What future for the semiconductor industry in the age of climate change?

Evolution and diversification of semiconductor technologies

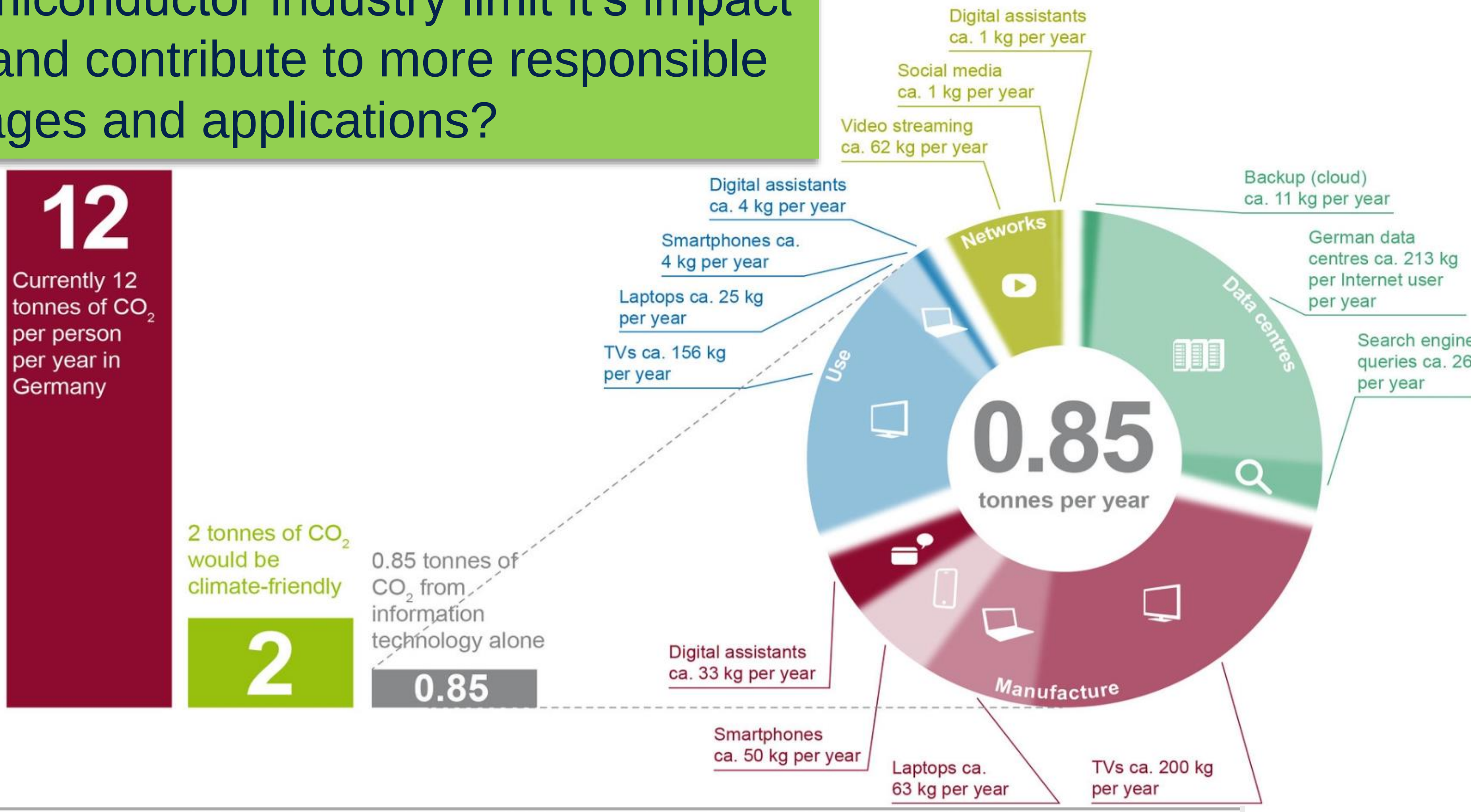
Stephane MONFRAY

Senior Principal Engineer

STMicroelectronics

CO2 emission related to numerical technologies

How can the semiconductor industry limit it's impact on fabrication, and contribute to more responsible usages and applications?



SOURCE: HTTPS://BLOG.OEKO.DE/DIGITALER-CO2-FUSSABDRUCK. DIAGRAM: ÖKO-INSTITUT 2019, CC BY-SA

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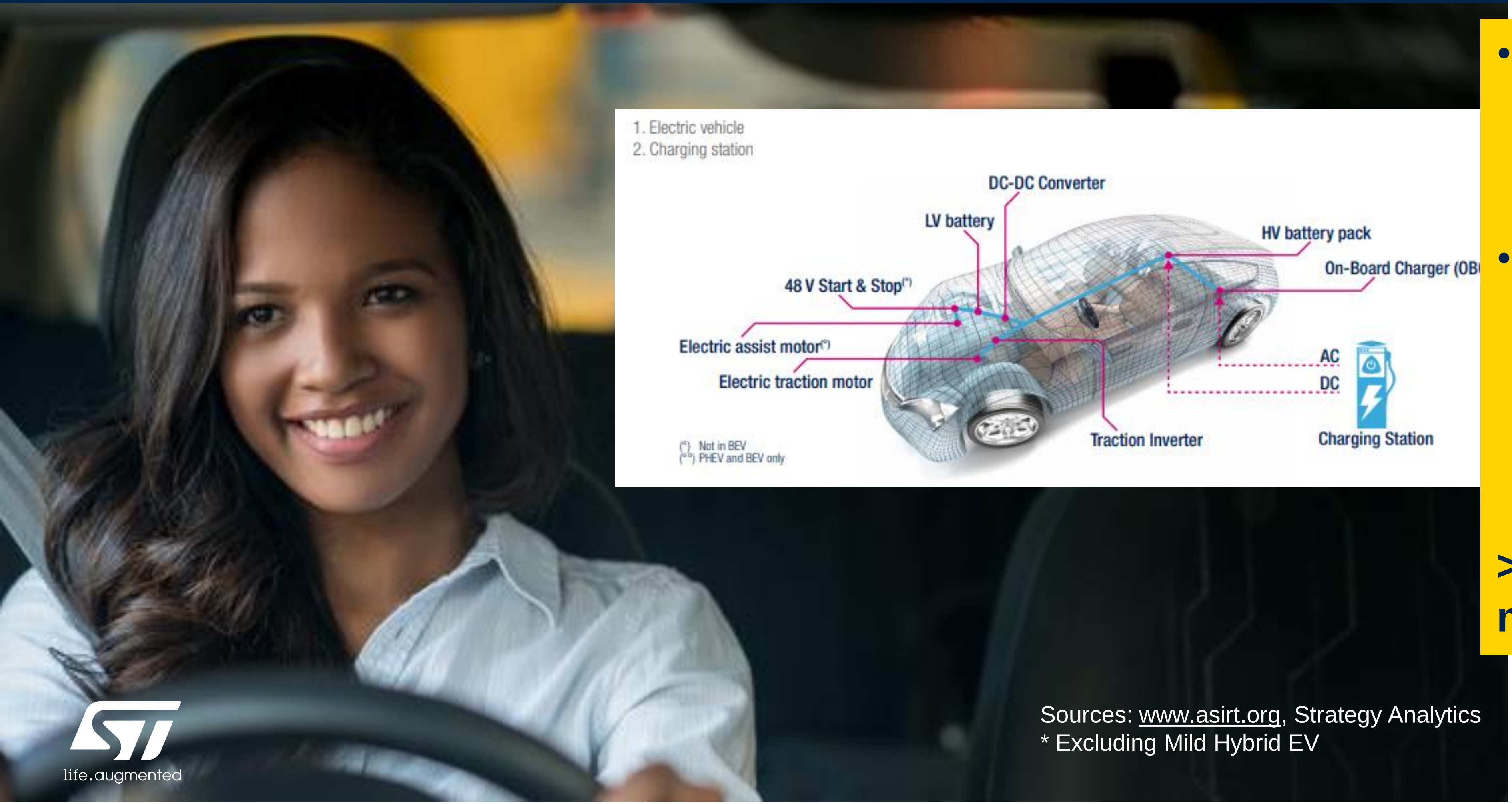
Examples of diversification in the semiconductor industry for responsible applications

- High impacts on end markets: **mobility, energy, connectivity**
- From ultralow power technologies to fully energy autonomous systems: **how mW can save kW**
- Examples of technologies for **environmental sensing**
- **Eco conception** & sustainability

Smart mobility: from thermal to electrical mobility

Electric vehicles sales* from ~10 million in 2021 to ~30 million in 2025



- **Electronics play a major role to deploy electric cars!**
- **Not only in a car: you need connectivity with charging station & all associated services**

>200 ST products mapped

Sources: www.asirt.org, Strategy Analytics
* Excluding Mild Hybrid EV

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Power & energy

Rising demand for and usage of electrical energy

Over **30**% global electricity demand increase from 2020 to 2030

Increase use of renewable energy

Electrical energy from renewal sources from **~10%** in 2020 to **~20%** in 2030

No performant power collection without dedicated electronics!

