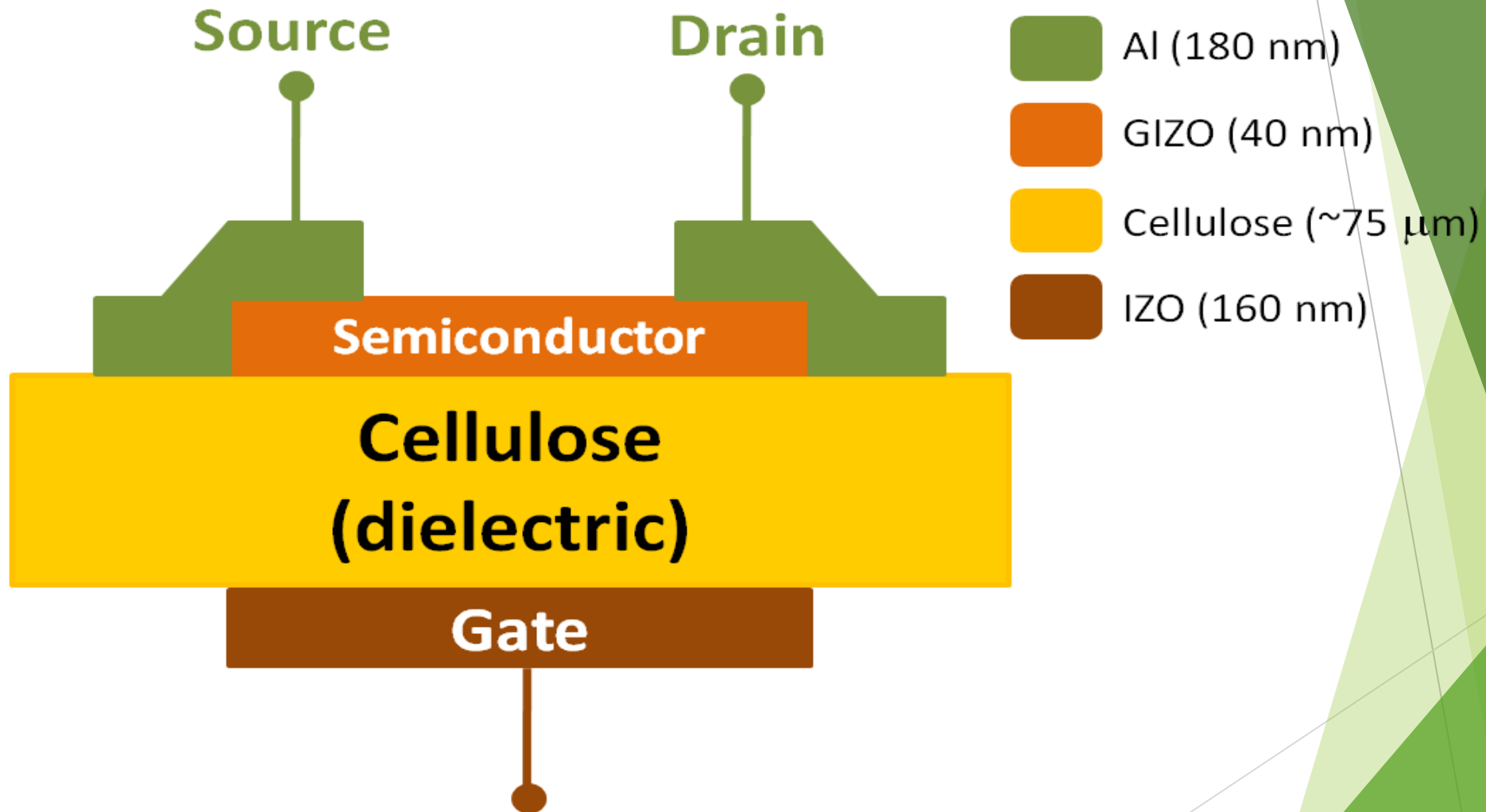
Paper-e®



Paper - e
Green electronics for the future

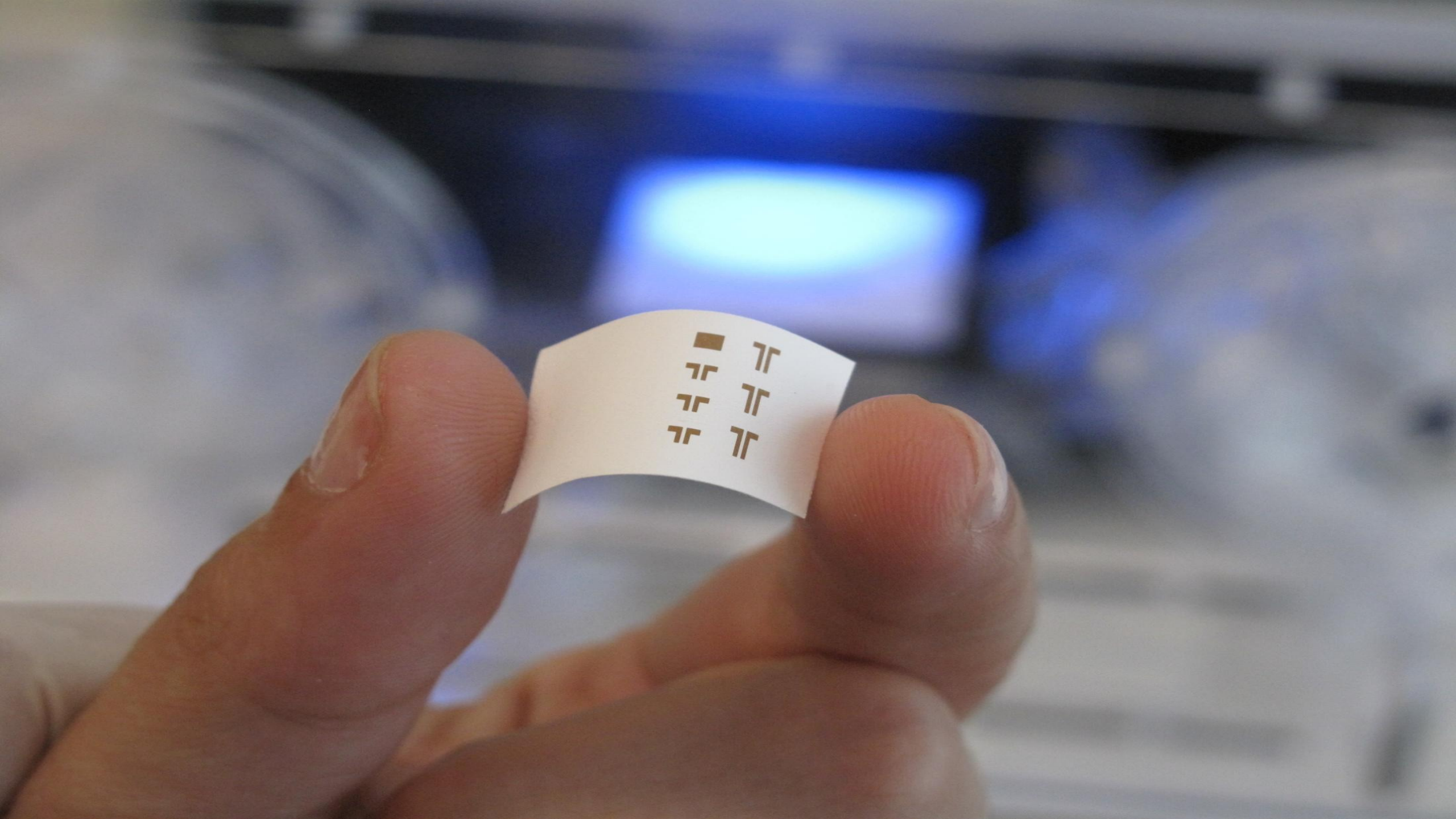
Physical support AND Active function

1st Paper transistor (office paper)



Fortunato, E. et al., High-Performance Flexible Hybrid Field-Effect Transistors Based on Cellulose Fiber Paper. *IEEE Electron Device Letters* 2008, 29, 988-990.

