
# Advancements in Micro & Nanotechnology and their Practical Application for In-line Monitoring

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# Centro Nacional de Microelectrónica. CSIC


MICRO
nano
FABS

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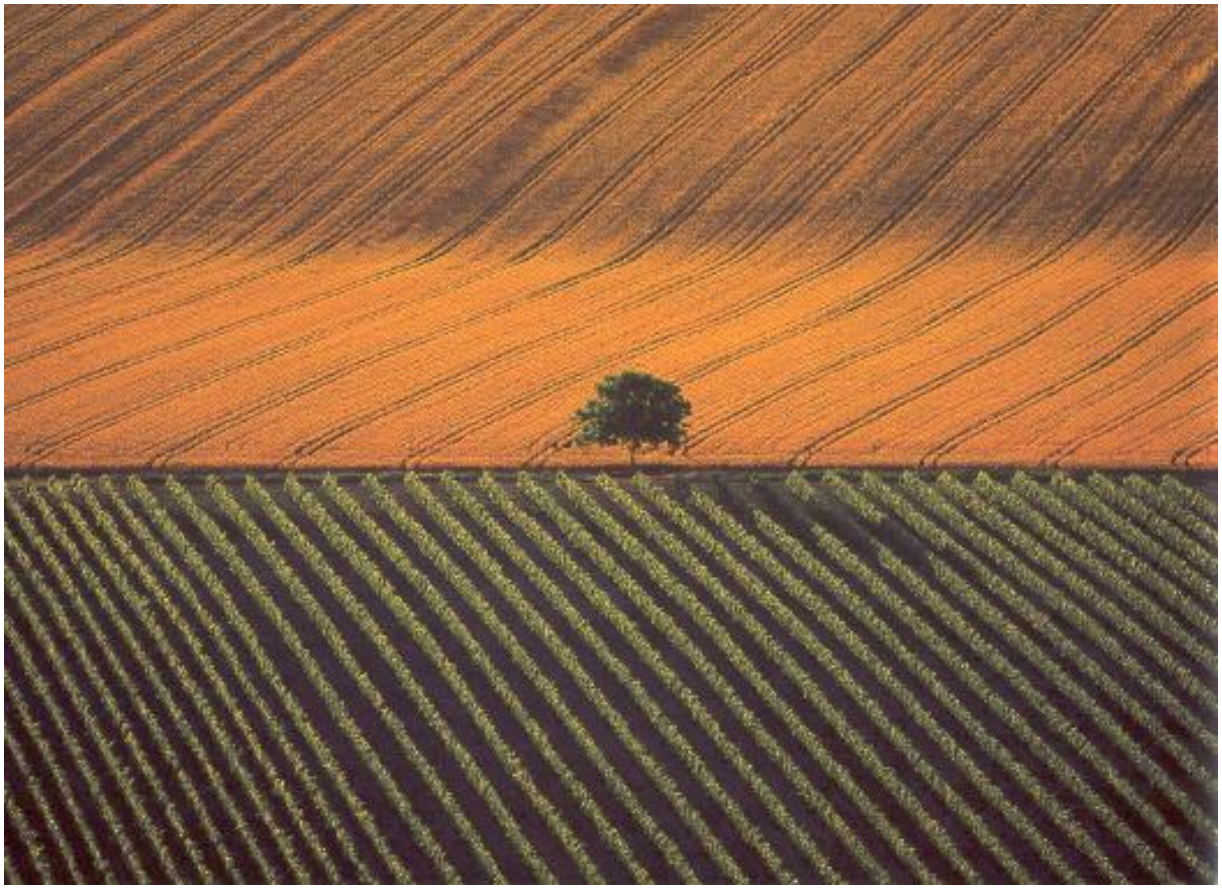
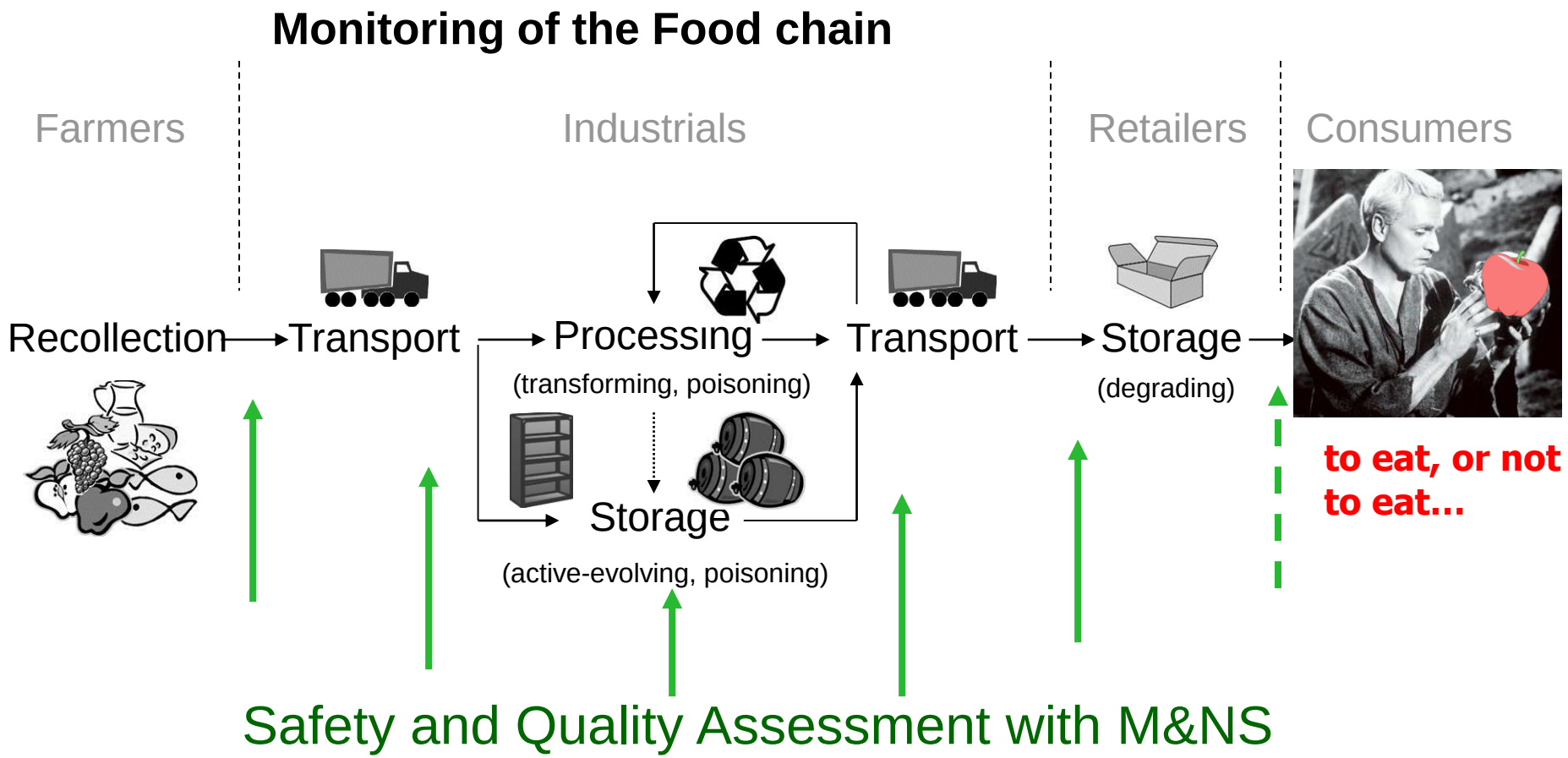
# Outline

- Introduction
- Needs from the Consumers and From the Food Demand in terms of Safety, and Quality
- In-line On-line measurement benefits
- What Sensors and Microsystems can offer?
- What else with Nano?
- Examples of In-line/On-line monitoring
- Other Commercial applications
- Conclusions

# When Food and Microtechnologies meet



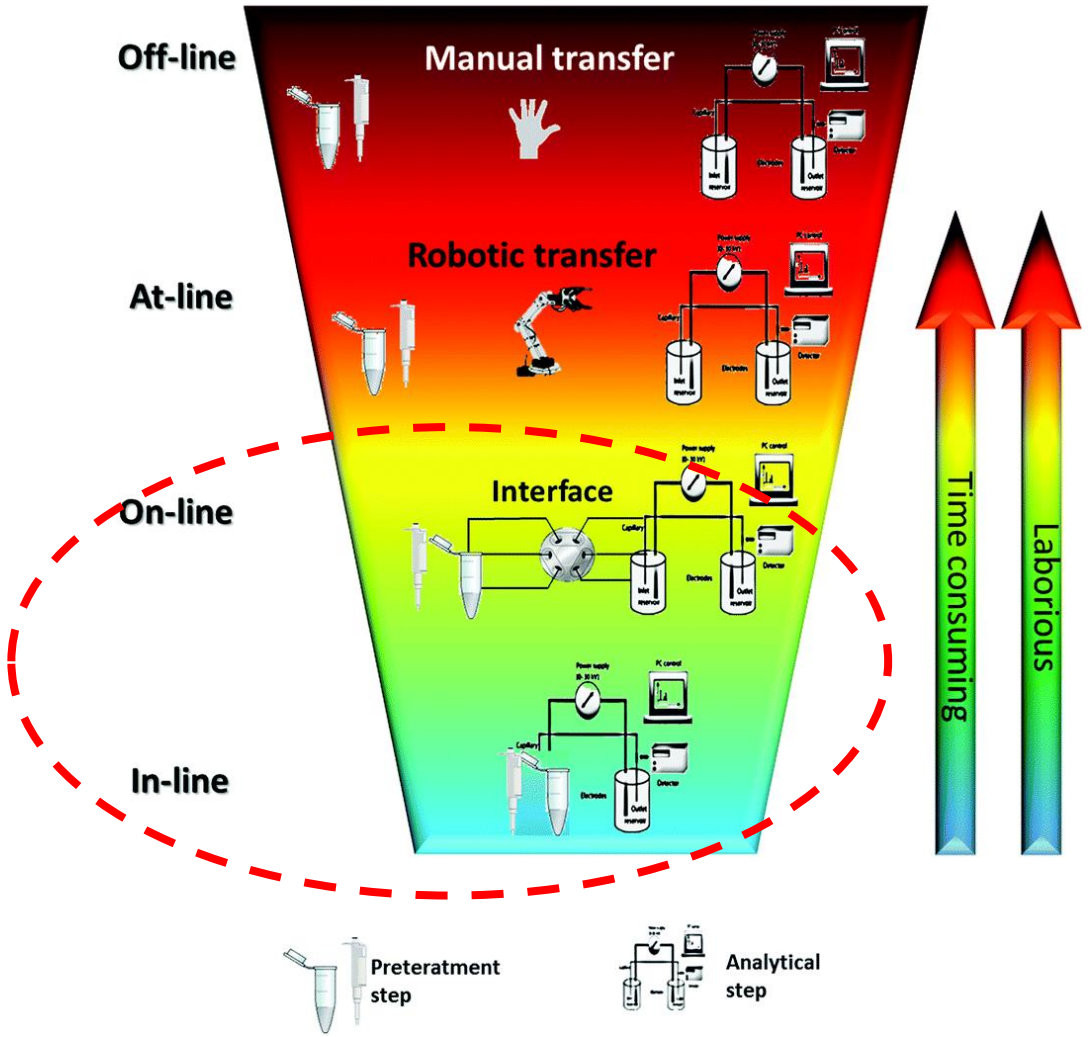
# Food Consumers Demand: Quality and Safety




M&NS contribution: bring lab close to the foodstuff & power of analysis & speed

(multisensing, multipoint sensing, continuous monitoring, automation/non-specialist intervention)

# Food Analysis: Proximity to the sample




Impact of the Sensors and Microsystems

From: http://pubs.rsc.org/en/content/articlelanding/2017/an/c6an02608g#!divAbstract

# What Micro and Nano Systems can offer?

- **Many solution based on:**
  - Lab analysis (costly and time consuming)
  - 'Expert' human intervention (subjectivity)
  - Destructive, not massive
- **Micro & Nano Systems alternative:**
  - **Miniaturisation: dimensions, weight, power consumption, portability.**
  - **Cost reduction** of the sensing devices and **less reagents required**.
  - **Fast response**… **Prevention.**
  - **Electronics reading & Autonomous Functioning**
  - **Connectivity, Communication, Data Transfer and Management**
  - **Non invasive**, **Pervasive** and **ubiquitous solutions**
  - **New functionalities**
  - **Ubiquitous, Redundant, Matrixes, Multisensing**

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# What In-line and On-line Solutions can offer ?

- Continuous monitoring. Repeatability
- Can provide early alerts and prevent contaminate products
- Decreased product loss
- Enable faster response to changes in raw material quality or process drifts.
- Cleaning of filtration processes based on direct measurements
- Sorting by quality.

