FUTURE RFID

SENSORS AND RADIOS FOR NEW LOGISTIC APPLICATIONS

Harmke de Groot- Senior Director Perceptive Systems for the Internet of Things

Holst Centre
Open Innovation by IMEC and TNO

imec

The Internet-of-Things

Networks of low-cost sensors and actuators for data collection, monitoring, decision making, and process optimization" *Source: McKinsey, May 2013*

CISCO

$14.4 Trillion

Total value created by the Internet-of-Everything from 2013 to 2022

Connected Health
$106 Billion

Smart Buildings
$349 Billion

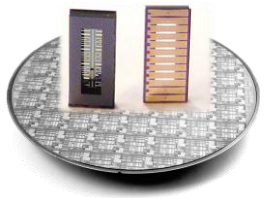
Smart Grid
$757 Billion

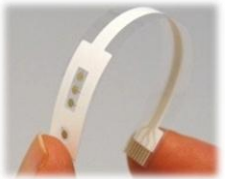
Smart Factories
$1.95 Trillion

INTEGRATED APPROACH: HELPING OUR CUSTOMERS SHORTEN THEIR TIME-TO-MARKET

FROM TECHNOLOGY BUILDING BLOCKS TO FULL APPLICATION VALIDATION

Applications | Data Analytics | Systems & Networking | Circuits & Sensors | Technology



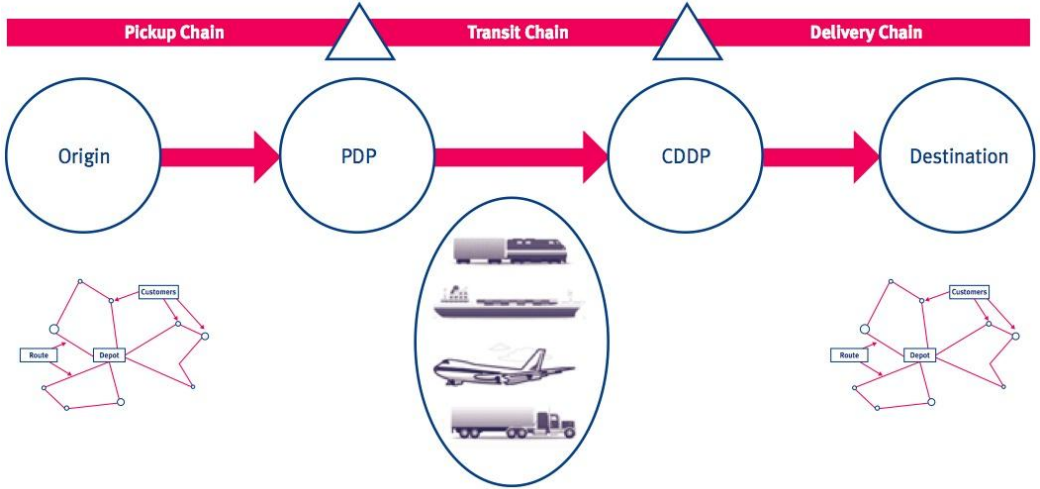


→ using customer components and unique Holst centre/ imec components ←

SMART LOGISTICS

imec

LOGISTIC LANDSCAPE



	Transit Chain	Pickup/Delivery Chain
Load	Full Truck Load (FTL)	Less than Truck Load (LTL)
Transportation modes	Multiple modes: road, rail, air and sea	Single mode: mainly road
Transit time	Long (at least a day)	Short (within the day)
Handling unit	Containers and pallets	Parcels and (mixed) pallets
Stops	Direct shipments	Multiple stops (routing)