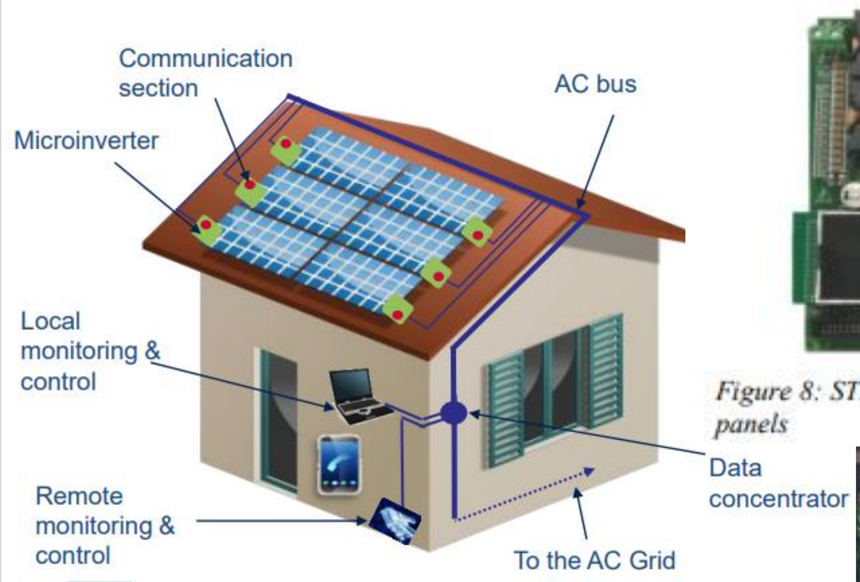

Figure 8: STEVAL-ISV003V1, 250 W microinverter for plug-in PV panels

10’s of ST products mapped in a solar panel

Sources: IEA, IPCC, BP

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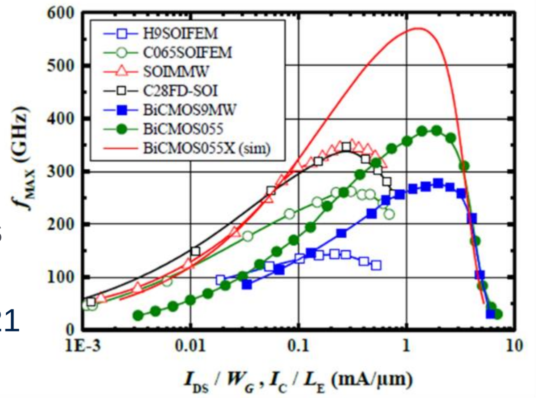
Internet of things & connectivity

ST provides sensors, embedded processing, connectivity, security and power management, as well tools and ecosystems

Silicon photonics platform

ULP MCU STM32

Advanced & efficient RF technologies



P.Chevalier, SSDM21

Cloud connected and data-enabled services	More than **20 Billion** IoT connected devices per year by 2025
Digital security for all data	IoT security services market over **$12 Billion** by 2025
Cellular accelerating the connection of objects to the IoT	**Four Billion** cellular IoT connections by 2025

Source: ABI, Ericsson, GSMA

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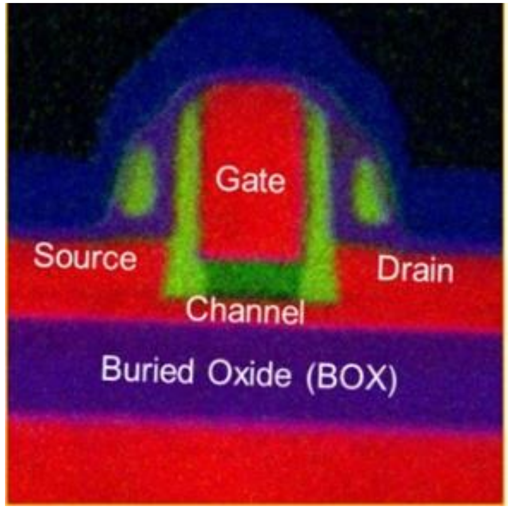
Electronic devices are everywhere and mandatory for greener mobility and power generation

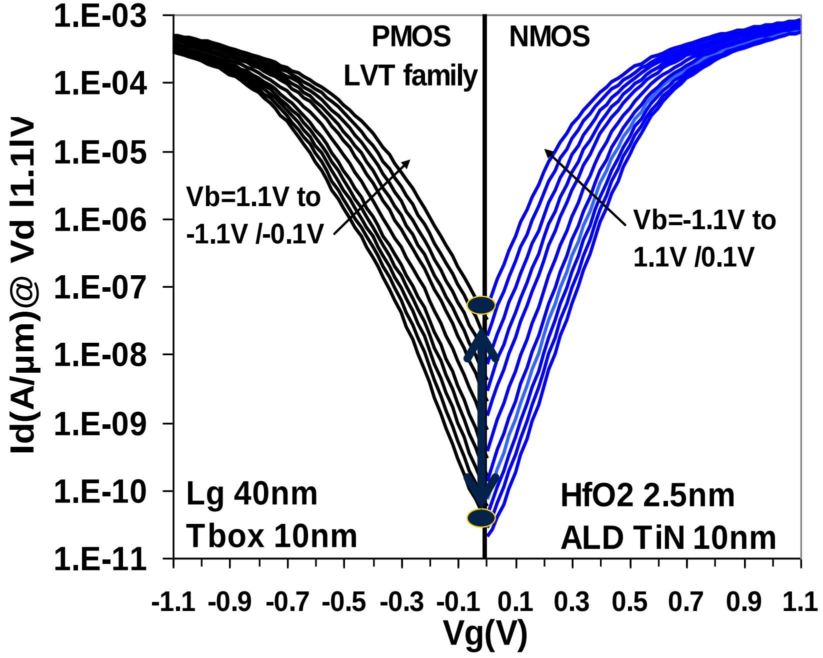
How the technology itself can contribute?

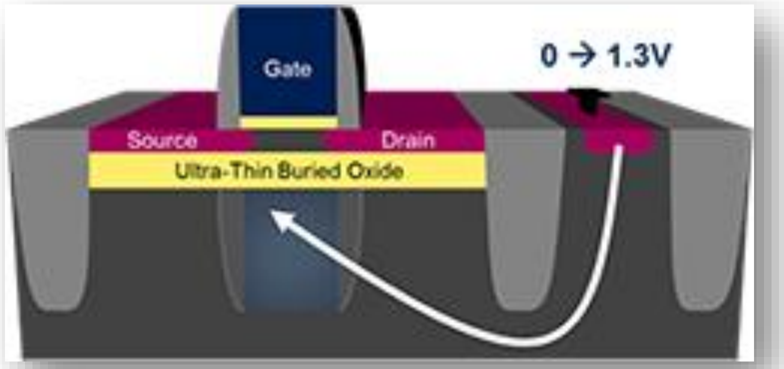
Technologies for ultralow power IoT: FDSOI



In ultra-low power IoT applications, we need to adopt a technology that is

- Ultralow leakage
- Ultralow power
- Ultralow voltage
- Cost effective!



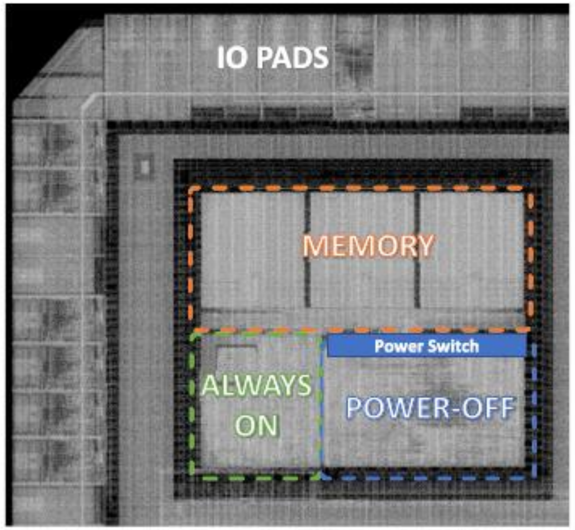


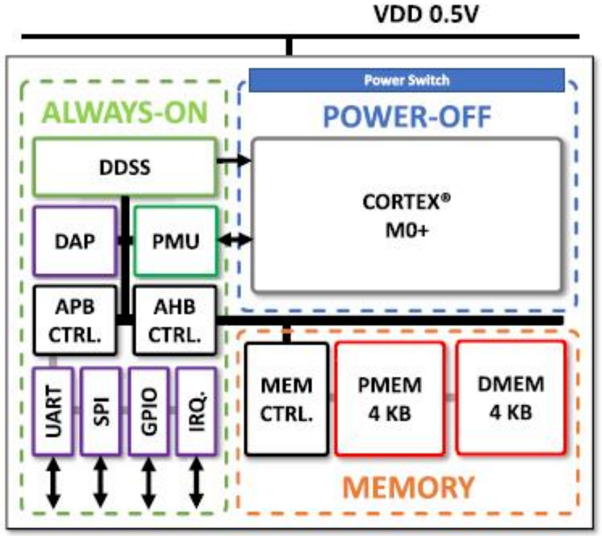
The presence of the buried oxide allows the application of back-biasing voltages, resulting in breakthrough **dynamic control of the transistor**