- But:

They will never replace the high precision of lab measurements

# In-line examples

- CIP: Clean in Process: saving water usage, energy and cleaning products
- Process control:
- Physic Parameters:Temperature monitoring, Pressure, Acceleration, Weight (load cells),
- Chemical Parameters: Flow, pH, Humidity, Viscosity, Conductivity, Density, Brix, Salinity, Alcohol, ..
- Other: Fermentation …

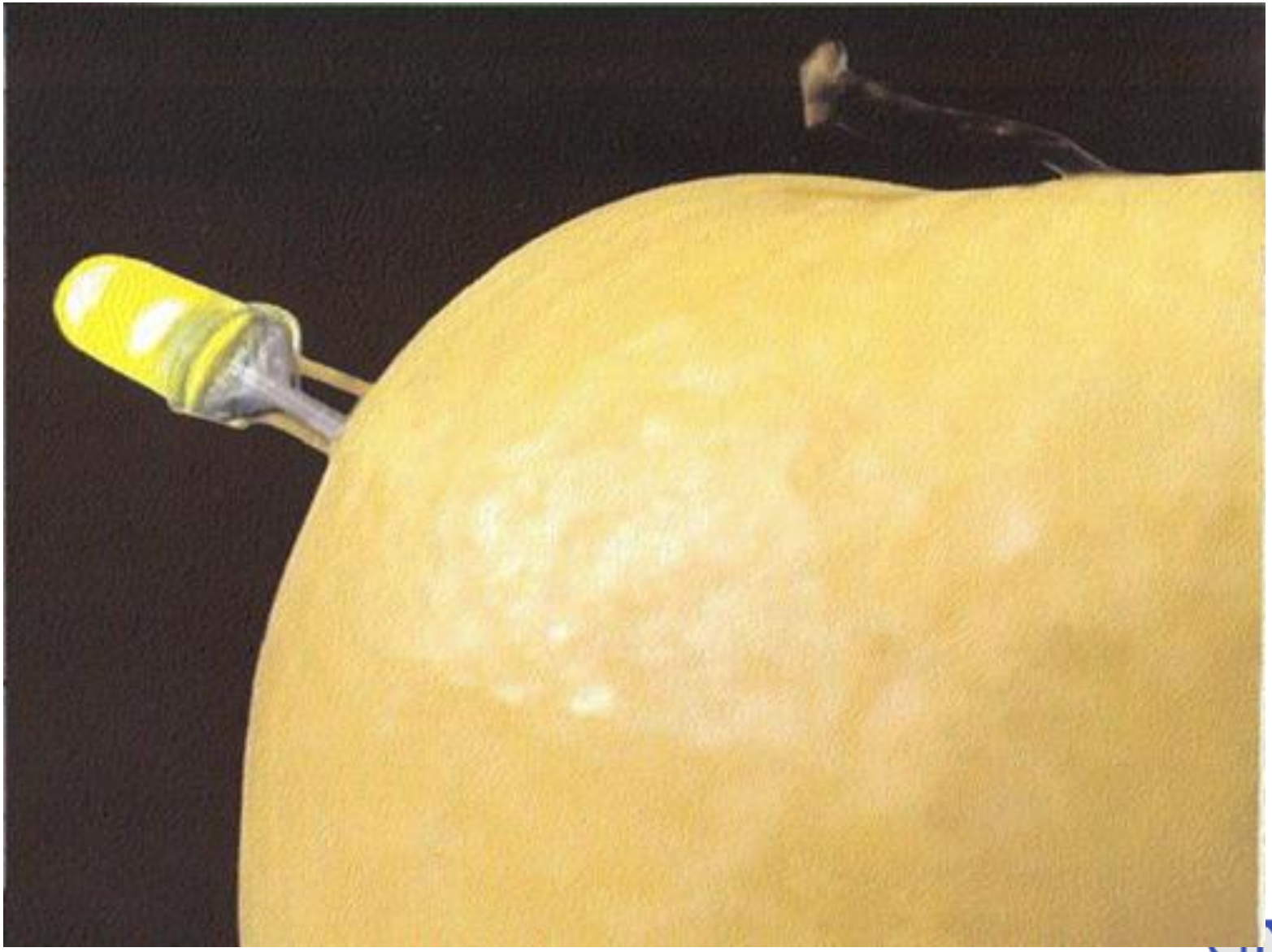
- Color, defect monitoring,
- Freshness, Ripeness,…
- Monitoring of Robotic equipment
- Agro,
- Logistics,
- Storage,…

# And In-line product quality: NIR

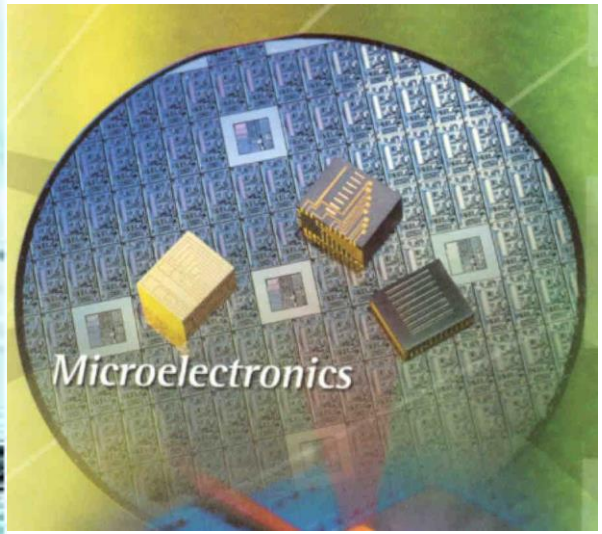
- **Product quality:**
- **Near Infra Red (NIR)** 780-2500 nm: No sample preparation, simultaneous Multipe measurements.

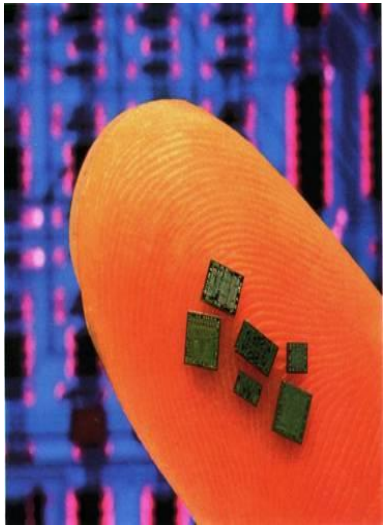
- **Milk**: process parameters: moisture, protein, fat, lactose,…
- **Meat:** Fat, moisture and protein content, NaCl in cured meat
- **Fruits and vegetables:** moisture,, sugar content, colour, transgenic or not transgenic tomatoes…
- **Grain and grain products**: quality grades, humidity, sugar, starch
- **Oils**: Acidity, oxidation levels, adulteration
- **Fish:** End point temperature, moisture in dried fish
- **Beverages:** Alcohol content, suggar, adulteration, fermentation control.

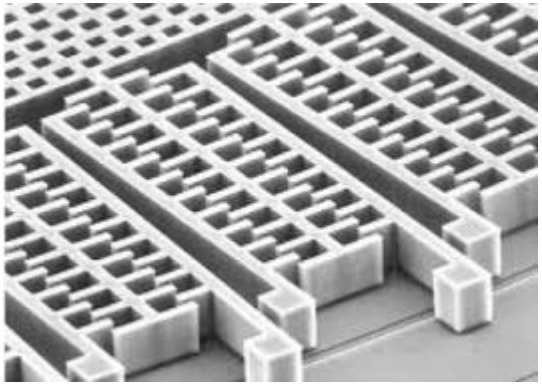
# Food and Micro and Nanoelectronics Sensors and Systems: Can we help?

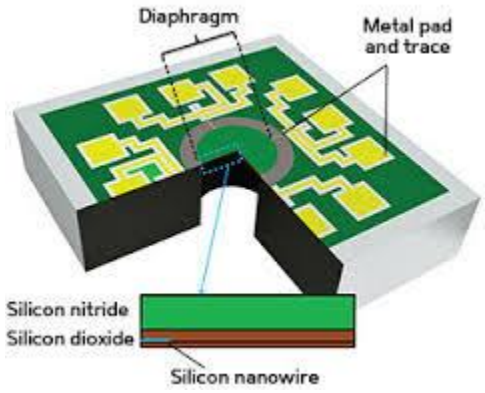


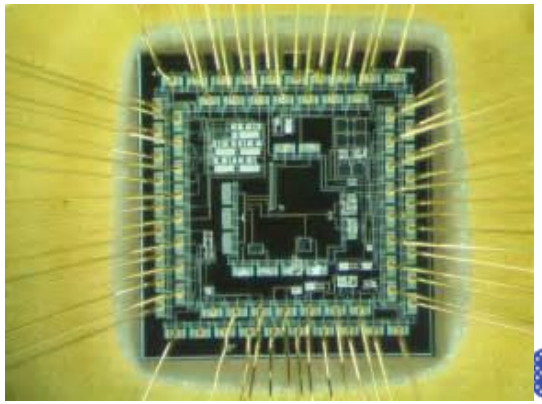
# What are Micro and Nano Technologies ?: Integrated Circuits but also Sensors and MEMS



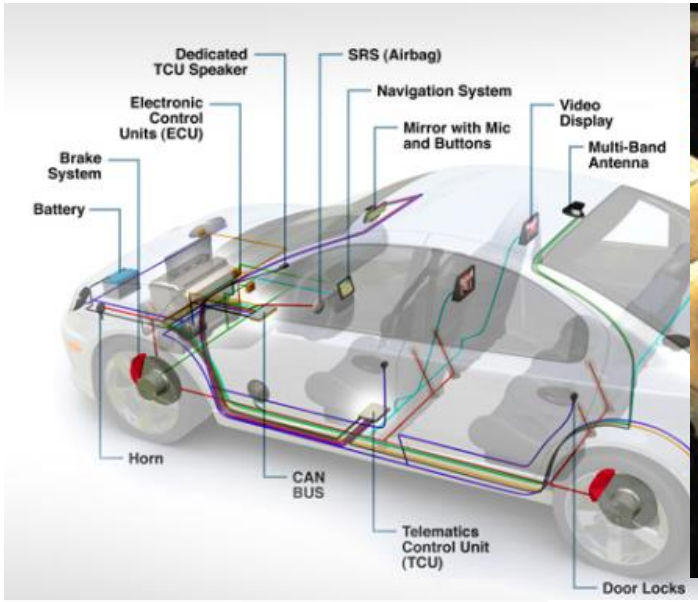



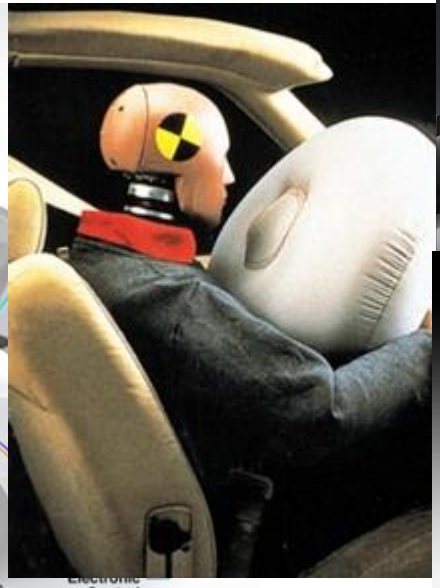


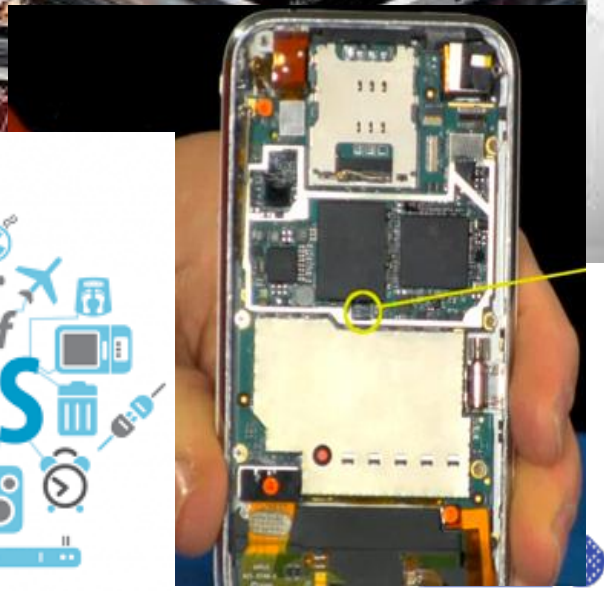


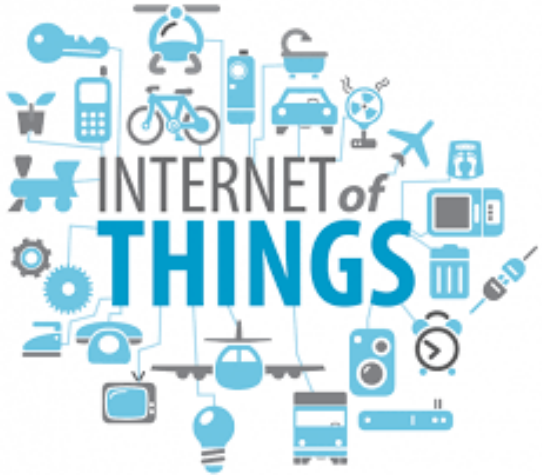



# MEMs: Application Drivers



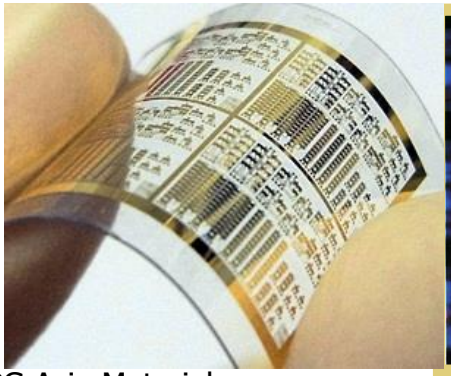



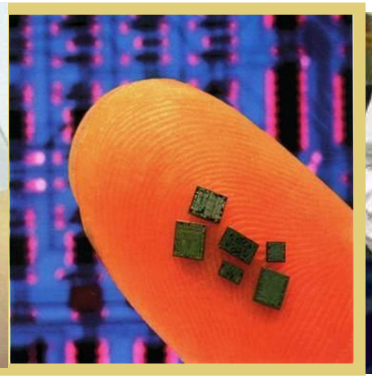


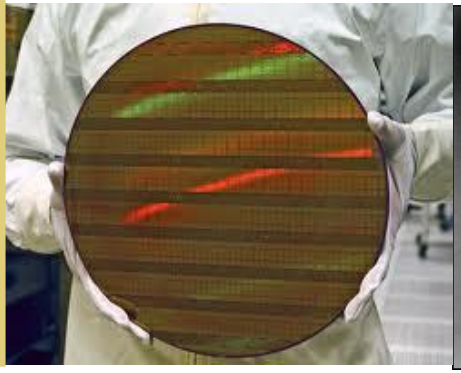



# Fundamentals of Micro and Nanoelectronics: The material


- **Second element on the Earth surface, after oxygen**







NPG Asia Materials

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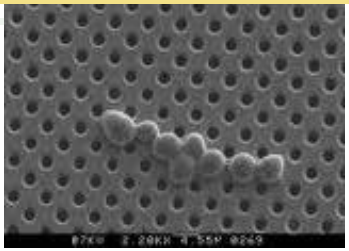
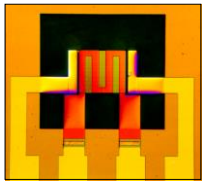
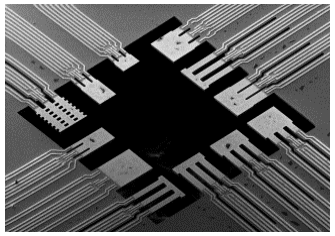
# Microstructures & microdevices & microsystems