Source: Smart Logistics Lab TU/e

LOGISTIC LANDSCAPE

- Each part of the chain has very unique requirements
  - For some actors in the chain the pick-up and delivery date is important. For others it may be important to know if temperature was elevated when e.g. an airplane was waiting on the tarmac.
  - Some actors prefer batch information, others per item.
- Not all actors in the chain want other actors to have access to the same information
  - Supermarkets may want to know if a batch of produce can still be sold, but may not want costumers to know which batch is better in fear of being left with produce, or have to sell the produce at a lower price.
- The beneficiary of more detailed information is often not willing to pay the price,
  - e.g. a customer of milk will often prefer the cheaper option with less accurate information over paying 25 cents per package extra for more detailed information
- No one solution fits all

APPLICATION AREA

PORT & MARINE CARGO
IMPROVED THROUGHPUT

- Container Management
- Electronic Seals
- Drayage Truck Tracking
- Handling Equipment Tracking

Automotive & Auto Logistics

Real-Time Visibility

- Vehicle Tracking
- Parts Replenishment
- Rack Tracking
- Just-In-Time Manufacturing

Industrial

Automated Asset Tracking

- Yard Management
- Multisite Tracking
- Automated Gates
- Dock Door Management

Manufacturing

Optimized Lean

- Forklift Tracking
- Asst Tracking
- Workflow Optimization
- Just in Sequence

Source: IEEE 802.15-09-0403-00-004f

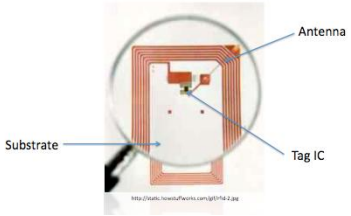
No one solution fits all

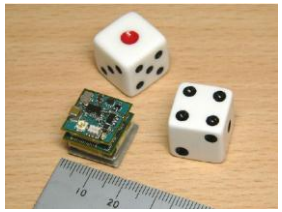
In the market multiple standards/solutions are offered

DIFFERENT RFID TAGS

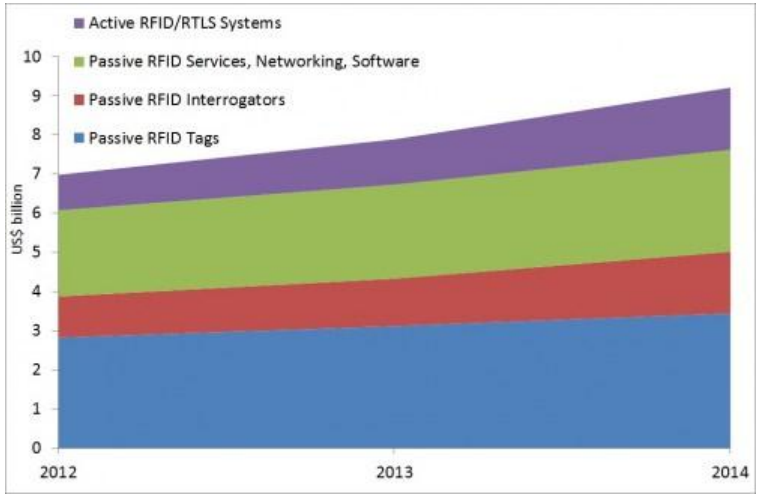
Radio Frequency Identification (RFID)

- Passive Tags
  - send information to an interrogator using backscatter
  - block memory,
  - optional password-protected access control,
  - optional user memory.
- Semi-Passive Tags
  - A power source that may supply power to the tag and/or to its sensors,
  - send information to an interrogator using backscatter.
- Active Tags
  - A power source,
  - communications via an autonomous transmitter.





CURRENT MARKET



Source: IDTechEx

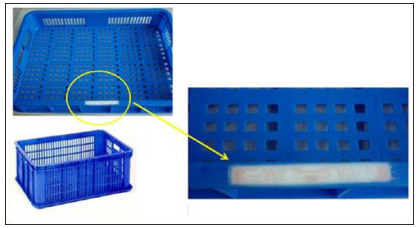
In 2008 IDTechEx projected 18 Billion USD in 2013, double the current number
Now the market is projected at 23.4 Billion USD in 2020 by IDTechEx