FDSOI for IoT: ultralow power FDSOI circuits

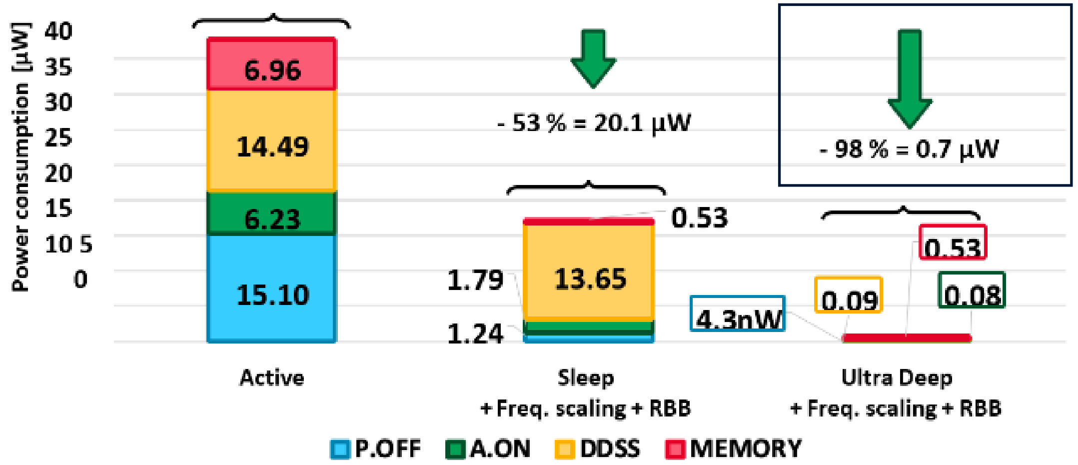
- FDSOI circuits in 28nm optimized for 0,5V operation
- **Back-bias technique is used to offer adaptive power reduction when the systems are asleep**
- 0,7µW deep sleep mode power consumption

- SoC compatible with energy harvesters that provide non continuous power





LALLEMENT *et al.*: 2.7 pJ/CYCLE 16 MHz, 0.7 µW DEEP SLEEP POWER ARM CORTEX-M0+ CORE SoC IN 28 nm FD-SOI



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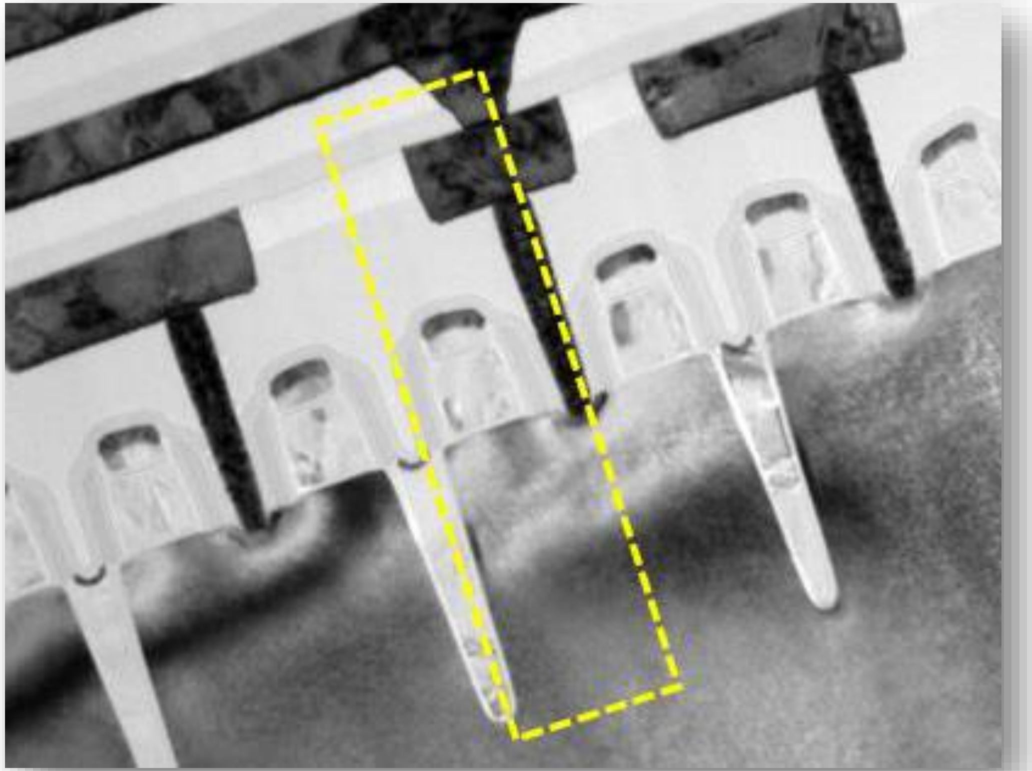
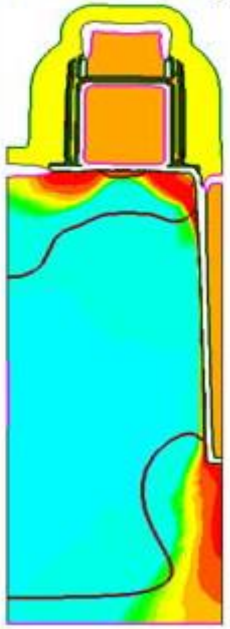
ULP microcontrollers with embedded Select in Trench Memory (eSTM)

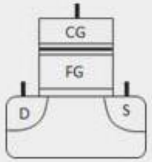
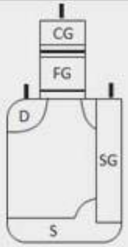
- Very low Ioff & compacity control with vertical access MOS
- Production on 40nm node



Electron current density



S.Niel et al, IEDM 2018

Cell Architecture	1T eFlash Planar	1.5T eSTM Vertical
Device Schematic		
Technology node (Prod → R&D)	40nm	40 → 28nm
Memory layer	FG	FG
cell Area (40nm)	0.059µm²	0.049µm²
P/E Mechanism	CHEI / FN	SSI / FN
Prog. Time	~ µs	~ µs
Prog. Consumption	> 50µA	~ 1µA
Endurance	100K	100K-1M
Scalability	-	+ +

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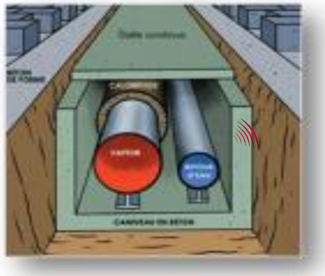
IOT: when mW can save kW

Home automation & malls
Detect any change in the environment:
door & window opening, control of light & heat in rooms, movements, occupancy, customers traffic in malls…




Monitoring and water saving
Heat distribution to detect pipes leaks, industrial monitoring to detect anomalous variations (temperature, vibrations, movement…), detection of leakage for water saving



Logistics:
Containers & freight wagon Identification, green mobility identification…