Patent: E. FORTUNATO, R. MARTINS, P. BARQUINHA, G. GONLAVES, N. CORREIA, PROCEDURE FOR THE USE OF NATURAL CELLULOSE MATERIAL, SYNTHETIC MATERIAL OR MIXED NATURAL AND SYNTHETIC MATERIAL SIMULTANEOUSLY AS PHYSICAL AND DIELECTRIC SUPPORT IN SELF-SUSTAINABLE FIELD EFFECT ELECTRONIC AND OPTOELECTRONIC DEVICES; PTI 40053-09-PT.



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FACULDADE DE
CIÊNCIAS E TECNOLOGIA
UNIVERSIDADE NOVA DE LISBOA

CENIMAT I3N





**Dangerous
gas detected**

TETRA solar



A. Vicente, H. Águas, T. Mateus, A. Araújo, A. Lyubchyk, S. Siitonen, E. Fortunato, R. Martins, Solar Cells for Self-Sustainable intelligent Packaging, *J. Materials Chemistry A*, 2015, DOI 10.1039/C5TA01752A.

Work done @CENIMAT

Biosensors

World Health Organization

Affordable

Sensitive

Specific

User-friendly

Rapid and Robust

Equipment-free

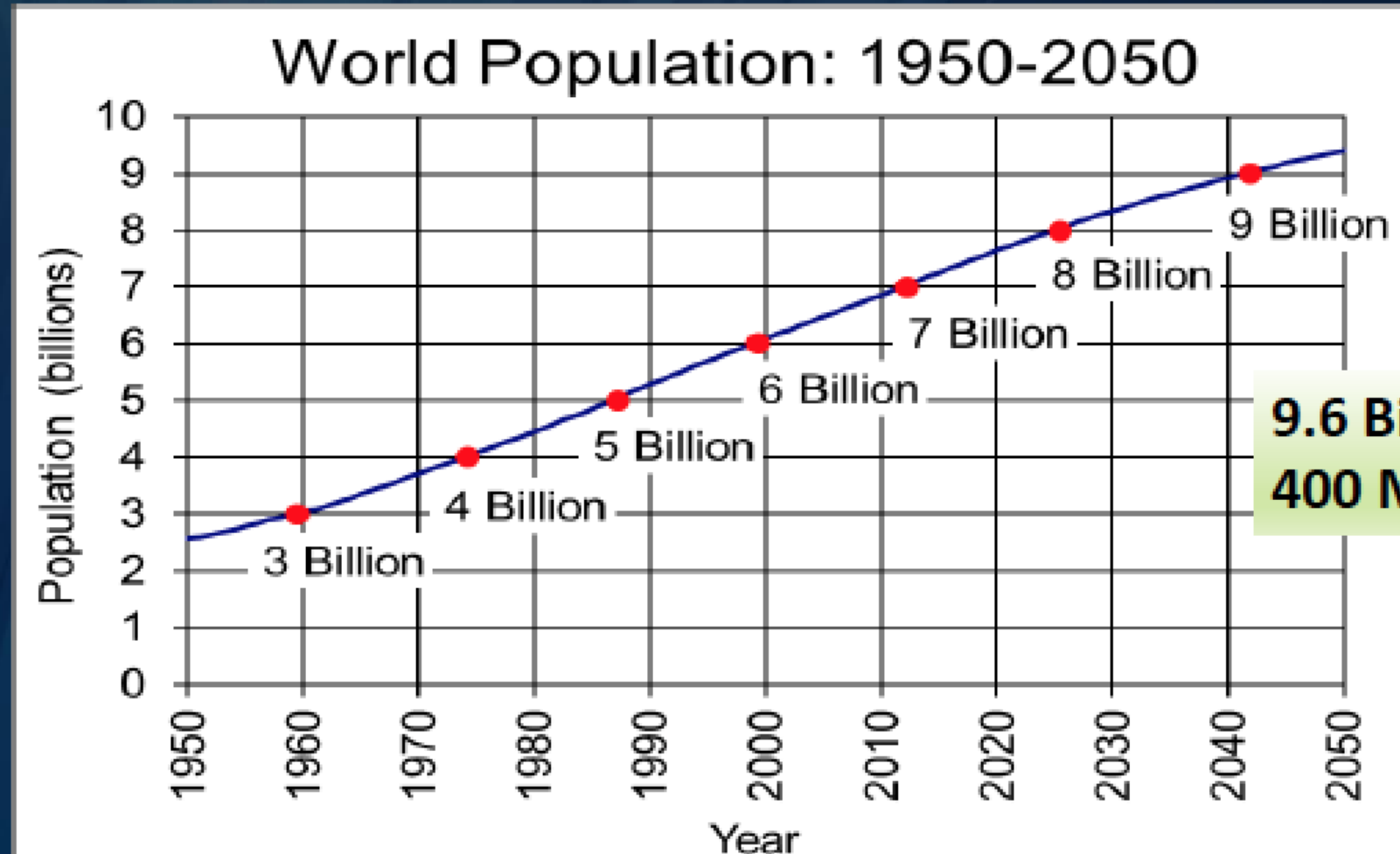
Delivered to those in need

The WHO established guidelines for developing **diagnostic tests** adequate for developing countries and resource-poor settings, which are summarized under the acronym **ASSURED**