- Passive Microdevices (membranes, microsieves)

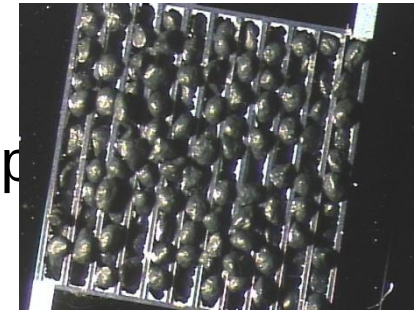


- Physical sensors: Temp, Humidity Pressure, Accelerarion, Optical,…

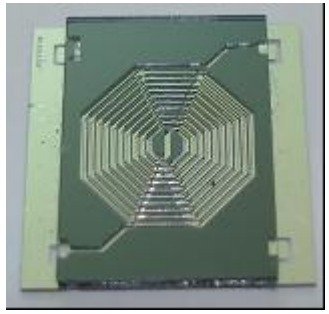




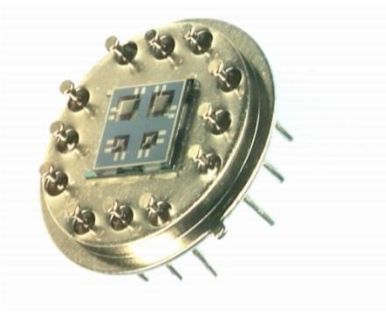
- Biosensors, DNA-chip Lab-on-chip



Micro preconcentrator

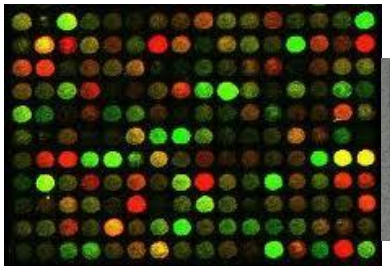


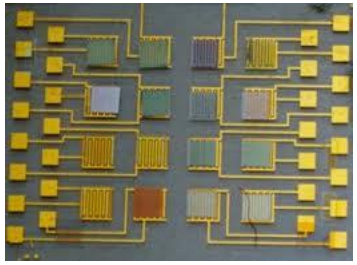
Chromatographic column

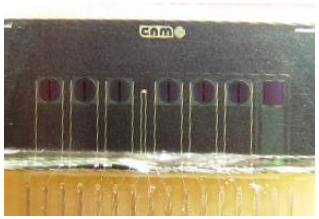


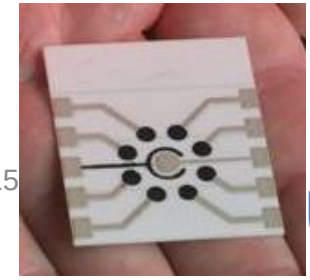
Sensor system

- Chemical Sensors / e-noses, e-tongues / Microchromatographs











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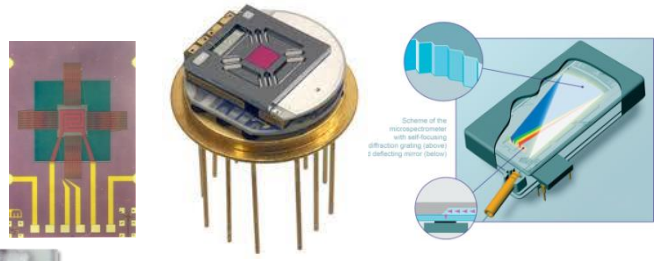
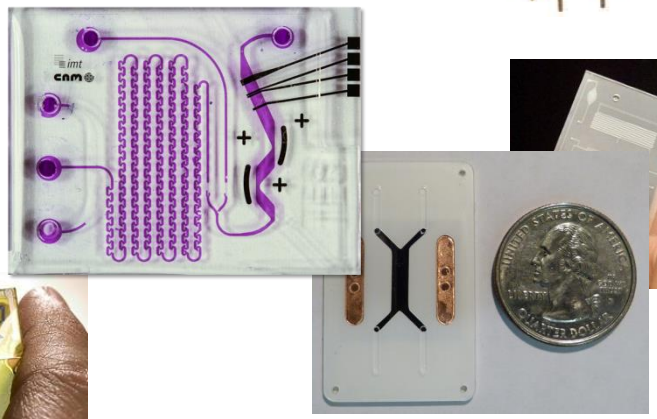
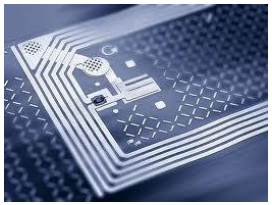
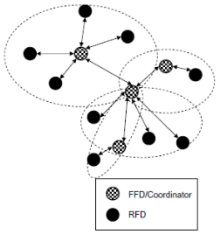
# Microstructures & microdevices & microsystems

- Optical Sensors / Microspectrometers
- Microfluidics / Lab-on-a-chip
- Printed electronics
- RFIDs / Wireless Sensor Networks











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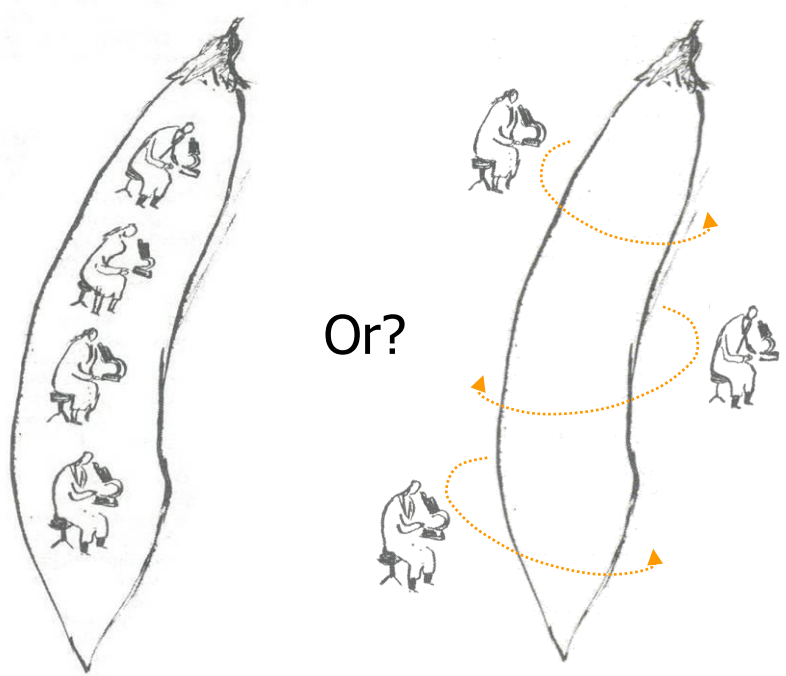
# In summary: Sensors and MST in AgrooFood applications

## Bringing the lab to the product...

- In Food Processing
- In Food Safety
- In Food Quality and Preservation
- Logistics and Packaging
- In Nutrition and new food products




Prevent Consumer Concerns like with GMO's:
focus groups, consumer surveys

Fish and Chips, not fish with chips...

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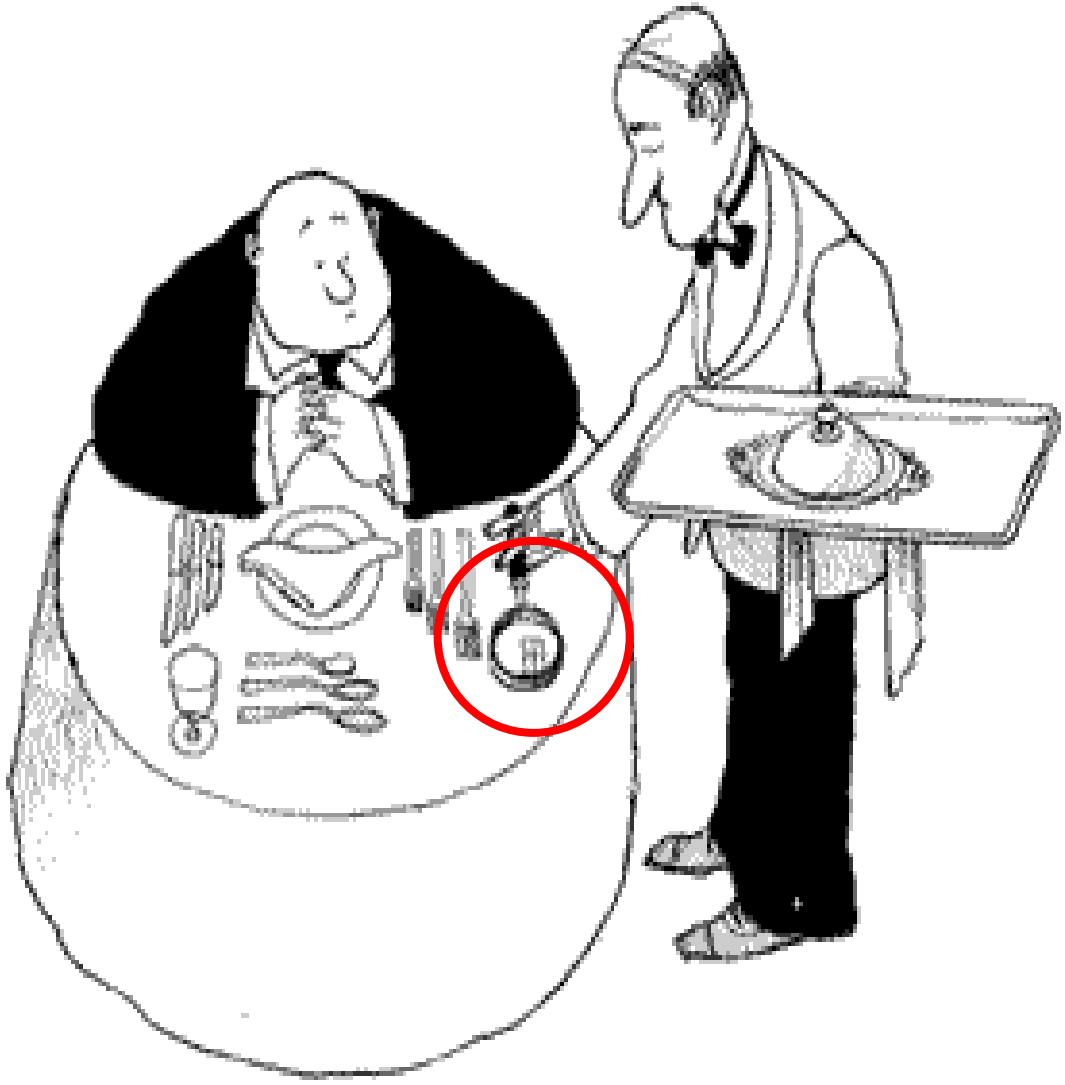
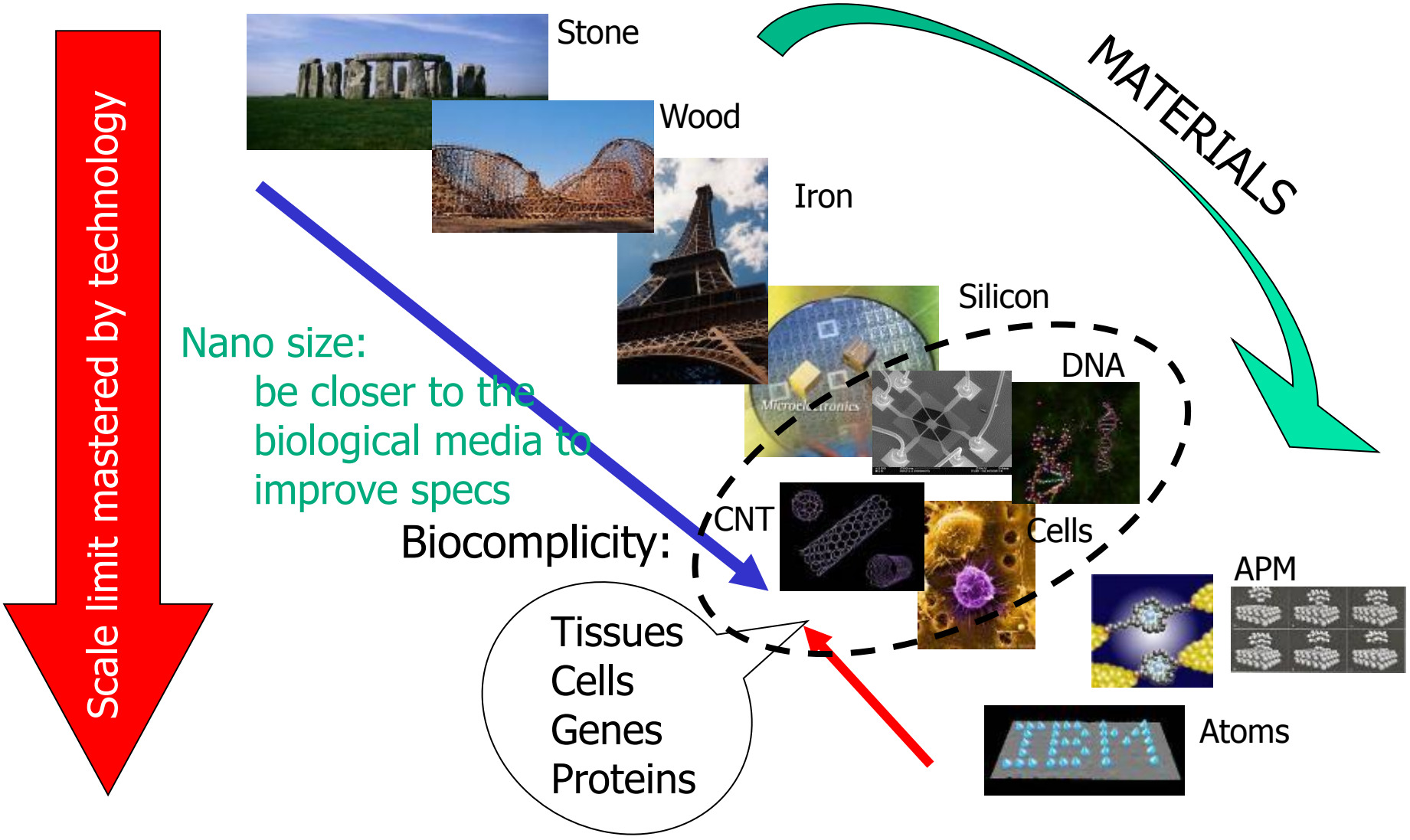
# And what about nano in food?