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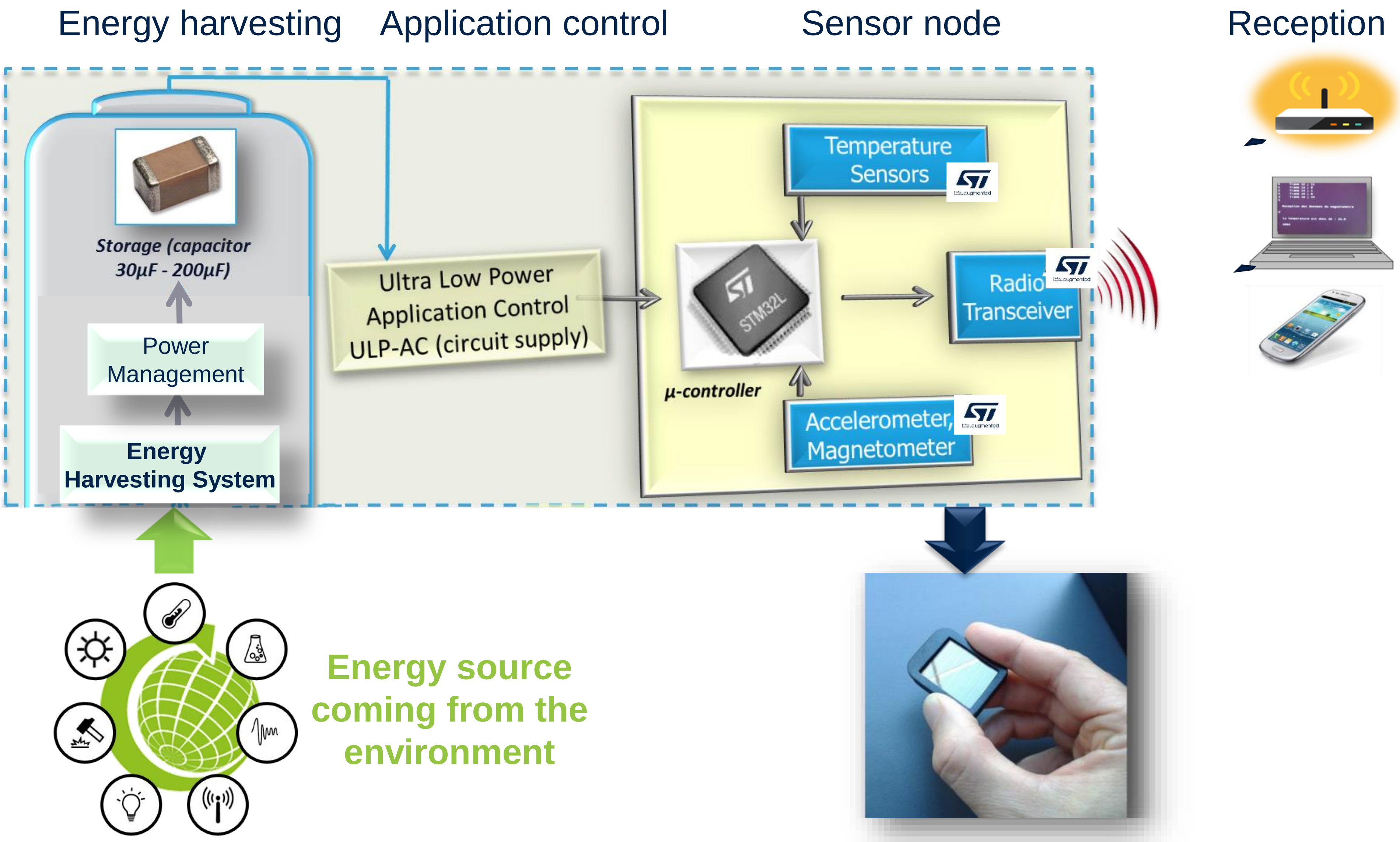
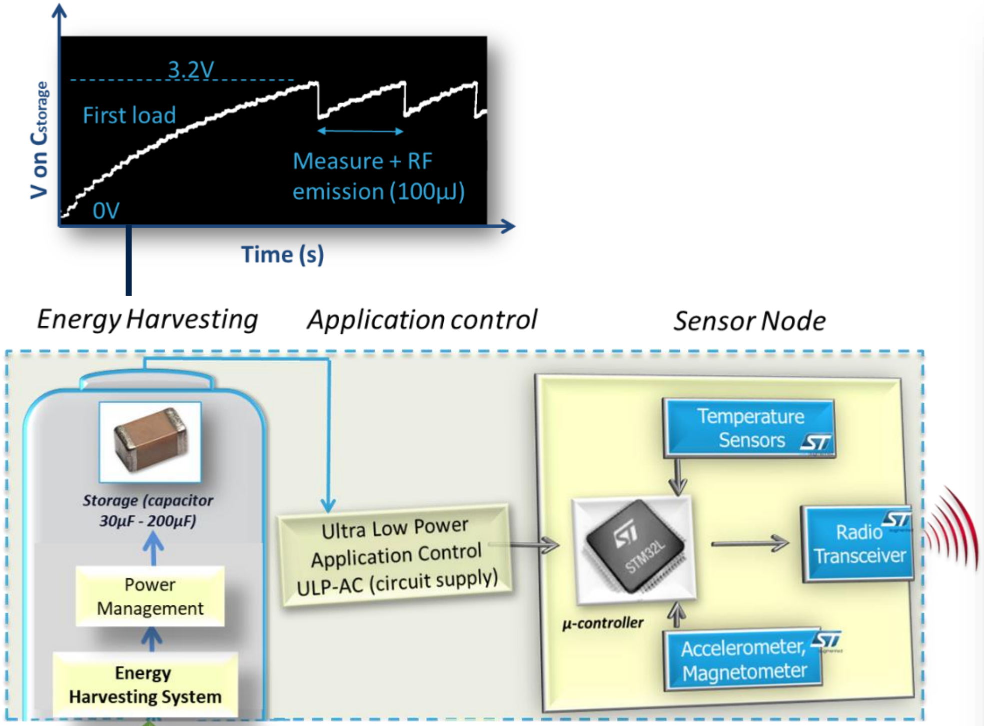
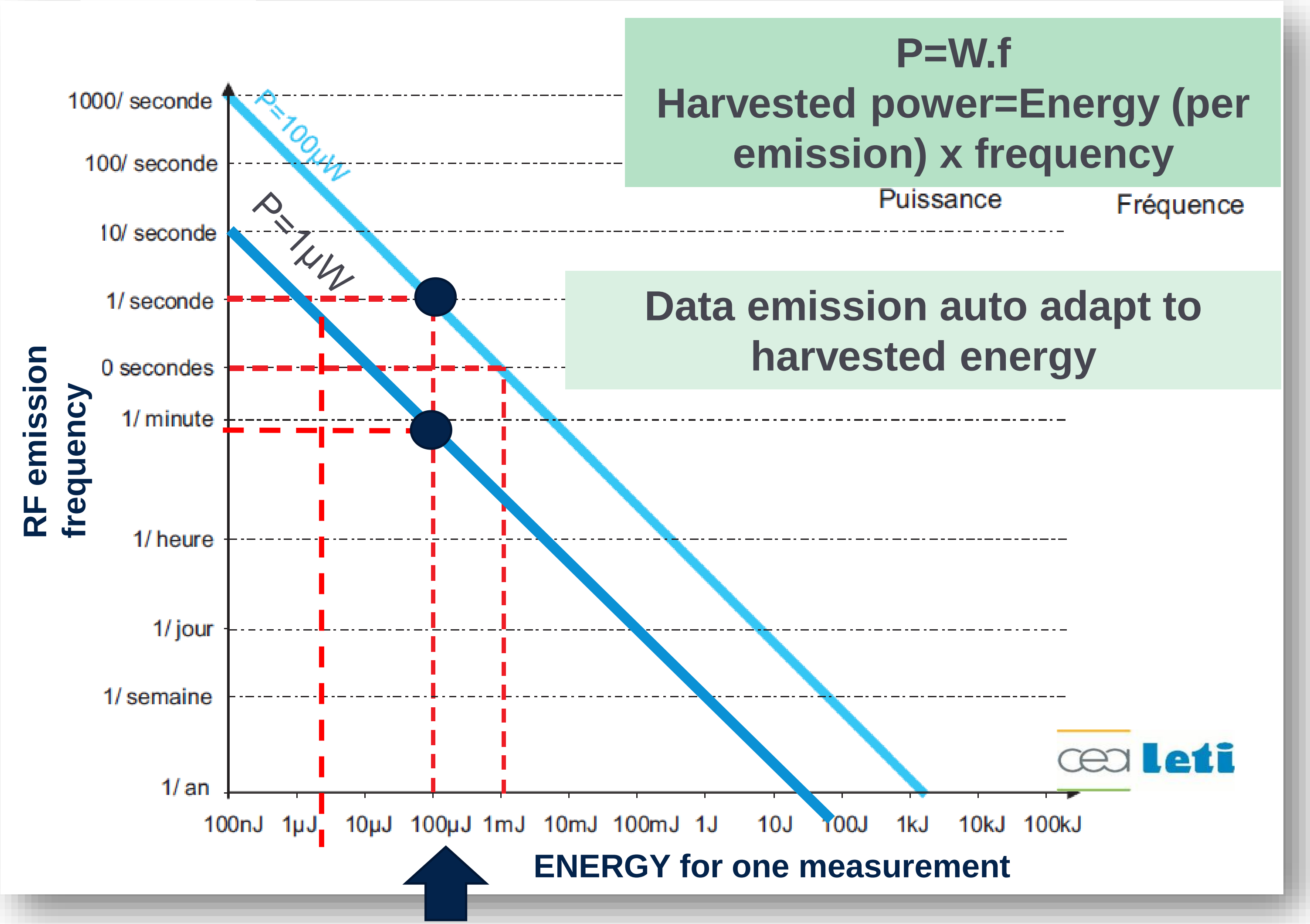
Example of system for autonomous sensor node