ON THE MARKET RIGHT NOW

Batch tracking (iGPS):
-4 passive RFID in each corner
Security:
-GPS unit that can access the Cellular network
-Pallet is rented for use
Source: 5 Mar 2012, RFID Journal

Batch tracking (Ctrack):
-Active RFID attached to batch of goods
Connects to hub that transmits GPS
and accelerometer information
Source: 20 Jan 2014, RFID Journal

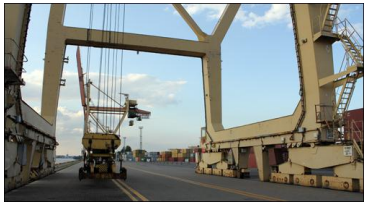
Batch tracking (ELA Innovation):
-Active RFID attached to batch of goods
Connects to hub that transmits GPS
and sensor information, targeting the cold chain
Source: 17 Jan 2014, RFID Journal



Batch tracking in facility (EPC Solutions Taiwan):
- RFID attached to fruit crate
- Active RFID tags at cooling units transmit temperature data to backend

Source: 9 Act 2013, RFID Journal

ON THE MARKET RIGHT NOW



Container tracking (Autepra):
- Passive RFID tag per container
- Track container when handling in port

Source: 12 Aug 2013, RFID Journal

Reefer container tracking (Identec Solutions):
- Active RFID tag per container; 250-500m distance; control freezer settings
- Track conditions within container once per 14 minutes

Source: 01 Oct 2013, RFID Journal

Unit temp "tracking" (ATI):
- Label added to batch, indicates if temperature extremes are breached
- Self activates
- Accuracy +/- 1 °C

Source: http://www.americanthermal.com/

Batch tracking (ATI):
-Temperature data logger
-3 years battery life
-Accuracy +/- 0.5 °C
-Logs once per 30 to 240 seconds

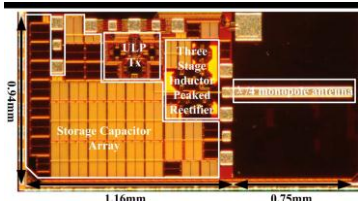
Source: http://www.americanthermal.com/

Non wireless alternatives

RELATED RESEARCH FROM THE SPEAKER'S COMPANIES

Smart-Blister,
Holst-Centre

Smart-Labels,
Pasteur project with NXP



Premiss project with TUe,
Antenna on chip 71GHz
Passive temperature sensor

TRENDS ON SMART LOGISTICS

- Container & Batch tracking is battery operated
  - Here e.g.: RFID, Cellular, GPS, WiFi, and RTLS is combined
- Tracking information for the end costumer is becoming more important
- Sorting with wireless is done on a batch and container level
- For Unit & Item tracking passive technology is used
  - Price of barcode is often too low for wireless to compete; bar code price is order of $0.01, RFID order of $0.10
  - Only added value for high margin products
  - Active technology is used for high margin products that require sensor information

PERSPECTIVE

- More solutions enter the market targeting very specific applications. Often these solution are on a batch or container level.
- Depending on the application both battery powered and passive tags are available
  - Sometimes Passive RFID is combined with battery powered sensors.
  - Systems currently on the market often employ a hub which can support other standards for data offloading while talking to passive RFID tags during transport
- Price is often the main bottleneck. Passive RFID tags cost 10 cents. More advanced solutions cost between 10-100 Euros. Contrastingly, a barcode costs only 0.1 cents.
- Some applications require proximity for security, while other require long distance:
  - Container tracking (+/- 500 meter)

OVERVIEW

Size	Distance	Specifics	Possible Improvements
Container tracking	250-500m	Battery powered Bi directional	Link distance, more functionality
Batch tracking	<10m	Battery powered, often combined with GPS/GSM unit, data loggers, and sensors	Link distance, integration, cost, more functionality
Unit tracking	<2m	Passive or active RFID, often no battery and no sensors, For expensive medicine there are data loggers	Integration, wireless power transfer, security, cost, more functionality
Item tracking	<1m	Passive RFID	Integration, sensors for expensive items, wireless power transfer, range, ***mainly cost is too high compared to barcode***