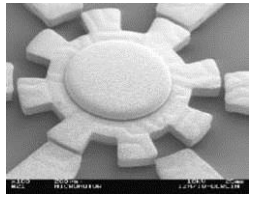
# NanoTechnology: A crossroad

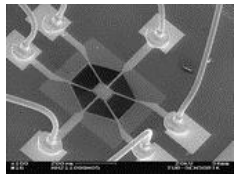


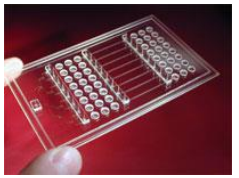
# Nano: The importance of the SCALE FACTOR

**When dimensions decrease:**

- **the Surface/Volume ratio increases**
- **the Lenght/Surface ratio increases**
- **the dinamycs of thermal structures is faster**
- **the structures heat-up with less energy**
- **the structures suffer from less thermal and mechanical stresses**
- **the diffusion in a fluid is faster**
- **the evaporation is faster**
- **the mixture in microchannels is more difficult**
- **the power consumption is smaller**

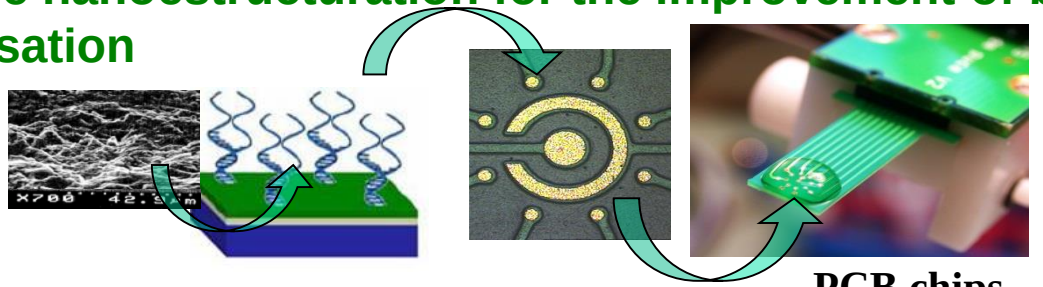






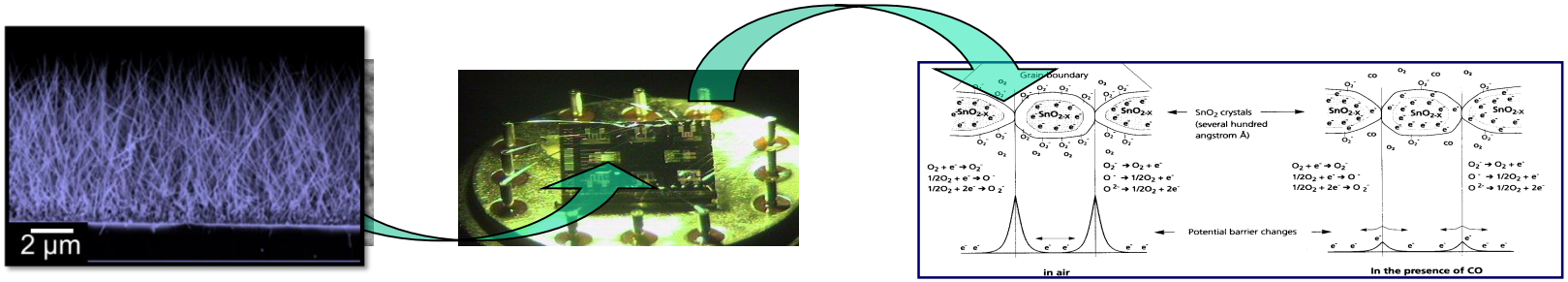
# "Active" Applications: Surface modification of sensors in the nano domain

**DNA: surface nanoestructuration for the improvement of biological material immobilisation**

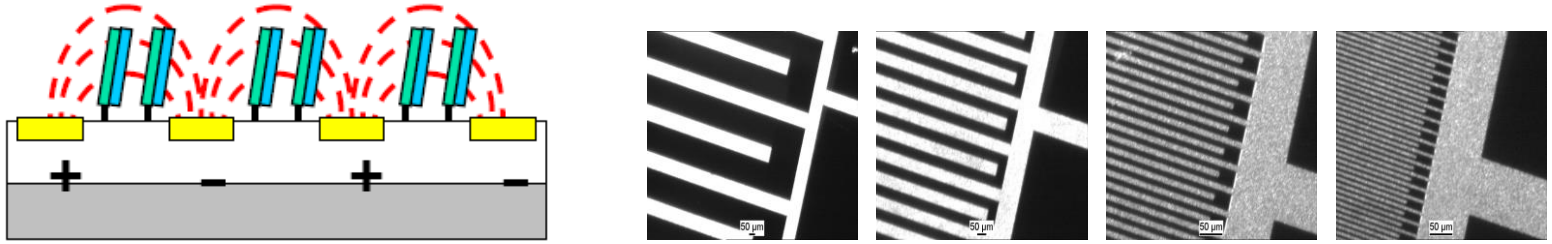


PCB chips

**Nanosized materials:** Increase odf sensitivity due to higher surface/volume ratio




**Nanoelectrodes for Inmunosensors:** Electric field confinement and Improved (spheric) diffusion from media to electrodes

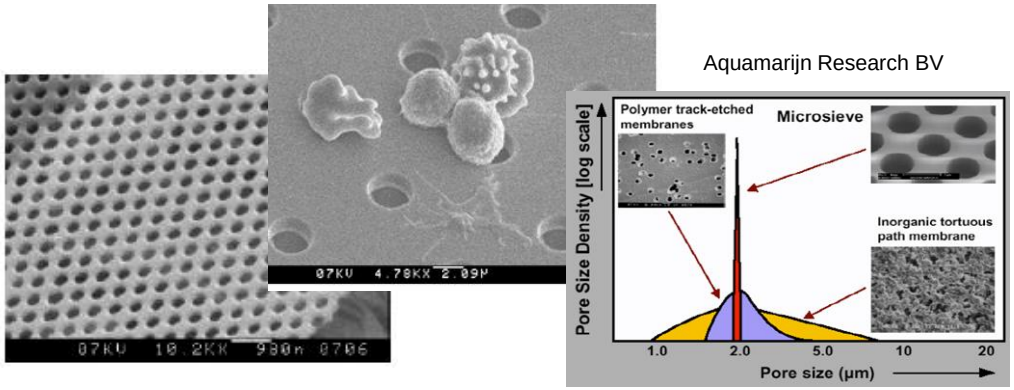


From GoodFood Partners

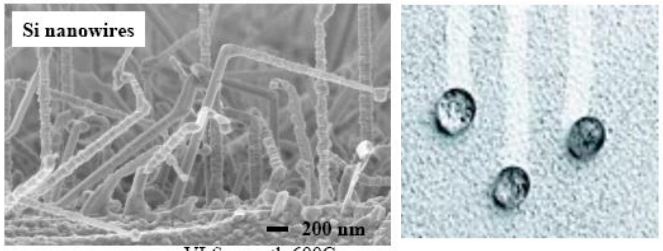
# “passive” nanoapplications in food

Separation, filtration…

Texture control, emulsification…

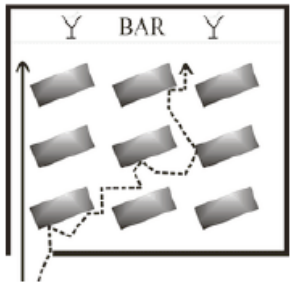



Surface to fluid interaction: surface coatings
(wetting, self cleaning, antifouling, microbial free…)

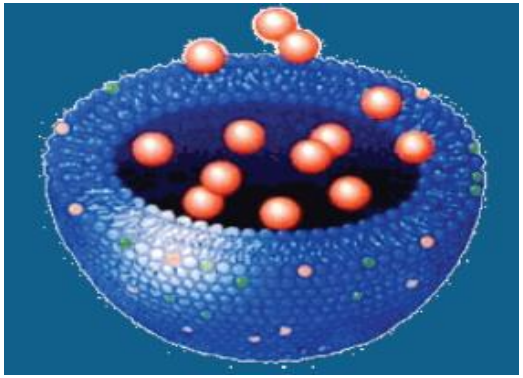


VLS growth 600C

Food packaging, barriers/scavenging
- Protective layers
- Anti Microbial Growth
- Anti Oxidation