Key to work with very low energy= AUTO ADAPTATION



Energy source coming from the environment

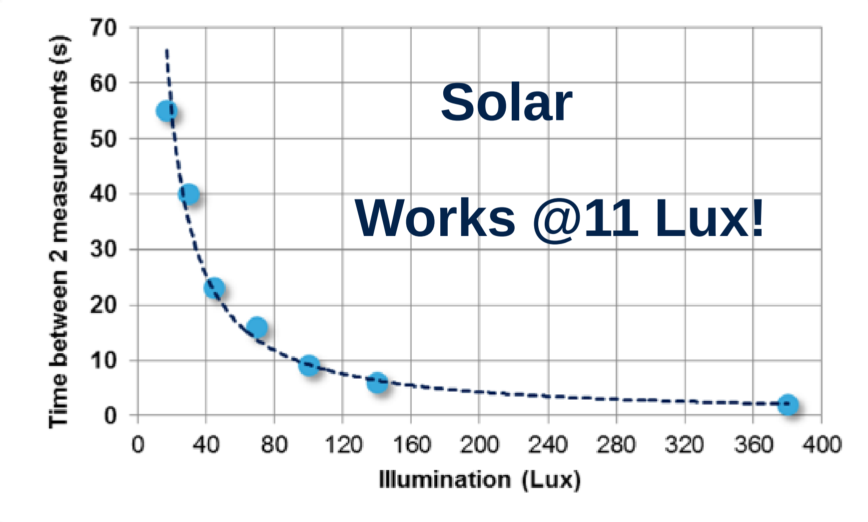


Energy needed to measure & send a t° with IEEE.802.15.4 protocol

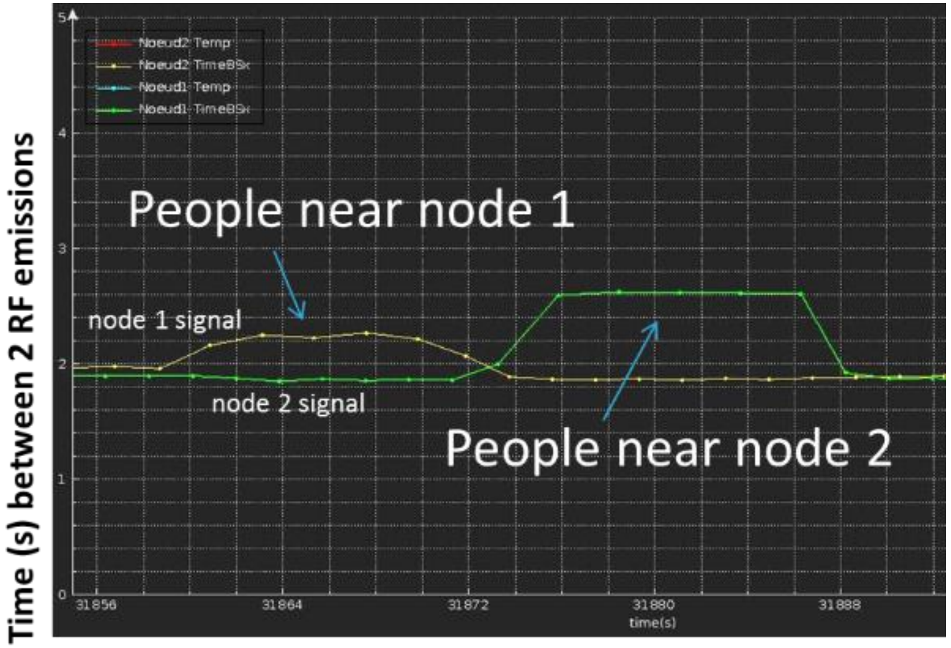
Harvested energy becomes the information

Sensor node powered by solar & thermal

Sensor node powered by solar



Example with 2 solar nodes: movement is detected due to solar cell perturbation



IoT for environmental sensors

Low power communicating sensors for water quality monitoring

Low power communicating sensors for air quality sensing

Challenge: sensing technologies have to become low power

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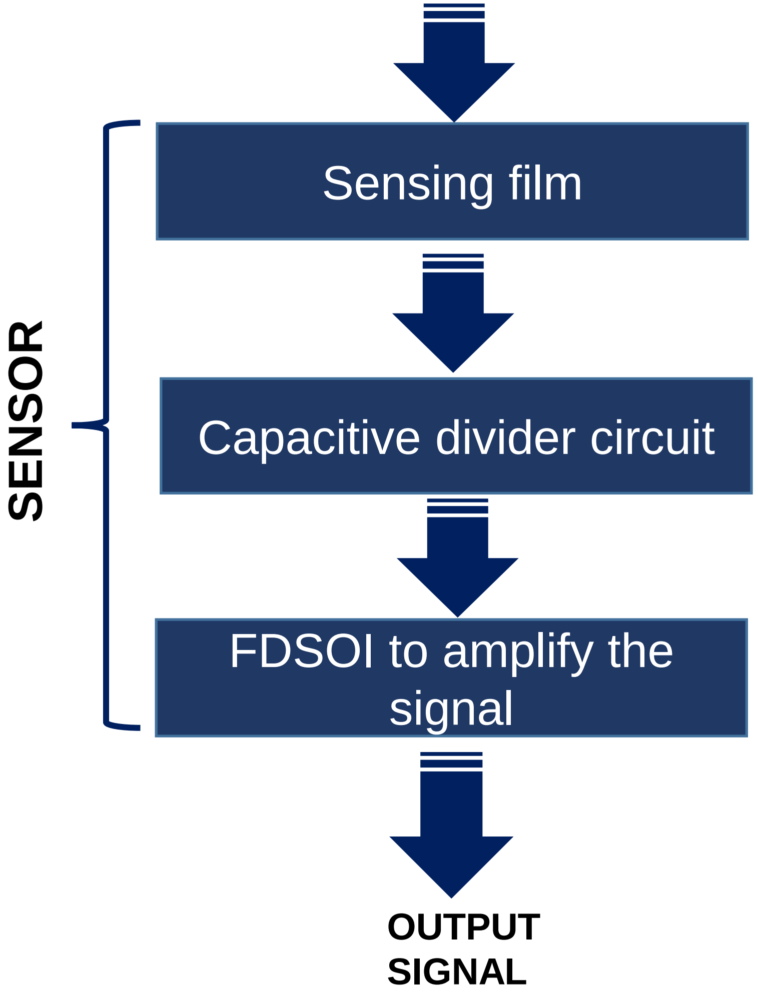
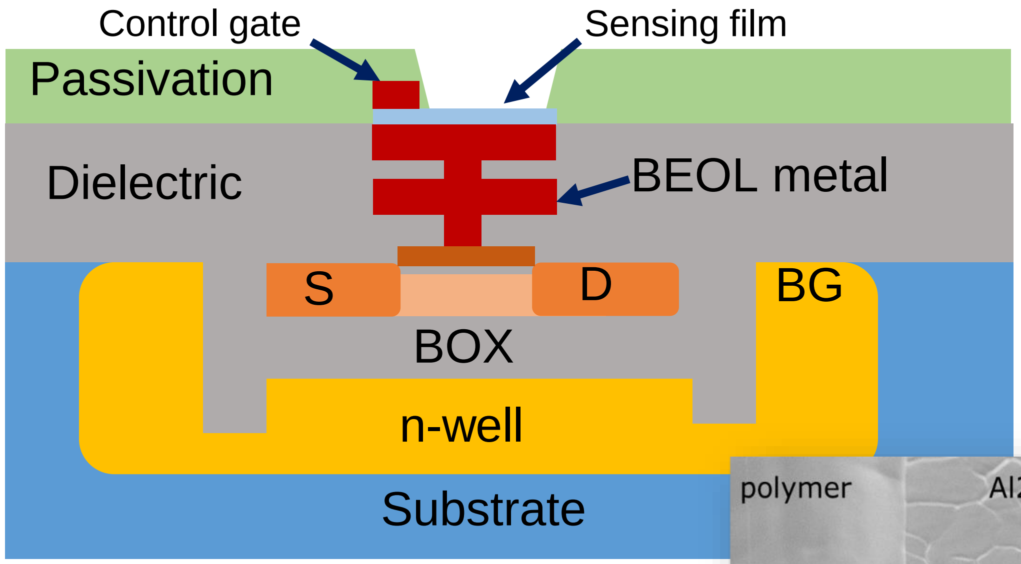
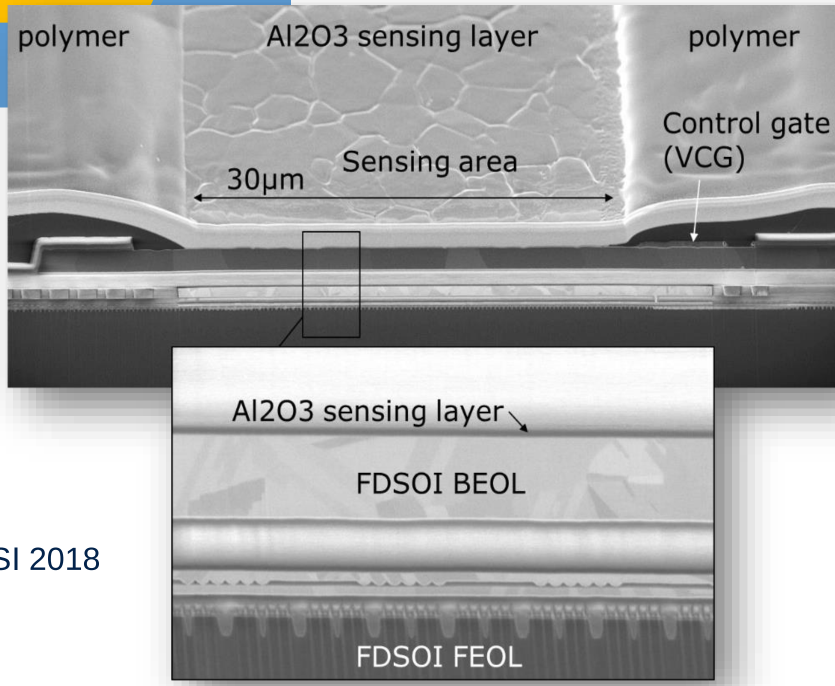
Integrated sensors on CMOS - FDSOI