Growing and Aging Population

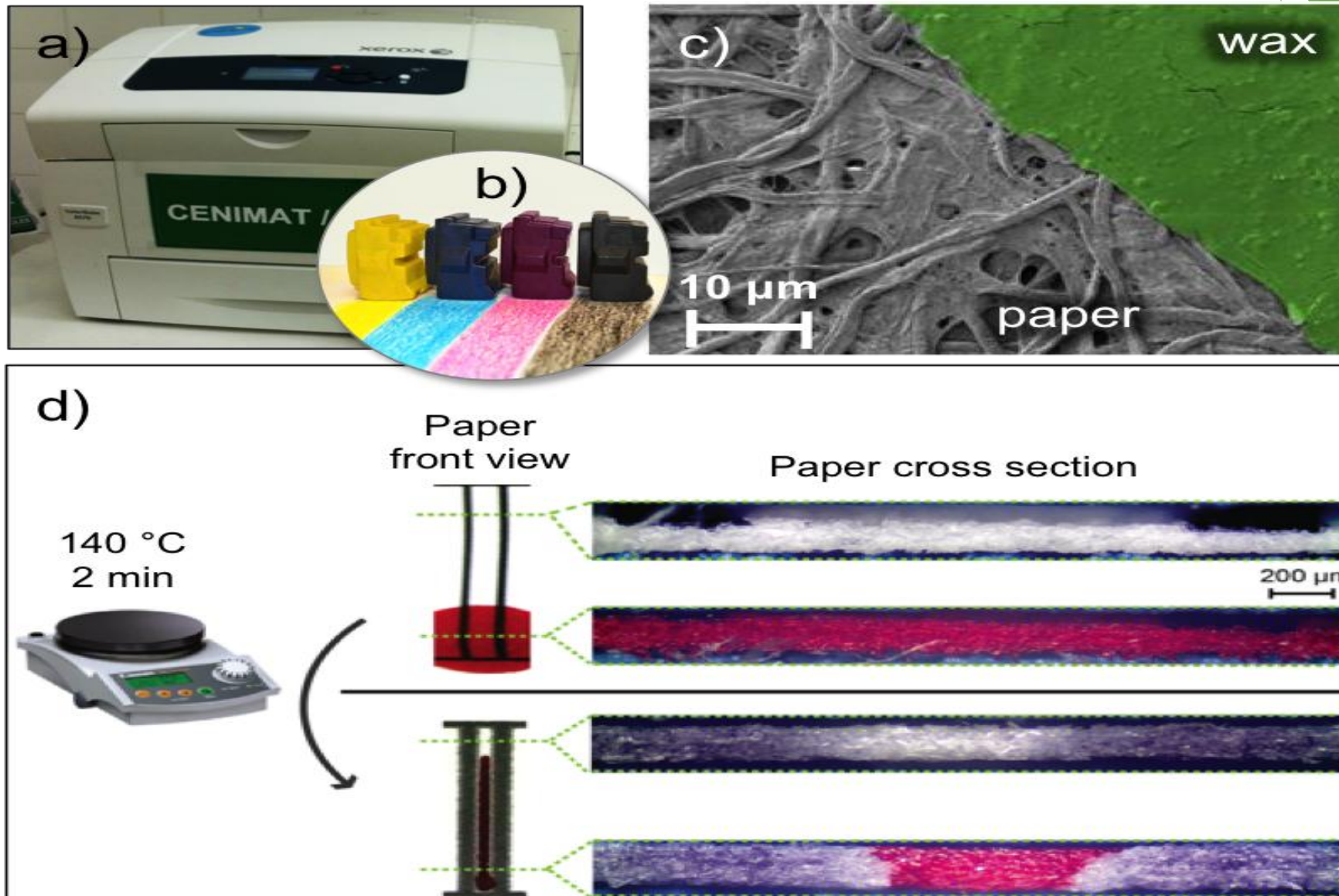
In 2050, the population aged 65 and over is projected to be 83.7 million, almost double its estimated population of 43.1 million in 2012.*



Source: U.S. Census Bureau, International Data Base, July 2015 Update.