Nutrient delivery, smell & flavour encapsulation…

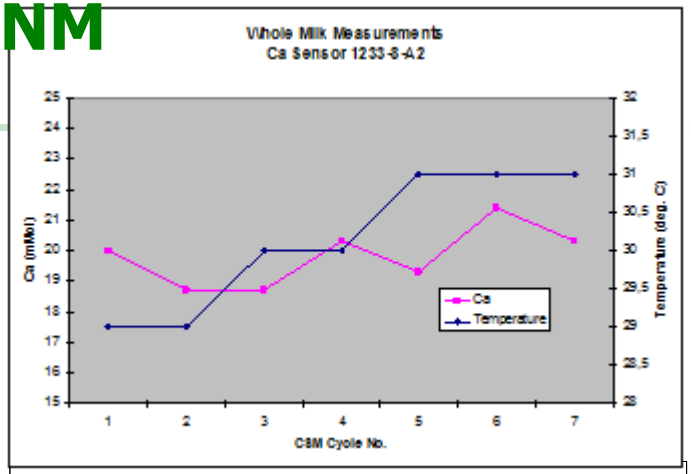


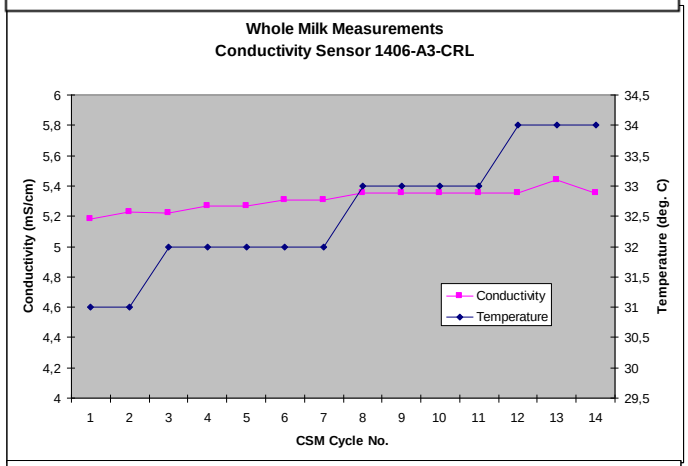
Courtesy of Aquamarine

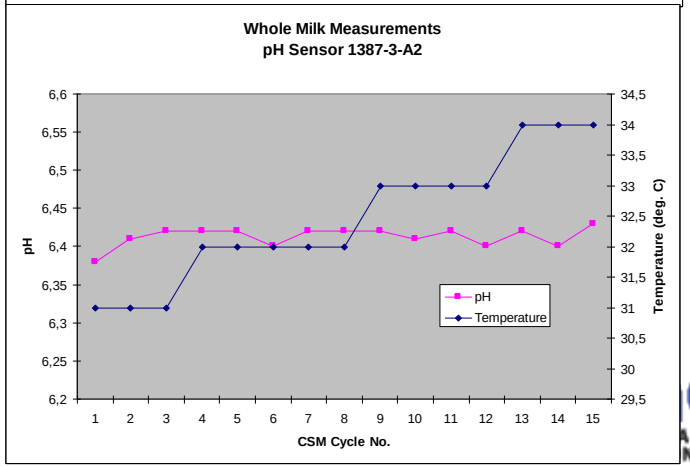
# Examples of In-line/On-line solutions

# CIP: Cleanning in Place: pH, Cond. CNM

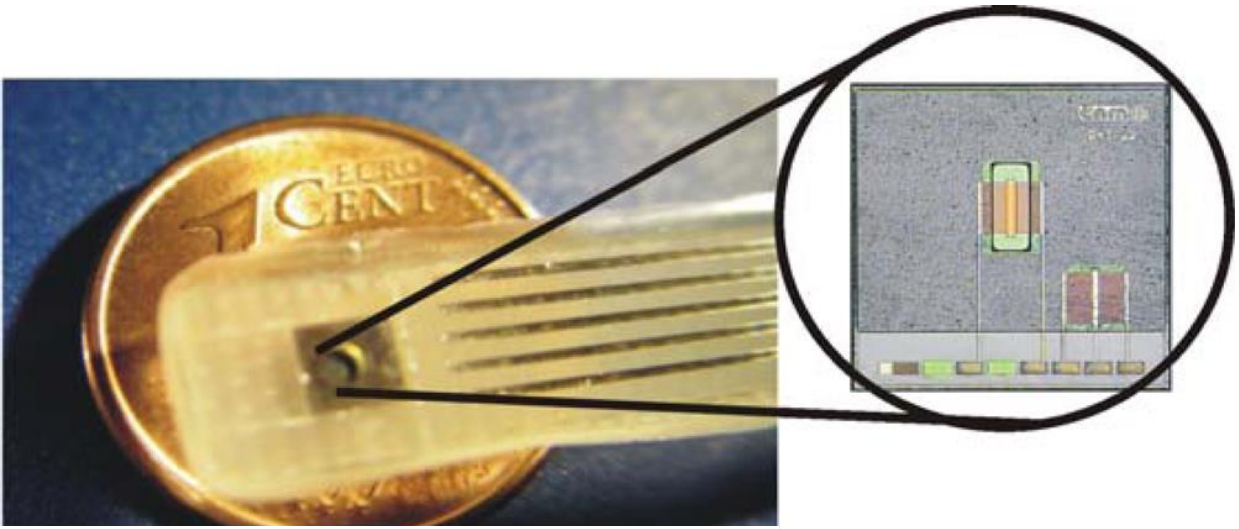
Clean in Place

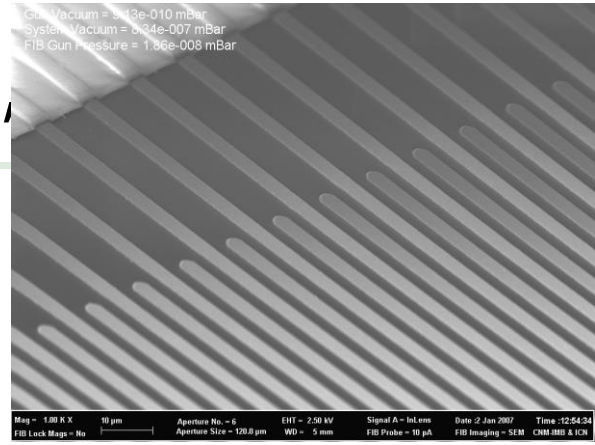


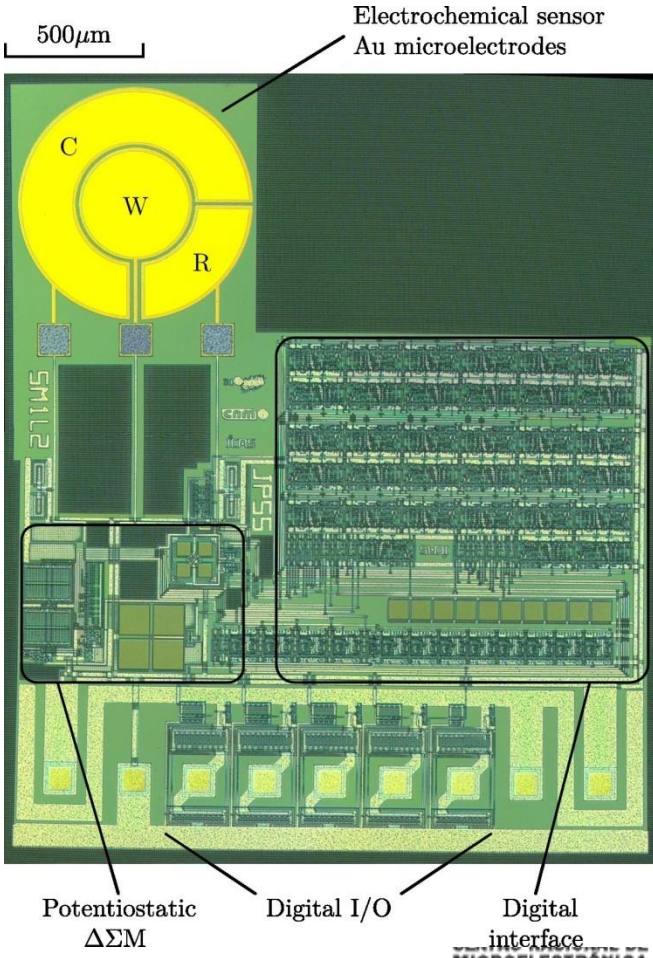
# ISFETs: pH, Ions, Temp. Conductance,





Multiparameter
Probe:
pH
Ions.
Conduct.
Temp.

Robust



# In-line water cleaning Monitoring


Benefits

- Real time water network monitoring
- In-line water contaminant identification
- Efficient control of water distribution

- Main features

- Measurement of the main
- disinfection species
- No interference with chloramines
- Chemical free operation
- Annual maintenance and
- calibration
- Easy field installation with direct
- insertion in pipe,
- Battery operated
- Real time telemetry data transmission

CENTRO NACIONAL DE MICROELECTRÓNICA

# Water quality control in food processing

## Chemical sensors probes

- Ingredient water purity
- Water use optimization
- Process efficiency
- Effective wastewater treatment

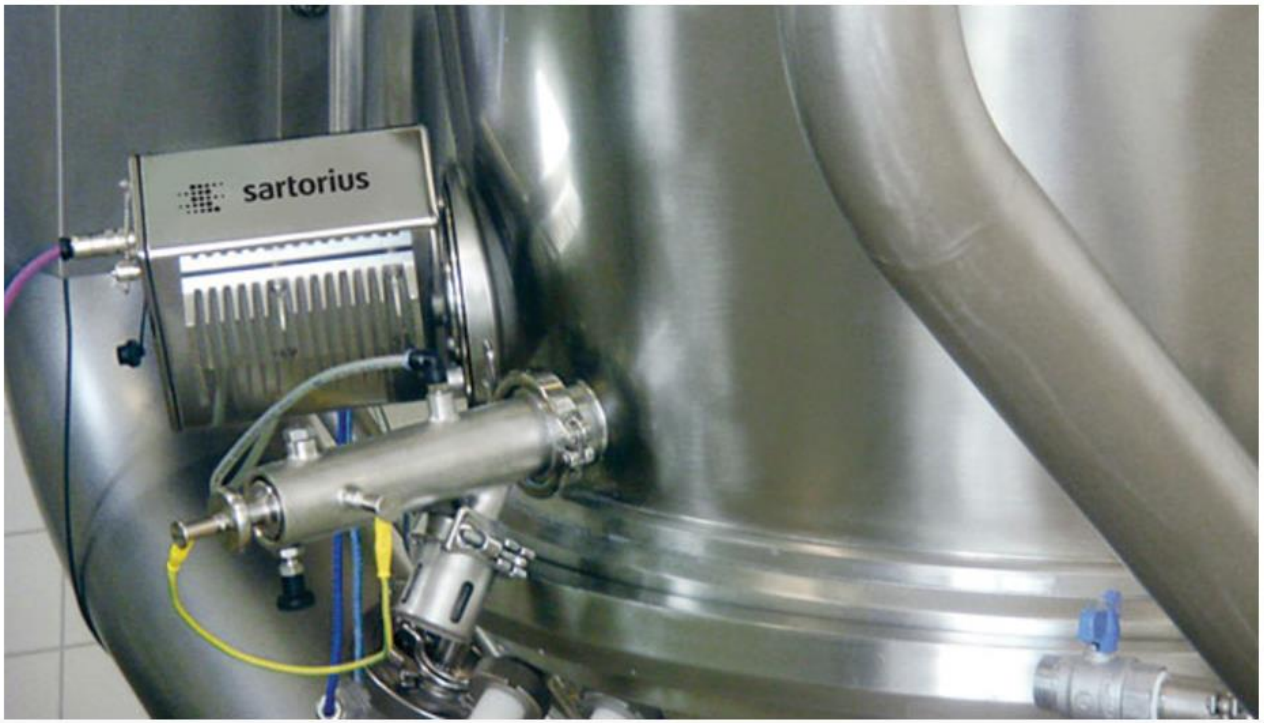
neosens
Pure Sensor Solutions

# NIR Spectroscopic System for milk monitoring

sartorius

## Inline monitoring aids in food safety and quality

What you don't measure could kill your brand.

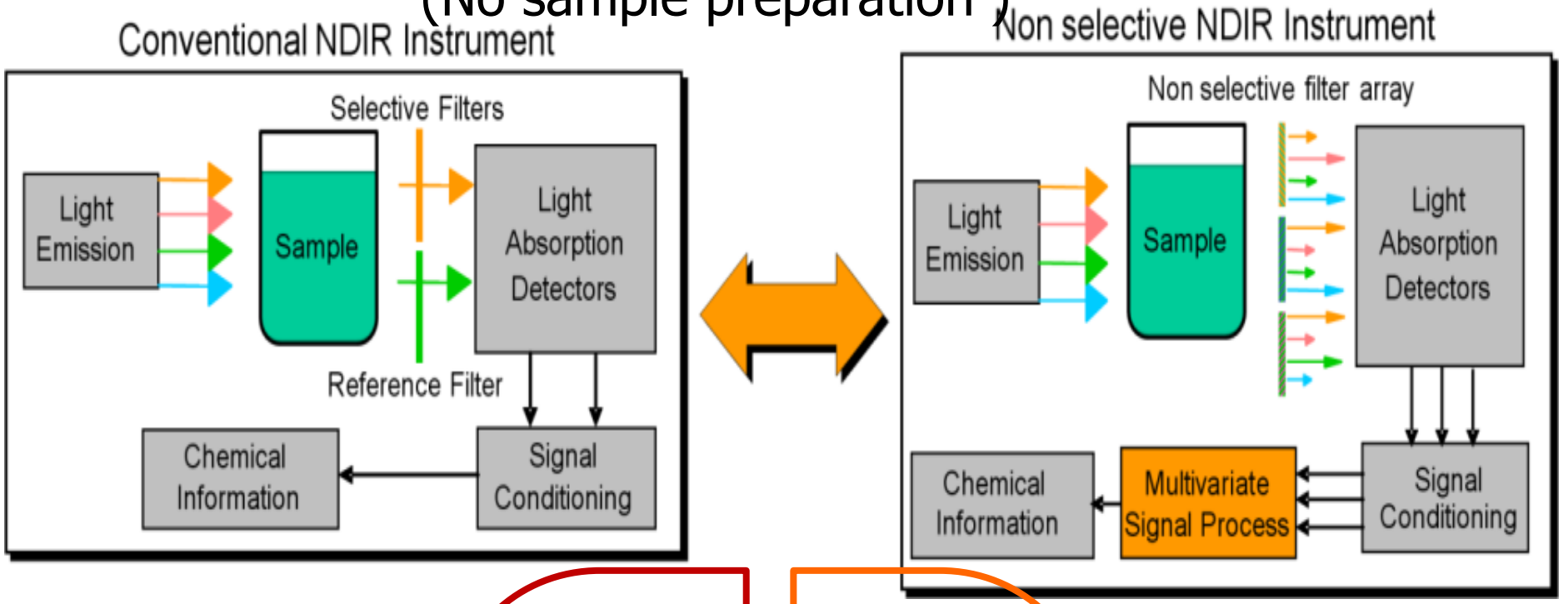



NIR spectroscopy and an imaging sensor make it possible for powdered milk process parameters—such as moisture, protein, fat and lactose—to be determined quickly and simultaneously using just one system, the Sartorius PMD500 NIR process analyzer. *Source: Sartorius.*

# MEMS NDIR Systems for Milk fat and Wine fermentation

## 'physical' interaction ex: Infrared absorption

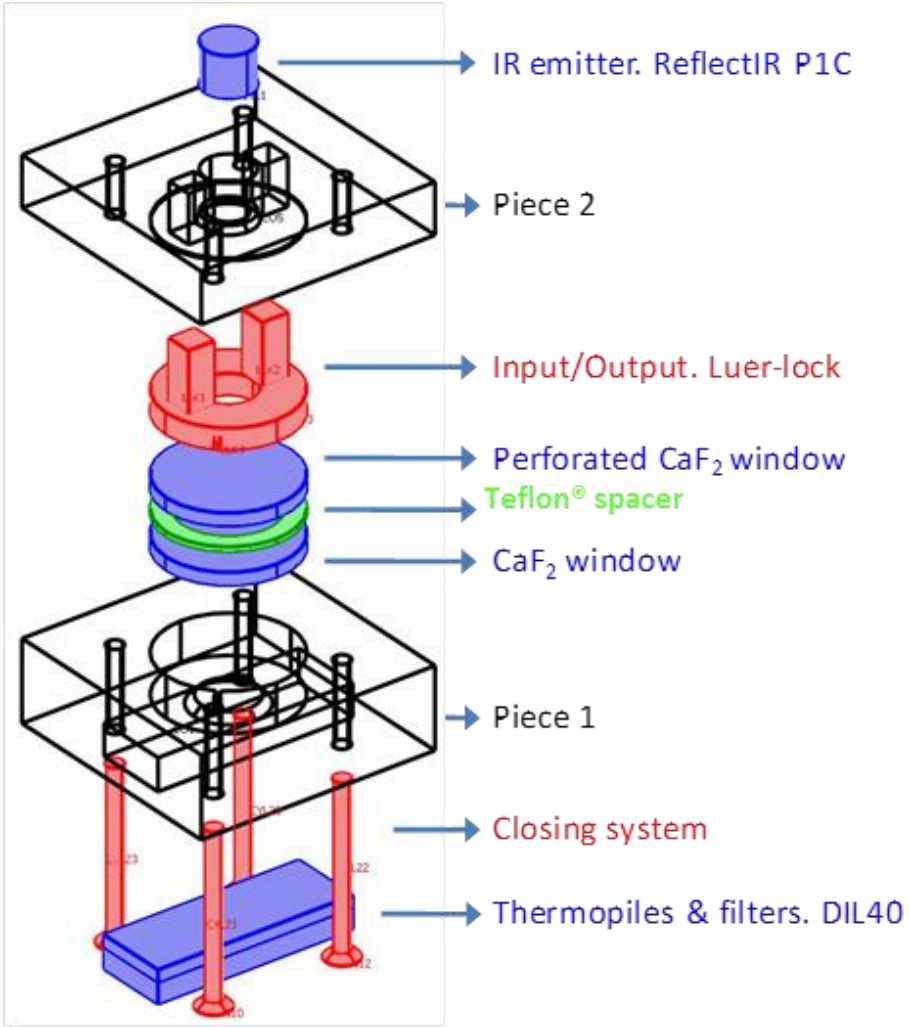
(No sample preparation )