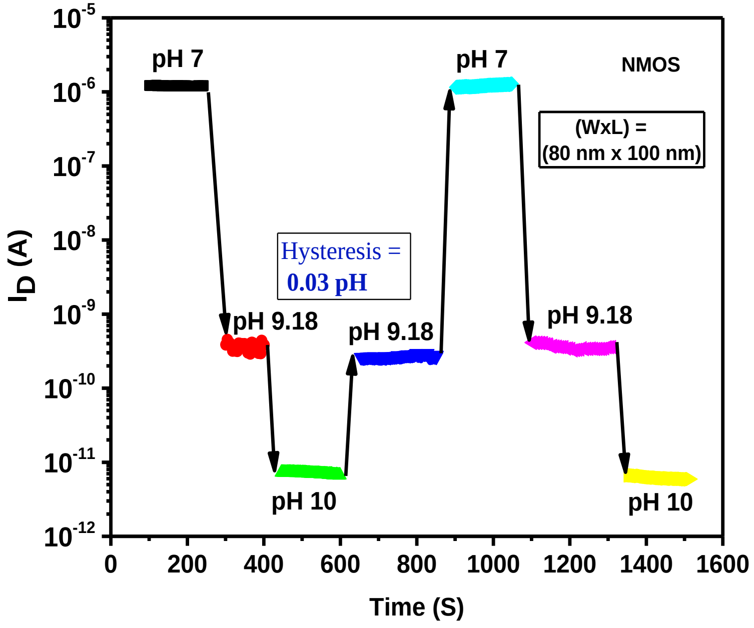




G.T. Ayele, VLSI 2018

Materials for environmental sensors

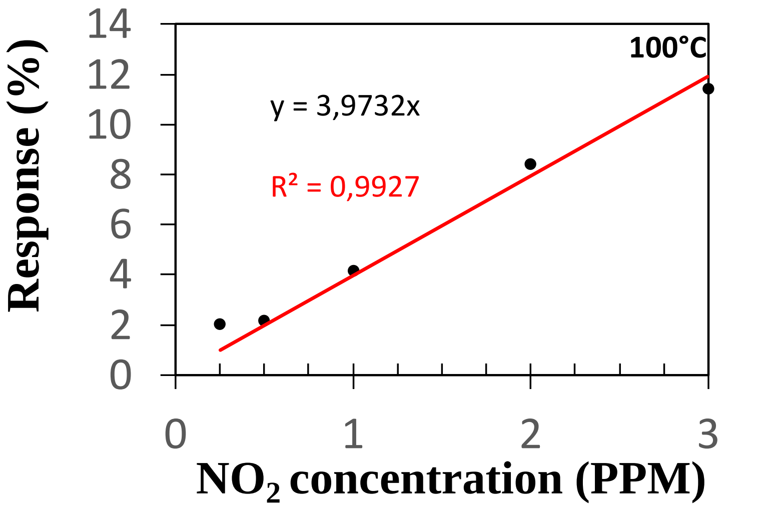
pH sensing with Al2O2 layer



G.T. Ayele, VLSI 2018

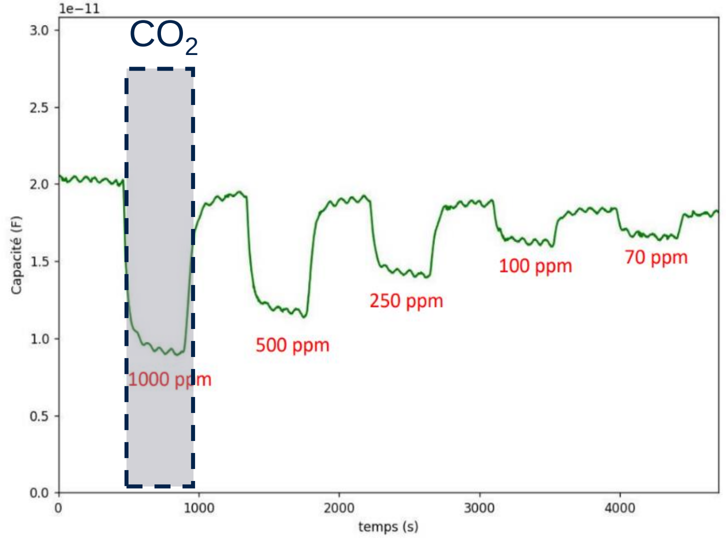
NO2 sensing with SnO2 layer

- **Highest and fastest sensing response at 100°C**
- Stable and reproducible response to NO_2



CO2 sensing with hybrid polymers layer

Sensitivity measurement for different CO_2 concentrations for T=65°C, RH=45%



A. Assaf, A. Souifi – EMCM-DS 2022

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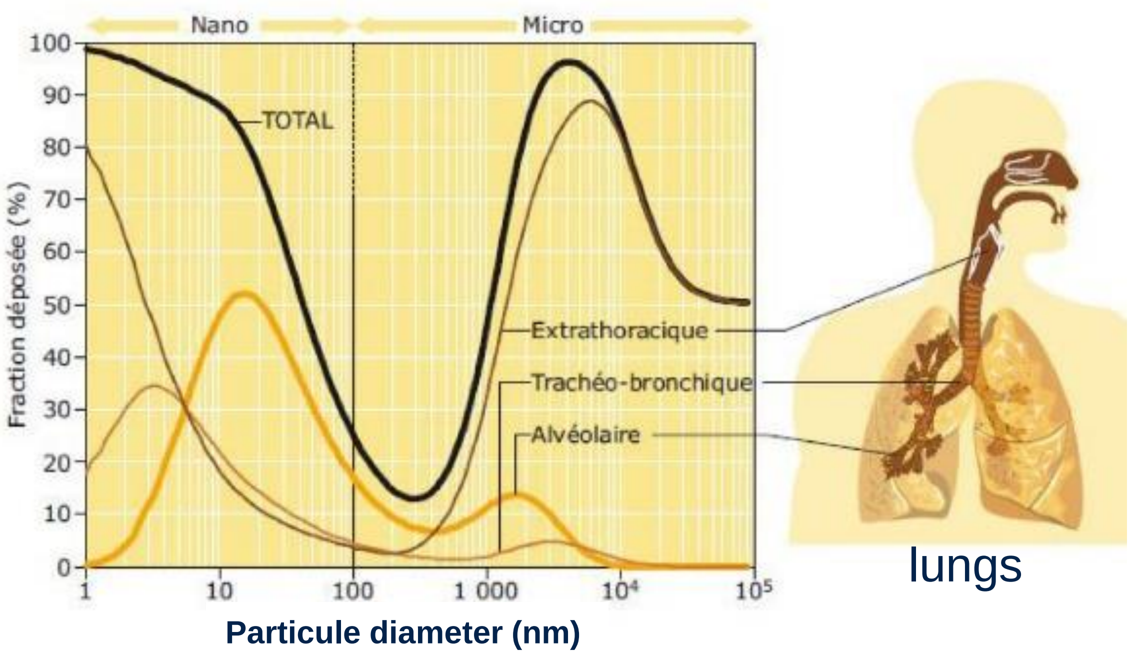
Photonics for environmental sensors

Nanoparticules sensing?