*U.S. Census Bureau, May 2014

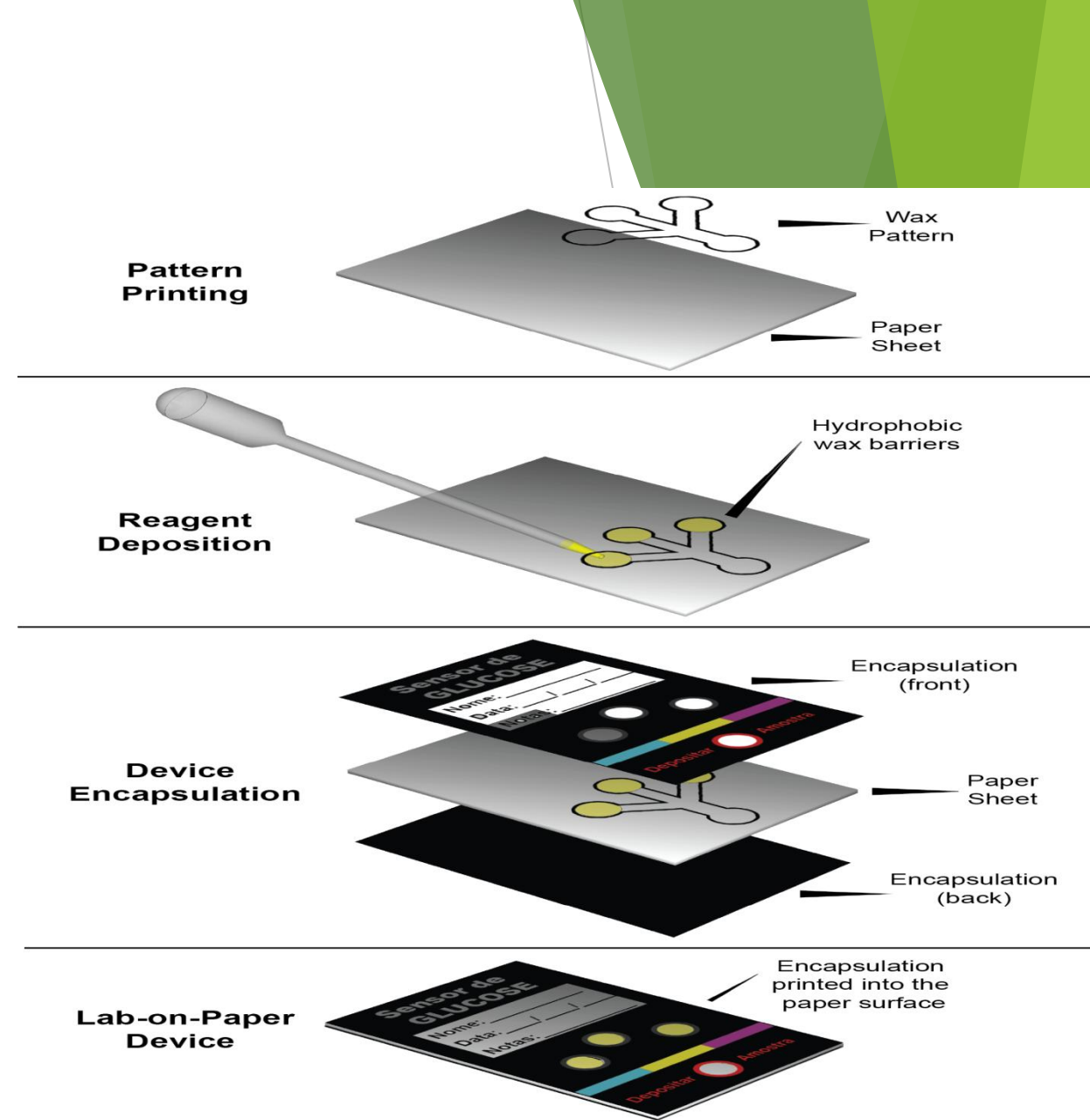
Lab-on-Paper



Glucose biosensor

1. μ PAD

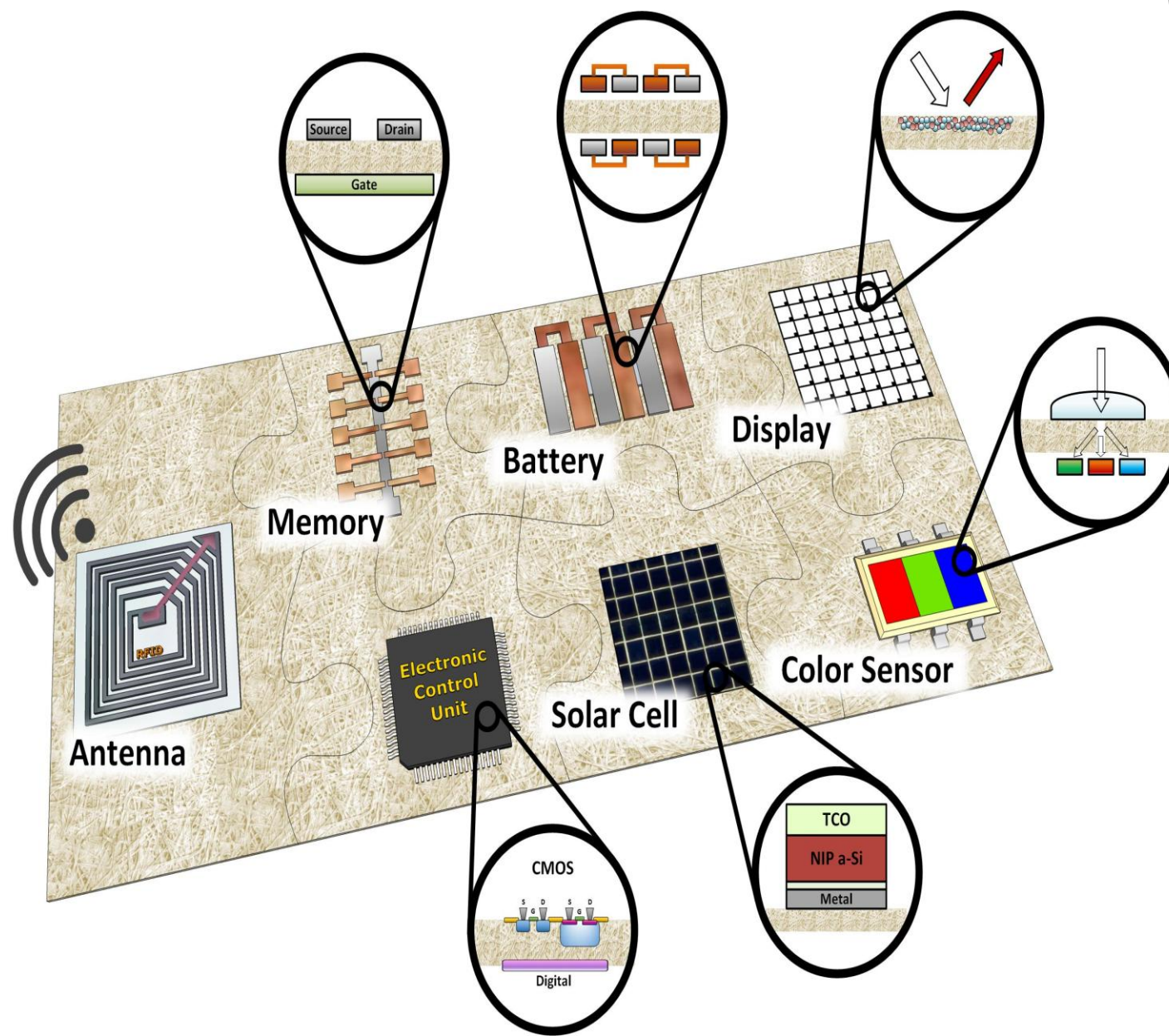
Paper Analytical Device



Costa, M. N. et al., A low cost, safe, disposable, rapid and self-sustainable paper-based platform for diagnostic testing: lab-on-paper. *Nanotechnology* 2014, 25, 094006.

Conclusions

All Cellulose Devices



Challenges/Opportunities

Healthcare

(aging population)

Water

Food

IoT

Paper ➡ **disruptive**

Applications

and

Applications ➡ **paper**
with more functions

Requirements for Future Ubiquitous Electronics



- **Ultracheap/disposable**
Scalable production of electronic inks
- **Seamless integration**
Printable flexible electronics
- **Power management**
Ultra low power electronics/
Energy conversion/storage
- **Efficient wireless communication**
High speed electronics/
New devices for WIFI



“If you want to go fast, go alone. If you want to go far, go together”

Acknowledgments - Current Projects

FCT

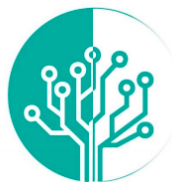
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Supporting top researchers
from anywhere in the world



roll-out



BET-EU

MATERIALS SYNERGY INTEGRATION FOR
A BETTER EUROPE



Symbiotic



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Elvira Fortunato and Rodrigo Martins (Portugal)

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RTP

➤ **Cientista portuguesa selecionada para prémio europeu**

P3

➤ **Cientistas portugueses são finalistas em Prémio Europeu do Inventor**



[CLICK to watch the video](#)

EUROPEAN INVENTOR AWARD 2016
RESEARCH

Elvira Fortunato, Rodrigo Martins
Paper transistors