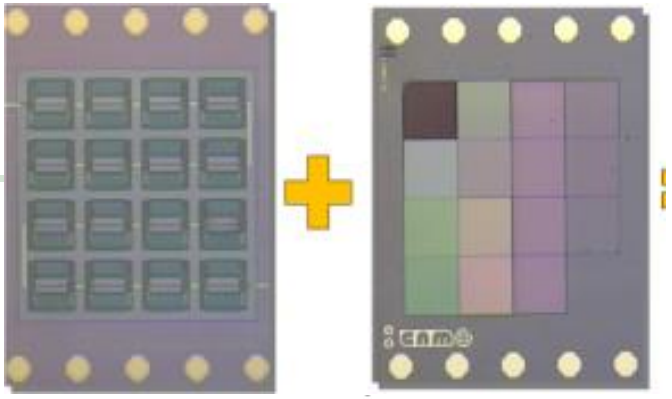


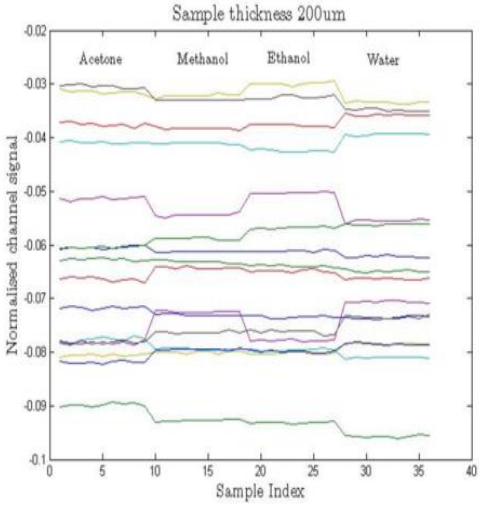

Each aroma/liquid
one filter
one signal

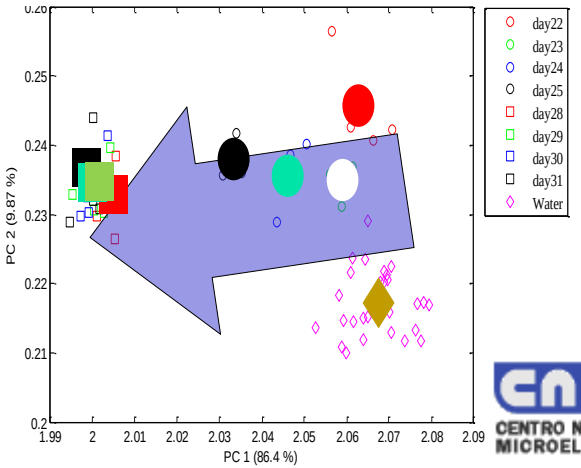
any vapour/liquid
one multi-filter
one fingerprint

# Micro NIR



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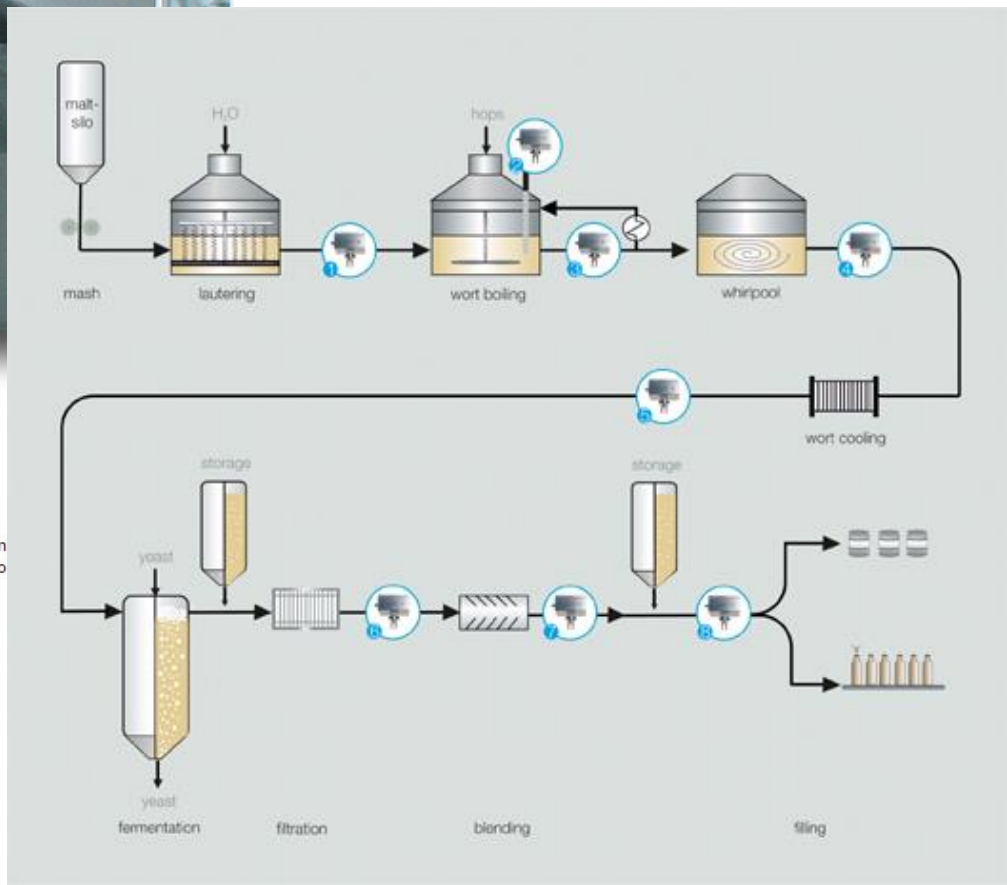
# In-line control in Breweries:

English ▼ Contact | Imprint | Login |

SensoTech
In liquids, we set the measure.

## Brewery

**LiquiSonic® Plato** is a high sophisticated inline analyzer for concentration and den
measurement of beer and wort in breweries. The system allows control and monito
concentrations at different points of the brewing process.



# In-line and Lab Concentration and viscosity

COBRIX multiparametric "on-line" Analyzer for beverages: Concetration, viscosity, CO2 density, temperature...

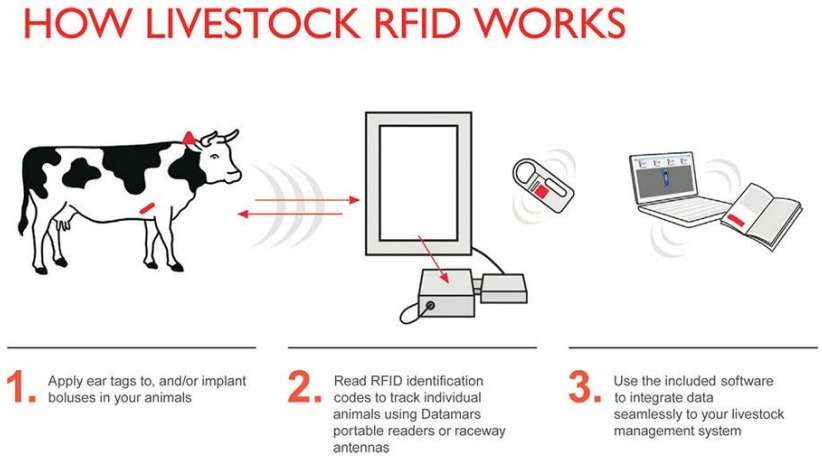
For beverages: the continuous, accurate and safe measurement of essential quality parameters such as °Brix, %Diet concentration, $CO_2$, alcohol, sugar inversion, extract, and more throughout your production process.



GoodFood Pomes

GoodFood peix

GoodFood Vi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# RFIDS + Sensors


Monitoring cold chain
of perishable products


Alvin Systems

KSW MICROTEC

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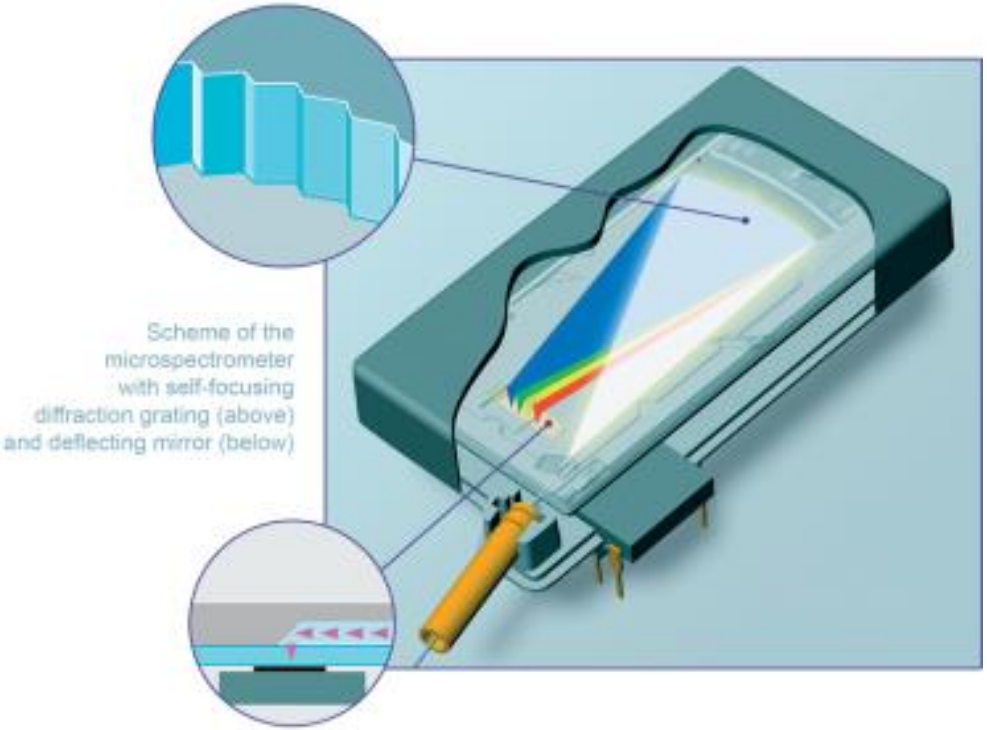
# Time/temperature indicators

# Quality control

Colour control with Microspectrometers




Insion GmBh



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# other on-line, at-line products


Quality control in wine, beer, fruit juices, milk,…

Determination of glucose, fructose, etanol, L-malic, L-lactic and gluconic acids,…

BIOFISH 700

Coordinator ACTIA

Biosensor para el análisis de
# Sulfito
# en Agua


BIOWINE 700

**Descripción ge**

Un biosensor es un
biológico con un trans
BIOLAN hace uso d
altamente específicas

Se trata de un Biosensor portátil y de bolsillo que a través de electrodos serigrafiados te permite controlar parámetros de interés como Ácido Málico y Glucosa, en la elaboración del vino en menos de 1 minuto.

interés

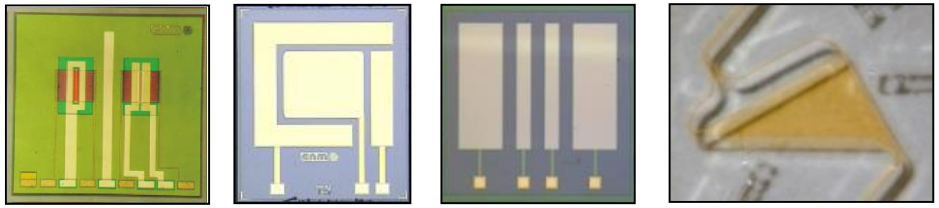
BIOWINE 700 ÁCIDO MÁLICO

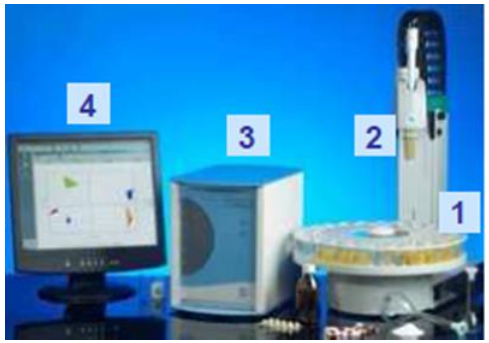
BIOWINE 700 GLUCOSA

# AlphaMOS: Electronic tongue system with CNM sensors

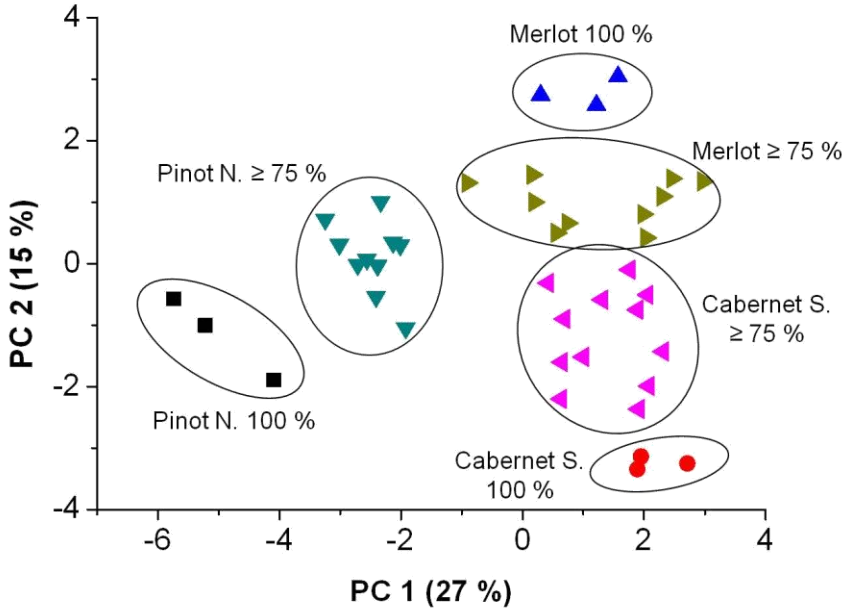
Analysis of food products such as wines, beverages and soups