THREE RESEARCH CHALLENGES

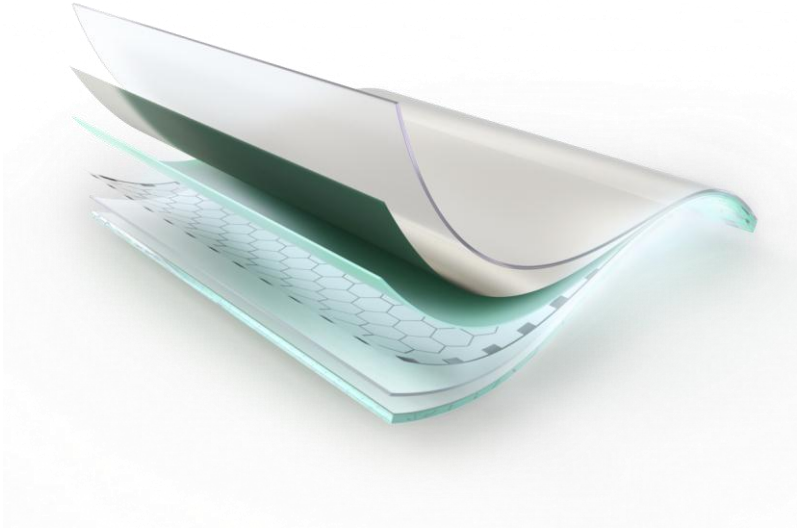
- Main challenge at short distances is currently in the cost of tags of both passive and active RFID
  - Passive RFID tag:
    - Antenna 3 cents, chip 3 cents and assembly 3 cents.
    - Possible directions:
      - RFID with integrated antenna on IC
      - Fully printed RFID
    - Component reduction reduces cost
- First challenge: *reducing cost of tag*
- Most tags currently only track temperature and position, could track more, for example with ion sensors
- Second challenge: *increasing functionality by adding sensors*
- Third challenge: *increase lifetime of active tags (or sensors)*

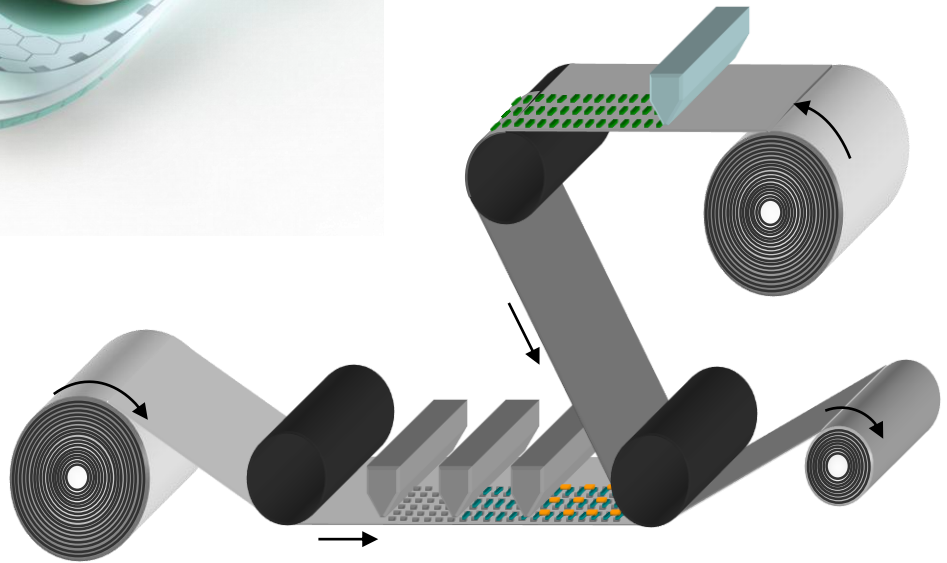
FLEXIBLE ELECTRONICS

FOR CHEAPER RFID TAGS

imec

Flexible Electronics: rationale





Large area printing

Roll-to-roll pilot tools

ORGANIC ELECTRONICS

Limited performance:

- Charge carrier mobility + transistor geometries ➔ transconductance
- Parameter spread

Is well-placed when applications demand:

- Large area
- Mechanical flexibility
- Low cost/area
- … at only moderate performance

Possible applications:

- Large area flexible displays
- Distributed (sensor) electronics
- Low-cost electronic tags
- …

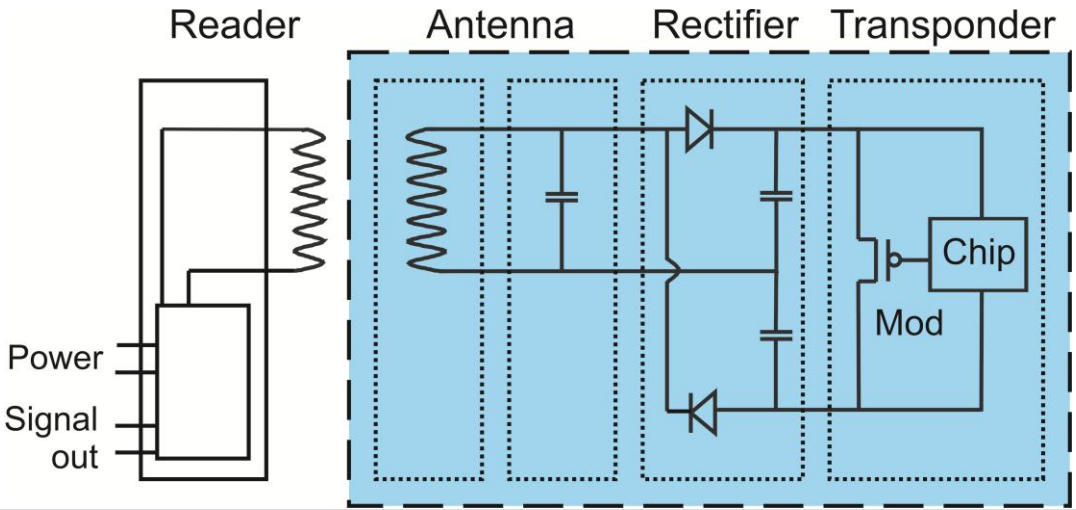
13.56 MHZ ORGANIC RFID TAG

Building blocks:

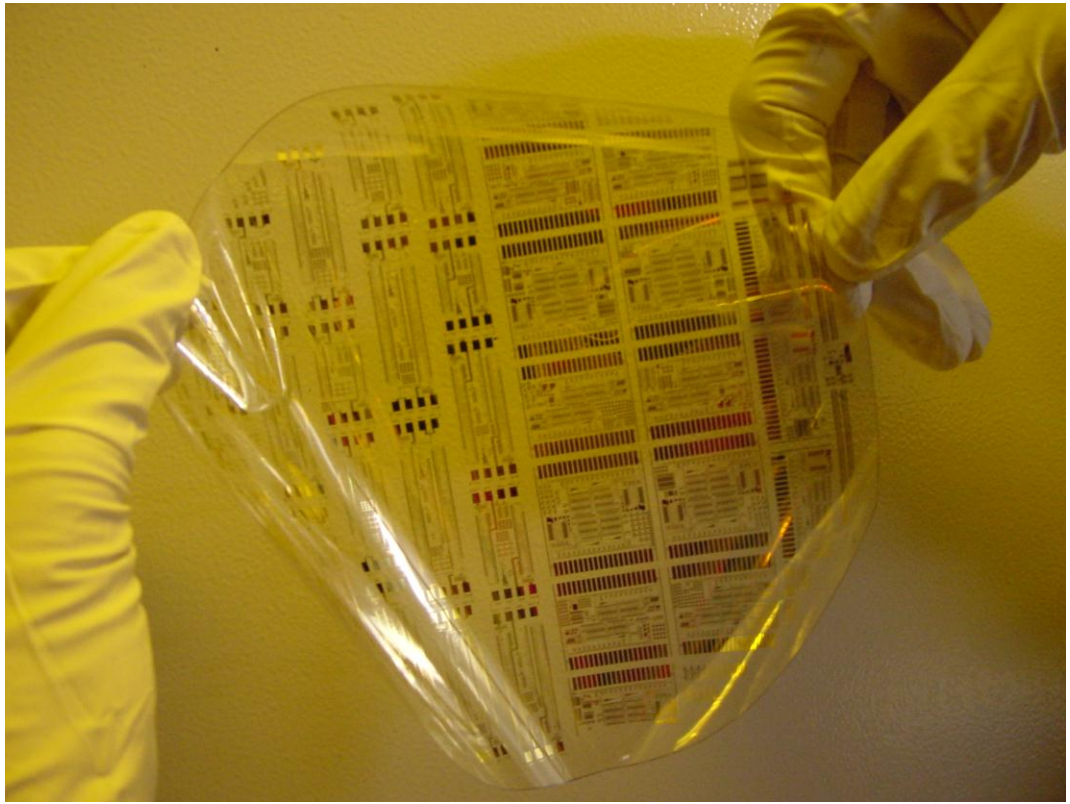
Antenna

Rectifier

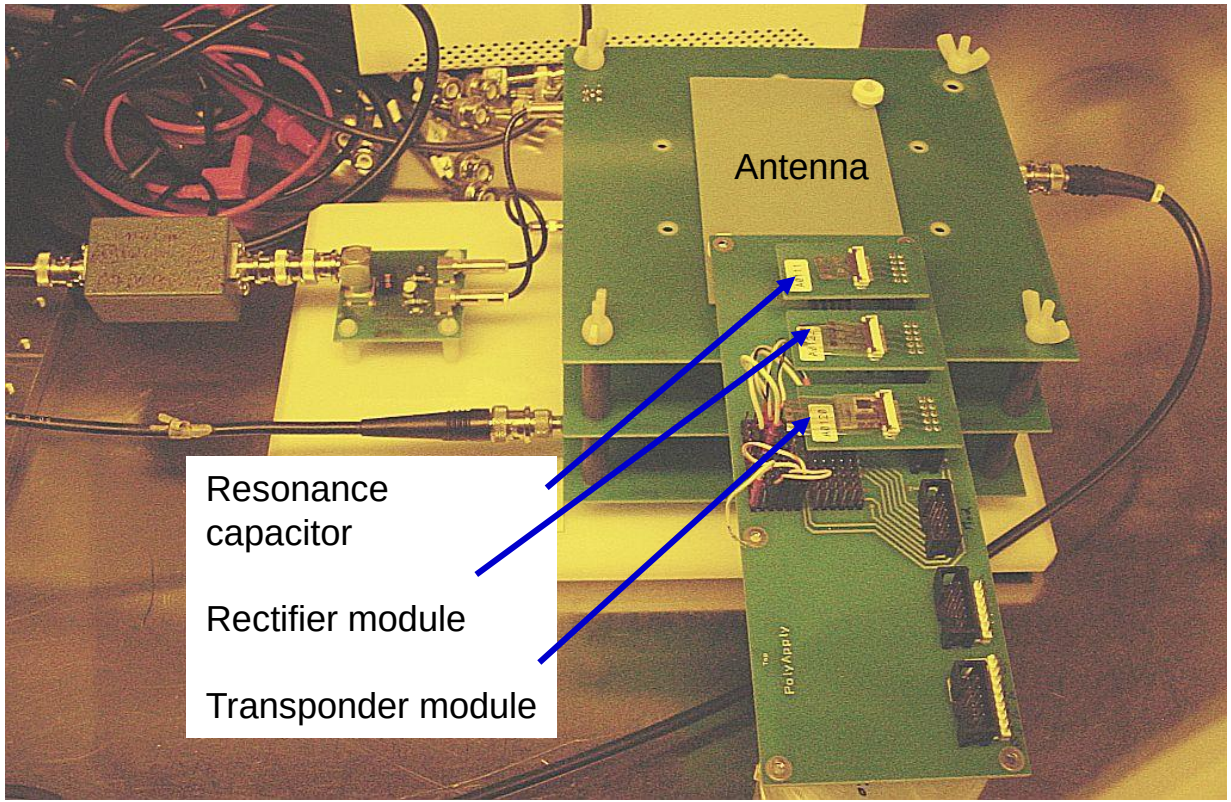
Bit sequencer and load modulator



6” FLEXIBLE WAFER

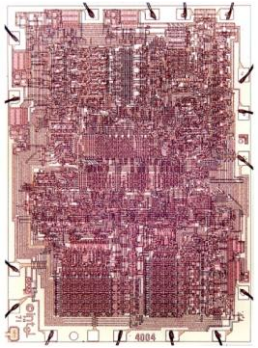


13.56 MHZ ORGANIC RFID TAG



FLEXIBLE TFT TECHNOLOGY

Intel 4004



Si IC		TFT IC
~100 µm	Thickness	< 25µm
-	Flexible	+