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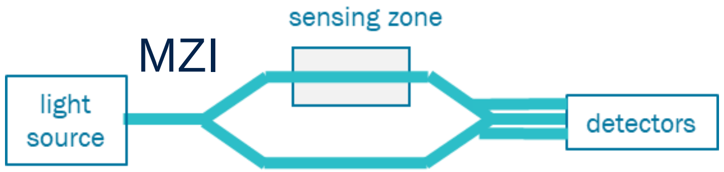
➡ **Can detect sub-100nm particules**

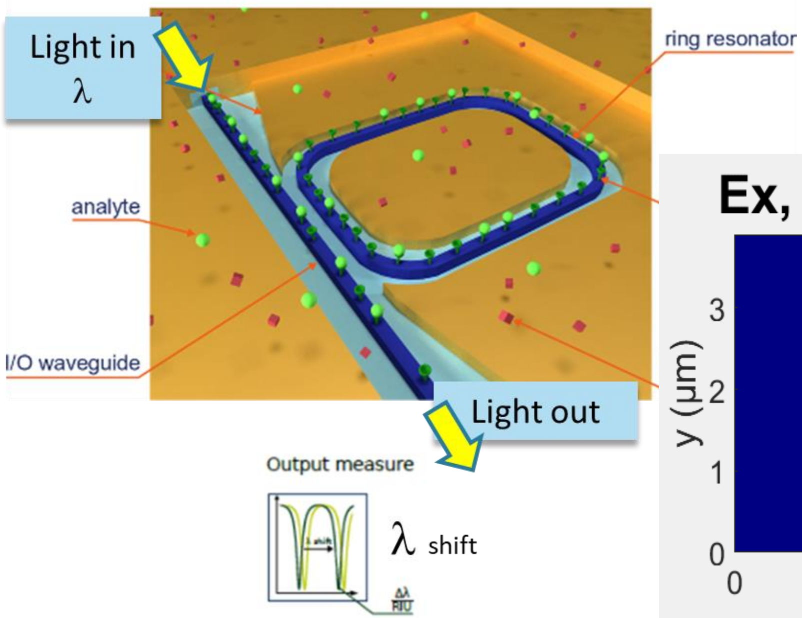
CO_2 sensing measurements

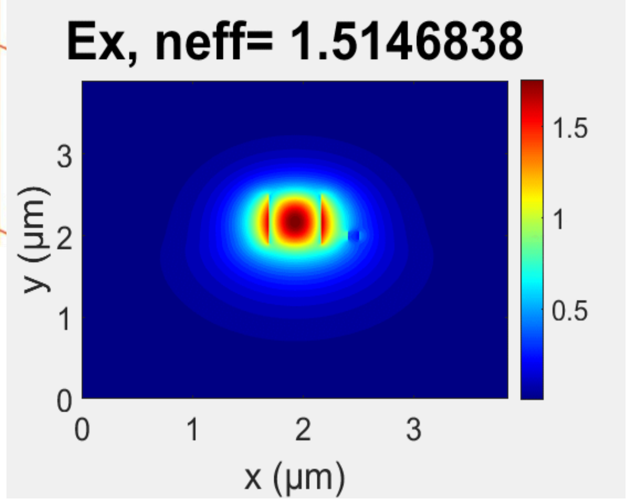


IRT Nanoelec

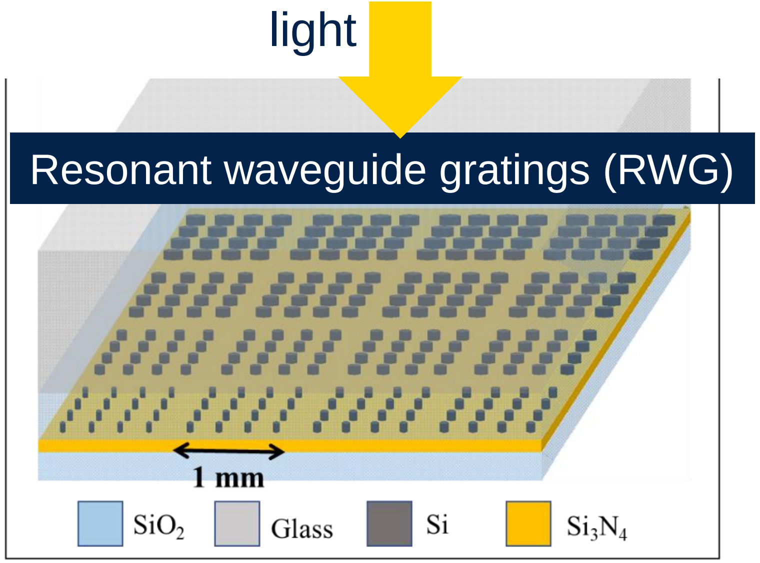
PhD C.Bhan
Col.ST-UdS

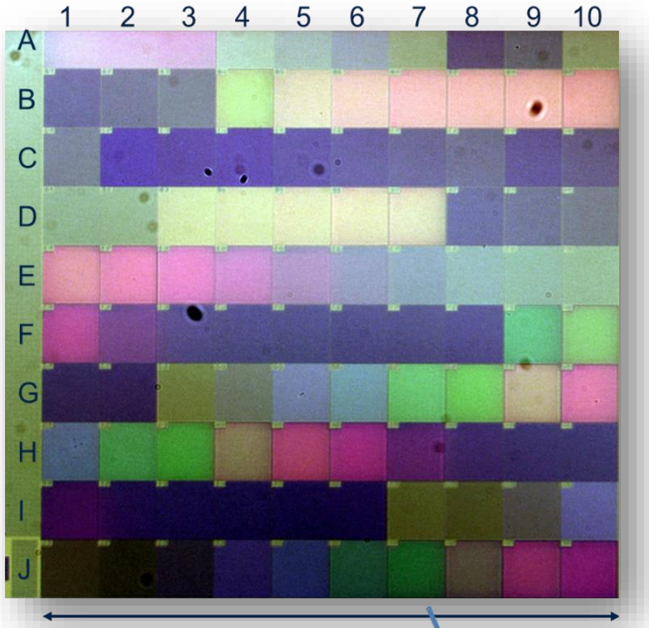
Ring resonator

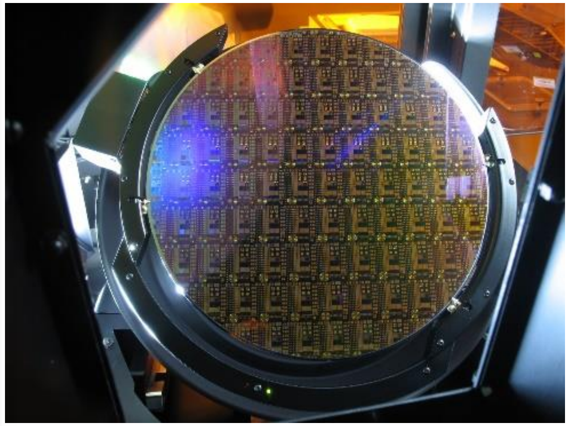




Optical filters on 300mm glass wafers

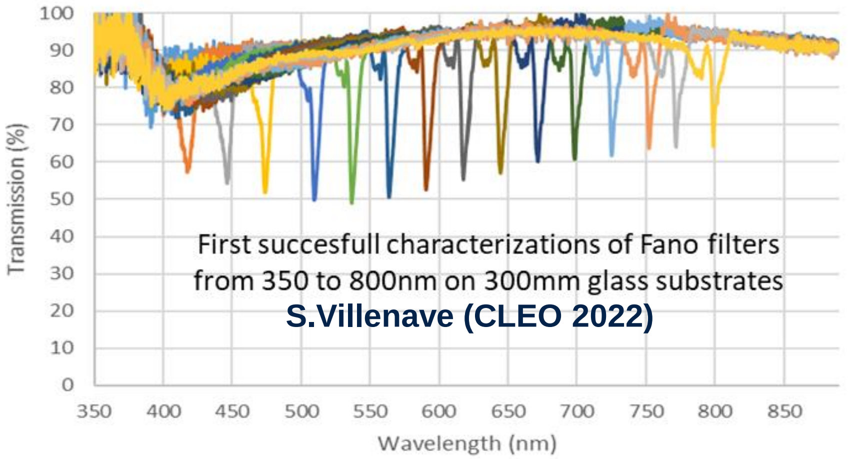






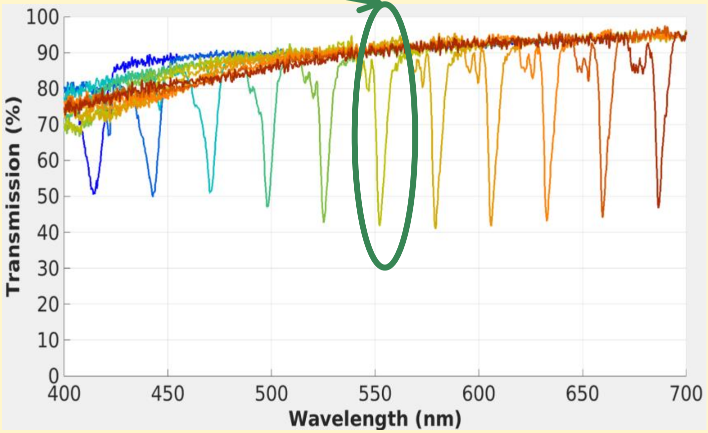
- Light incident on a periodic surface structure **excites a confined mode** in the layer
- **Sharp reflectance** peak (resonance for a given λ)
- Matrix of filters / **selection of wavelength with the matrix design -> micro spectrometer**