**Multisensor system with different optical and electrochemical andchemometric transducers**

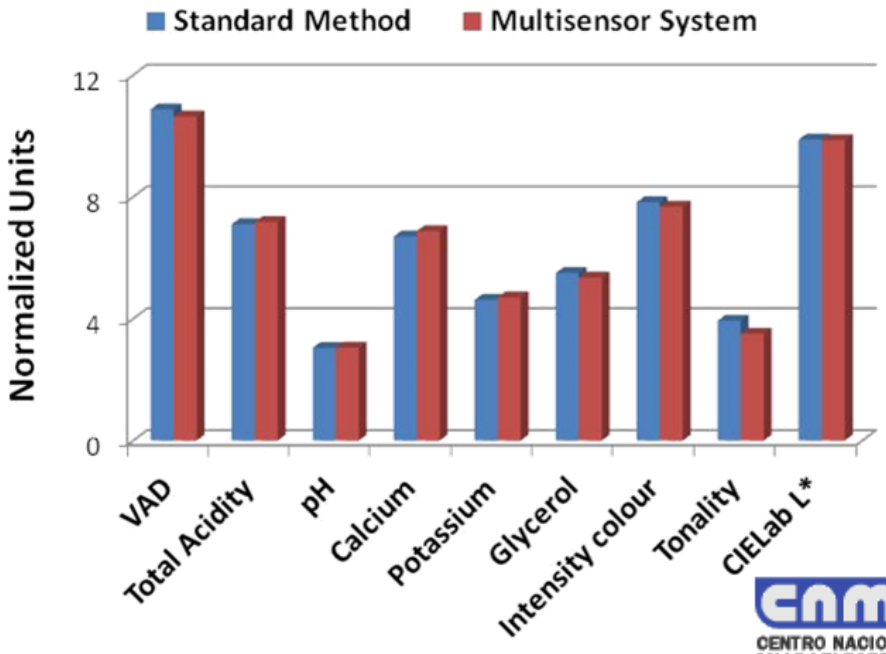





**Classification approach**




**Quantification approach**

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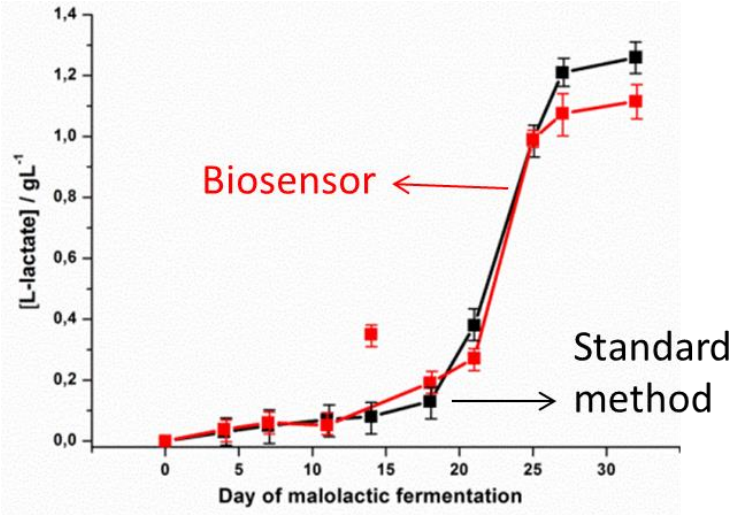
# Wine analysis: pH sensors and Biosensors: CNM

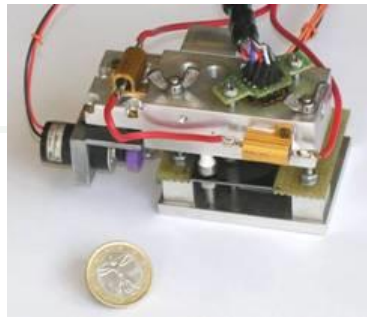
- **Acetic acid, $SO_2$:** Flow sensor approaches integrating diffusion membranes and pH detection (ISFET)
- **Lactic & malic acid:** Amperometric biosensors showing

Thin-film enzyme biosensors with polypyrrole membrane

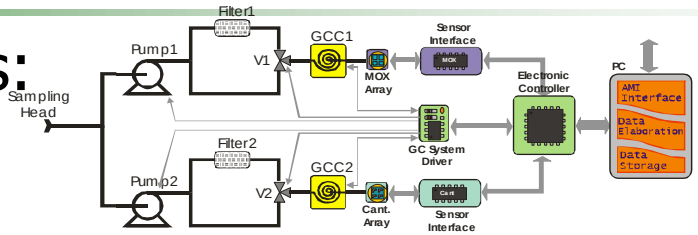


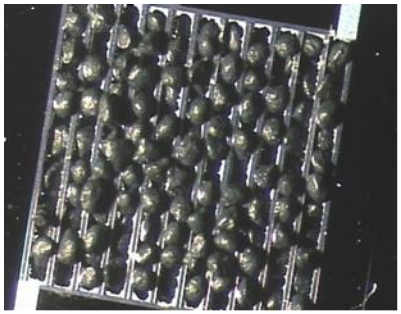

- Analytical performance compared with the standard analytical protocol
- Biosensors long lifetime over 45 days

# E- Nose: Fish, Fruits,… vapour sensors

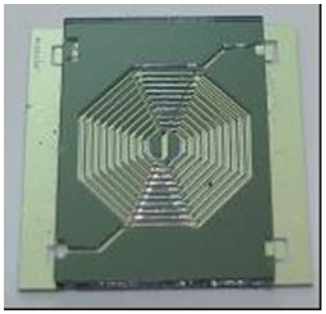


## Freshness:
DMA, TCA, NH3…

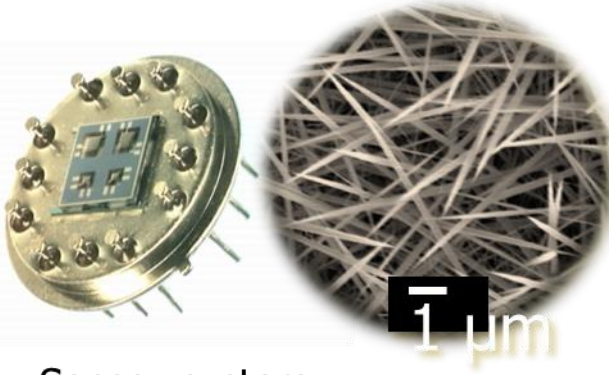


Micro preconcentrator

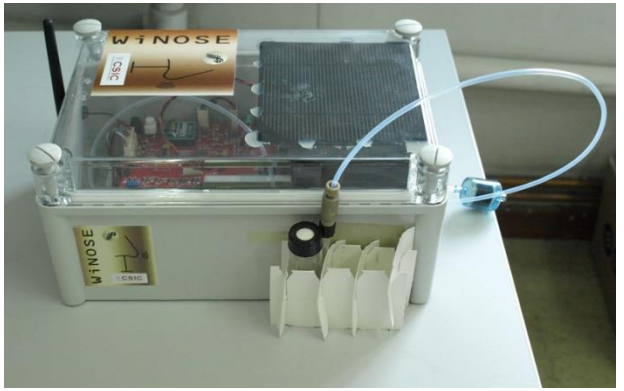


Chromatographic column




Sensor system

## Ripeness:
Ethilene




WINOSE. ITEFI CSIC

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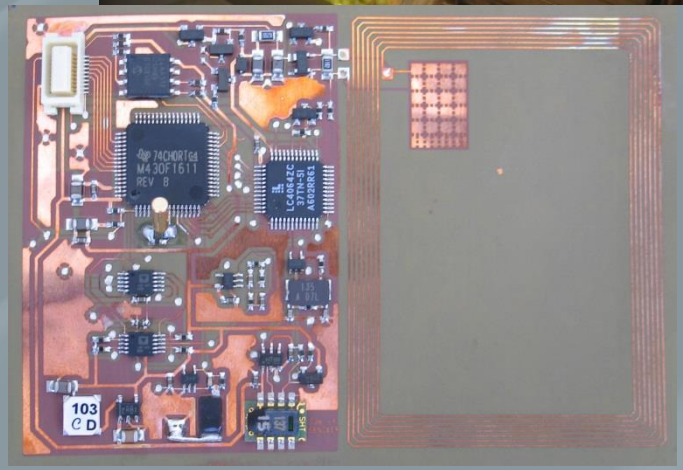
# RFID Systems for Logistics: False Alarms in Cargo Planes

- Objectives:
  - Sensor system with RFID communication
  - Tracking and tracing of goods
- Challenges:
  - Power consumption of sensors, especially gas sensors
  - Reliable integration and packaging into flexible substrates
  - Vapours: Ethilene,..

# Accelerometers and Vibration sensors for Machinery health, plant control

Hansford Sensors
Excellence in Vibration Monitoring

The food and drink processing sector uses a broad range of equipment in its production processes including mixers, centrifuges, pumps, motors, air compressors, ovens, fans and conveyors. In each case, equipment has to be maintained in optimum condition, requiring a proactive approach to maintenance and condition monitoring.

Vibration monitoring plays a key role, helping maintenance and plant engineers with early identification of component wear in bearings, rotating shafts, conveyors and other line equipment.

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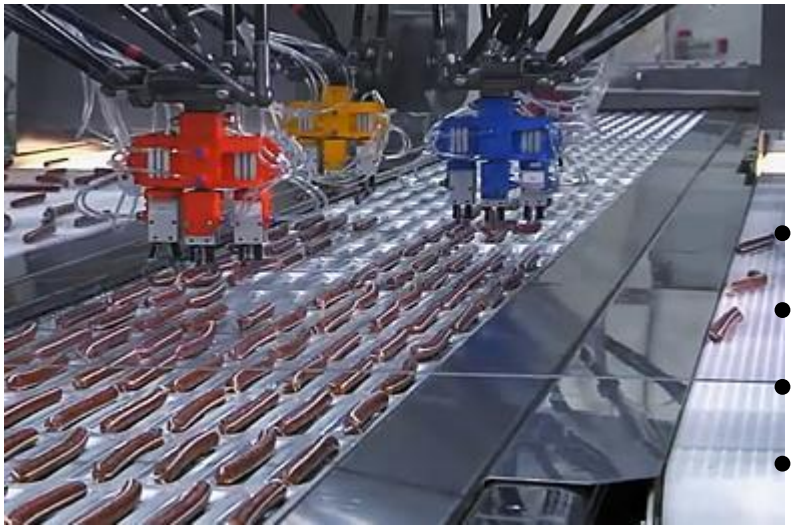
# Robots in Food: Sensing motion



- Packaging
- Picking
- Production
- Harvesting robots
- Exoskeletton for working with heavy loads

Abb

Omron


Hook assist

# Robots of the future: Drones

Automatic Supervision

Plant to plant actuation….

From T. Dobbs

# Examples: In situ control Harveters & Tractors

Millions: machines

**Mature sensors**

Engine (FT4) ~32 sensors
Cab ~12 sensors
Drivetrain and chassis ~15 sensors
Harvesting system ~40 sensors

Total ~100 sensors

**Emerging sensors**

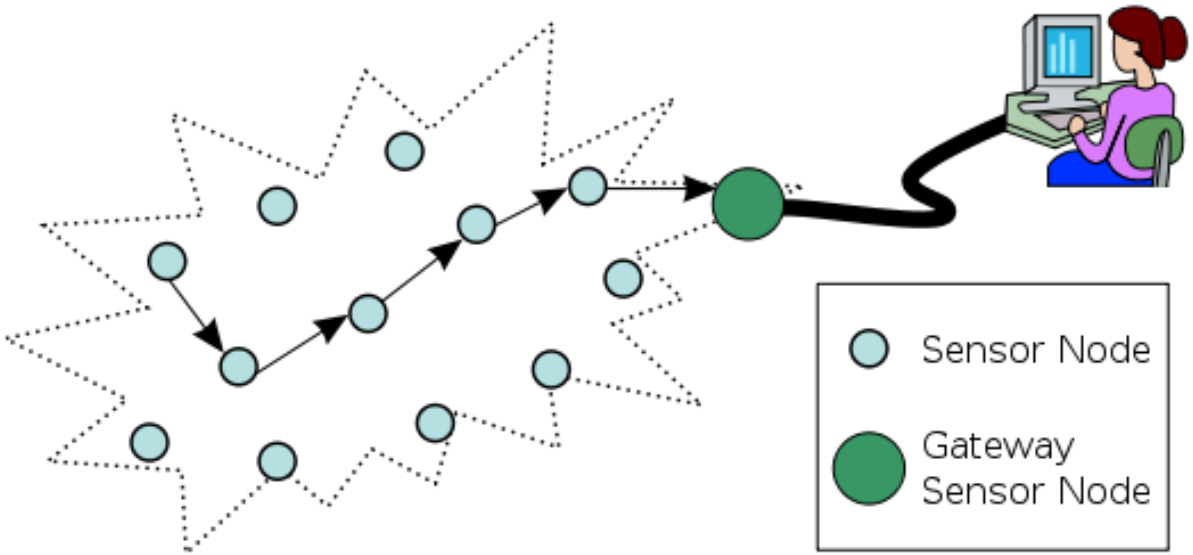
Improved mass flow/moisture
Grain loss/harvest quality
Constituent (protein)
Spout aiming
Header control

Knowledge-based sensing ~10 sensors

- pressure,
- aceleration
- temperature, tilt
- emissions, NoX, CO, CO2
- Turn speed,
- Ultrasounds
- Load, overload,

CSIC

# Ex : Wireless Sensor Networks for precision agriculture




- Energy
  - Solar
  - Bateries
  - Energy Harvesting

libellius

**Netsens, italia**

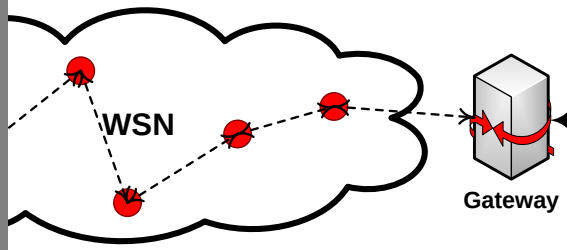
# Ejemplo: Agrisense, Vinesense Agricultura y Viticultura de Precisión



- Evalua condiciones de crecimiento de patógenos.
- Ayuda a realizar efetivamente tratamientos químicos
- Mide datos medioambientales directamente en la viña (temperatura aire/humedad relativa, humedad de las hojas, lluvia acumulada).
- Interfase vía desktop, notebook, smart phone o tablet.

# Precision Farming
# System Arquitecture

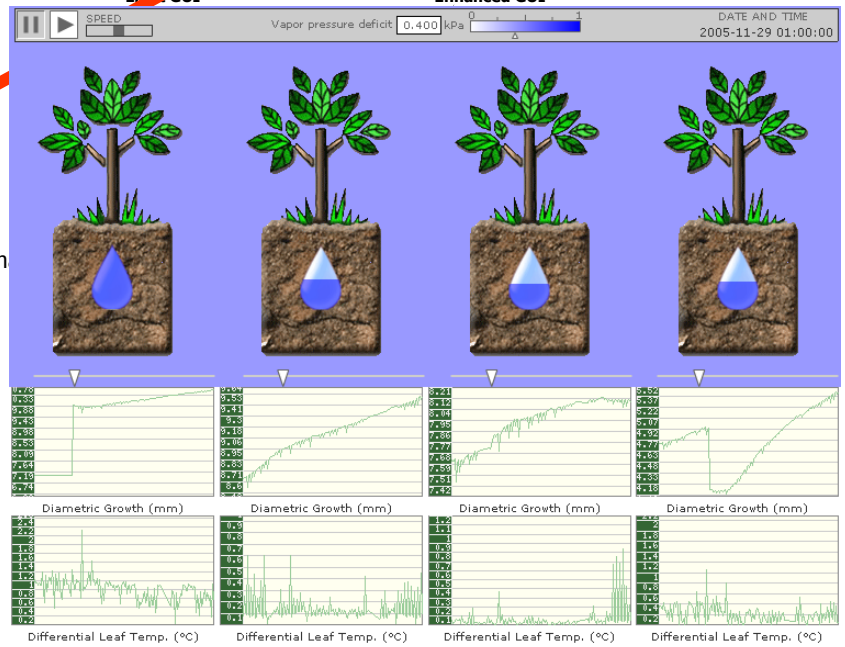
**System Specifications**




CSIA

Synapsis

Enhanced GUI



# Conclusions

- **Increasing concern on Food Safety and Quality**.
- **Real need of new diagnostic systems** for safety and multisensor solutions for quality and traceability.
- Many of the **current available solutions in the market do not rely on electronic sensors and Microsystems**.
- **(bio)-MST are interesting** enabling technologies **as far as they improve performances** and increase applications:
  - Portable, Faster, Cost reduction, Higher sensitivities and selectivities
- **Nanotechnologies are interesting** enabling technologies **as far as they furter improve sensor/system specifications**.

**… but we have to convince more the Food Industry on the goodness of MNT/MEMS based sensing systems.**

**In line/on-line is an example…..**

Thank you for your attention !!!!.

carles.cane@cnm.es

Tel +34 93 594 77 00

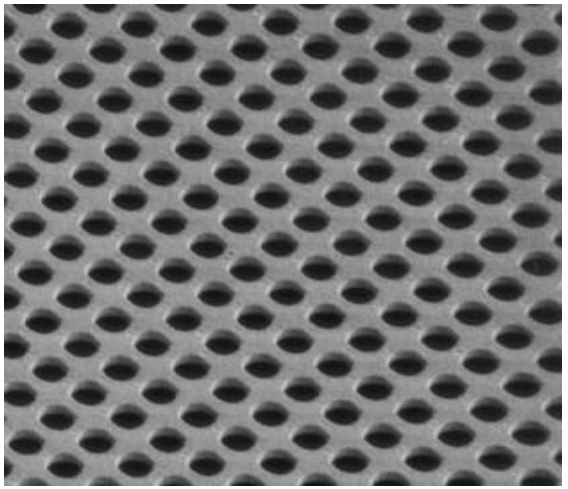
# Other Commercial Examples for Different Applications

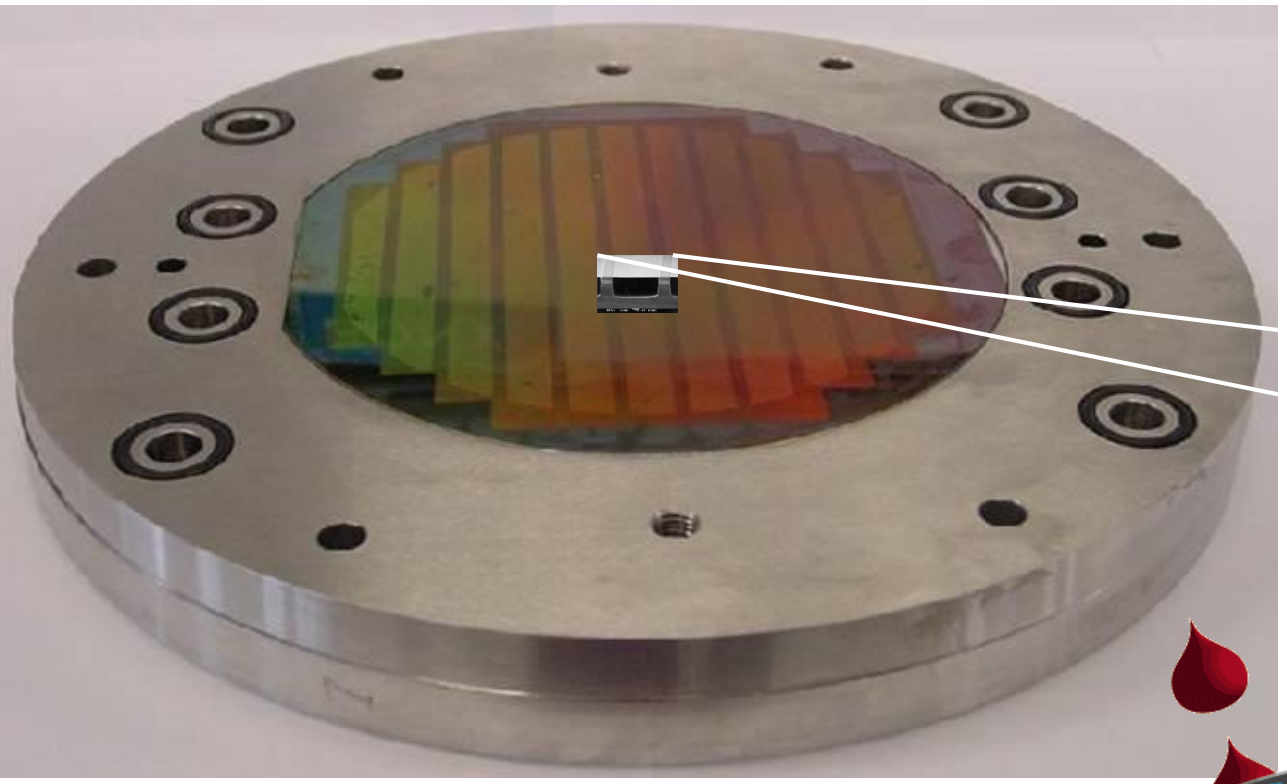
# Packaging: Ripeness

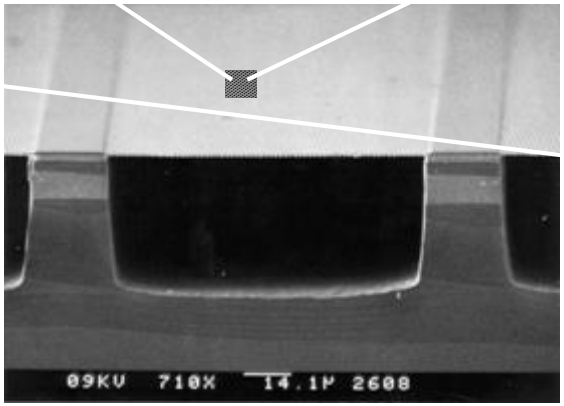


www.ripesense.com

# Separation / Fractionation





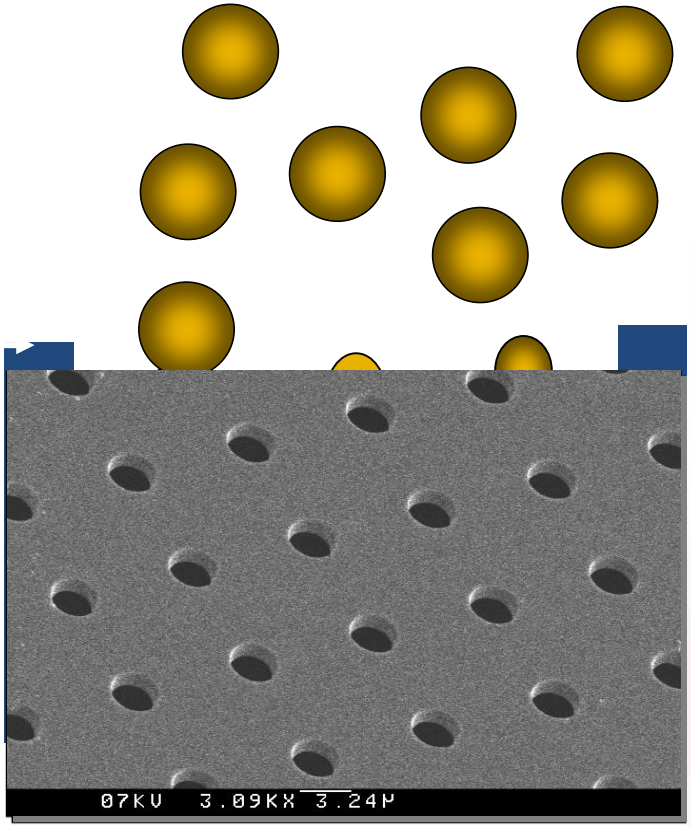



Cees van Rijn – Aquamarijn

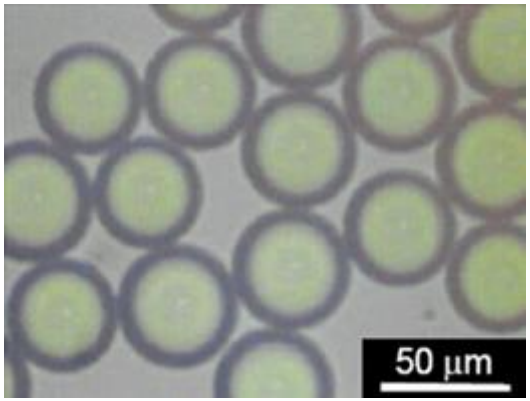
FOOD MICRO SYSTEMS

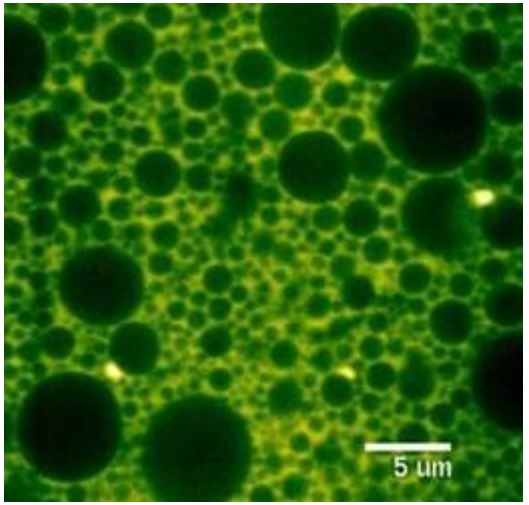
Coordinator ACTIA

# Membrane emulsification



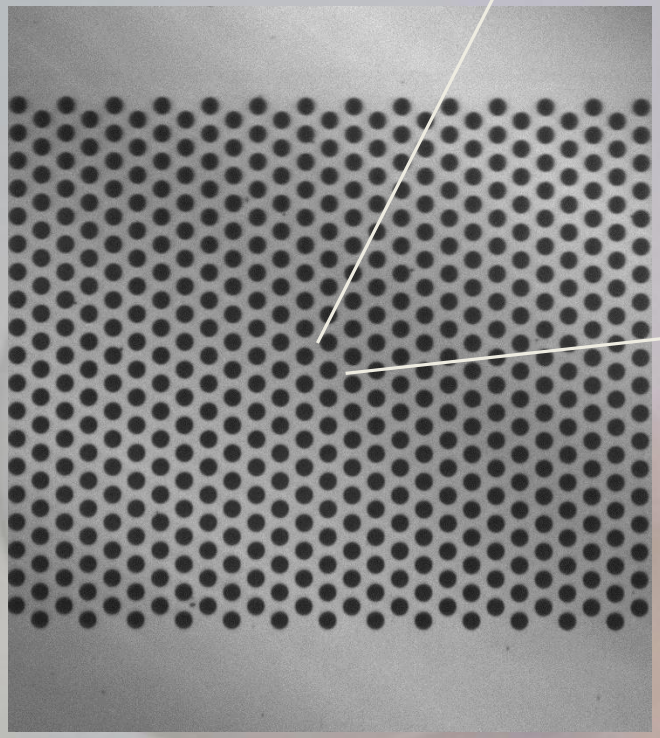





nanomi
emulsification systems

# Pathogen detection




FOOD MICRO SYSTEMS