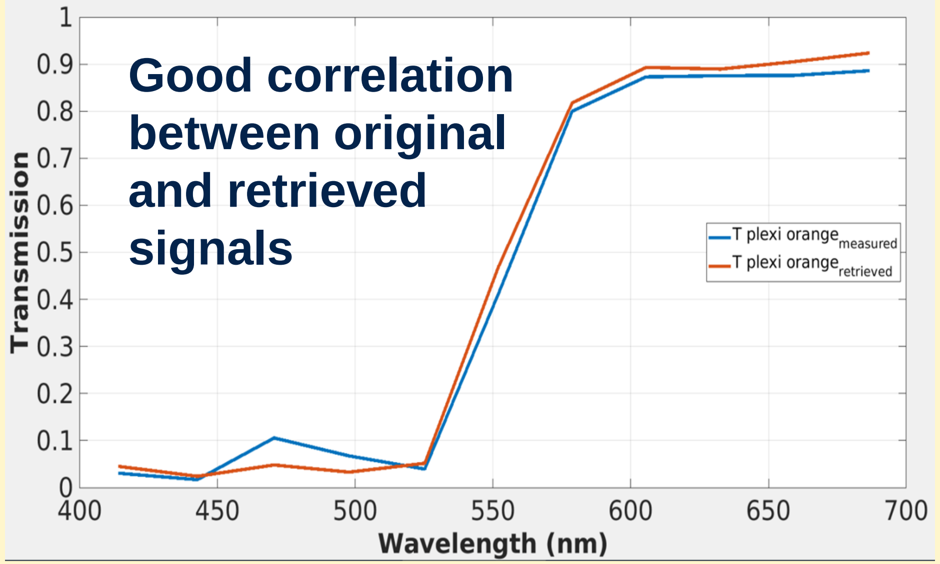
Application for environmental analysis



Environmental analysis with spectrum retrieval

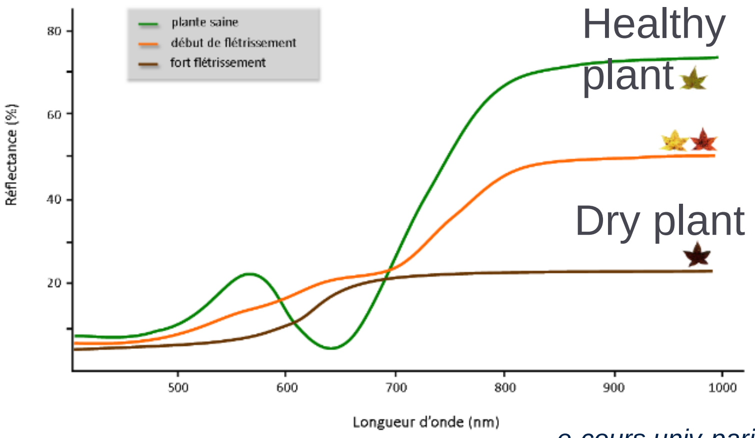
Example with 11 filters covering most of the spectral visible range





Retrieve the original spectrum of a sample thanks to a set of our filters

Example of application: chlorophyll spectrum retrieval and analysis of dryness



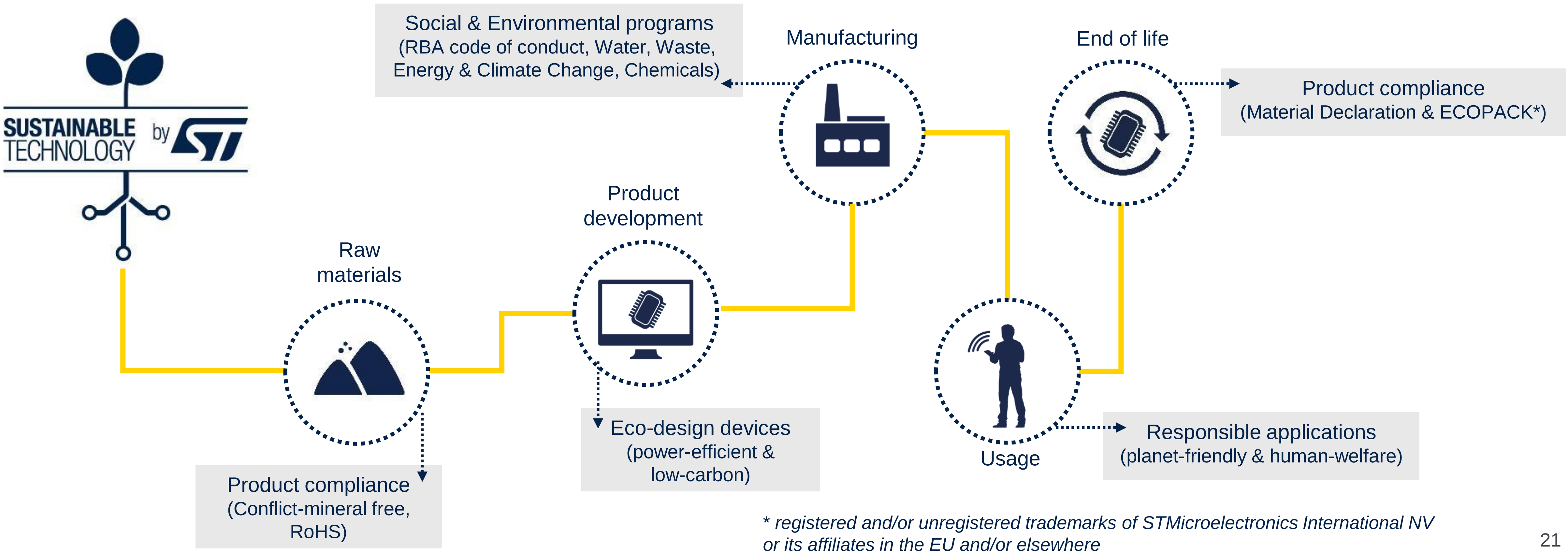
e-cours.univ-paris1.fr

Agriculture, water saving…

Sustainable technology

Our Sustainable Technology program aims to develop responsible products which:

- **Improve our social and environmental footprint at every stage of the product life**
- **Have the greatest positive impact on the planet and people in the end-application**



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ST will be carbon neutral for its 40th anniversary

Milestones

- Compliance with the 1.5°C scenario by 2025 – recognized by SBTi
- Carbon neutral by 2027
- Sourcing 100% renewable energy by 2027
- Collaborative programs and partnerships for carbon neutrality throughout our ecosystems

SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

-40%
GHG emissions scope 1 & 2 since 2018

CARBON NEUTRAL

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Energy saving: example in eco conception

- Identification of most impacting recipes
- Develop « eco designed recipe » per level
- Verify impact on products
- Quantify environmental improvements

Numero	9	10	14	15	20	21	22
Description	TRANS T1	TRANS T2	TRANS T1	TRANS T2	STBL	EP STRIP	STRIP OE
Pression	5	5	7.5	7.5	10	10	10
Cl2	0	0	0	0			
HBr	0	0	0	0			
CF4	0	0	0	0			
He	0	0	0	0			
O2	0	0	0	0			
CH2F2	0	0	0	0			
Temperature	[redacted]						
Step Type	Time	Time	Time	Time	Stab	EndPT	OverEtch
Duree	15	15	15	15	30	40	0
OverEtch (%)	0	0	0	0	0	0	50

Suppress gas during some temperature ramp or stabilization steps

Reduce overetch time

Conclusion

Many technologies for diversification are in development in the semiconductor industry for responsible applications

A lot of efforts are made to contribute to a more sustainable industry

All are concerned, not only industry (Labs in France >15 000m² of clean room)

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Our technology starts with You

Find out more at www.st.com

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