xx nm	Channel length	µm
+	Performance	-
-	Cost/area	+

TFT CPU

K. Myny et al., ISSCC 2011

Applications

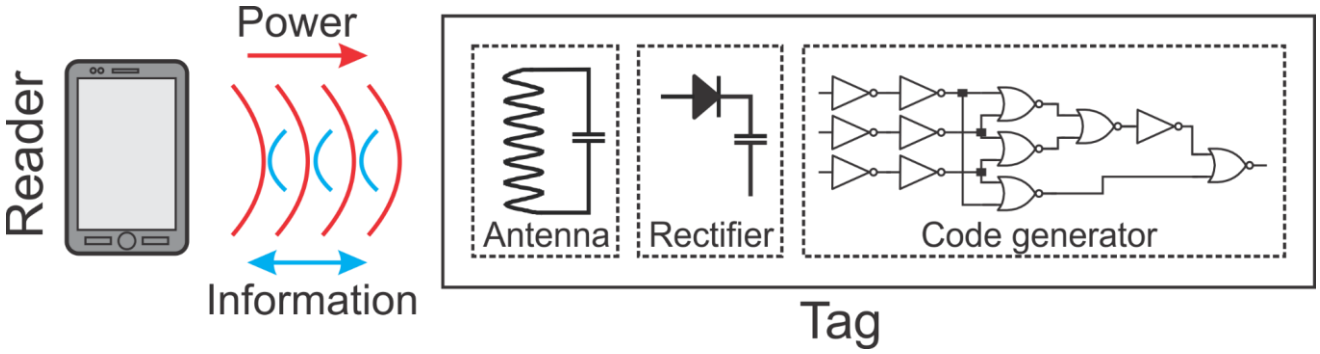
- Item-level RFID
- Smart packaging
- Brand protection
- Electronic paper

NEAR FIELD COMMUNICATION

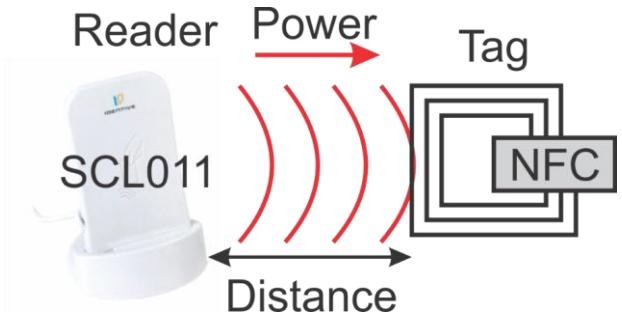
Short range wireless technology (few cms)

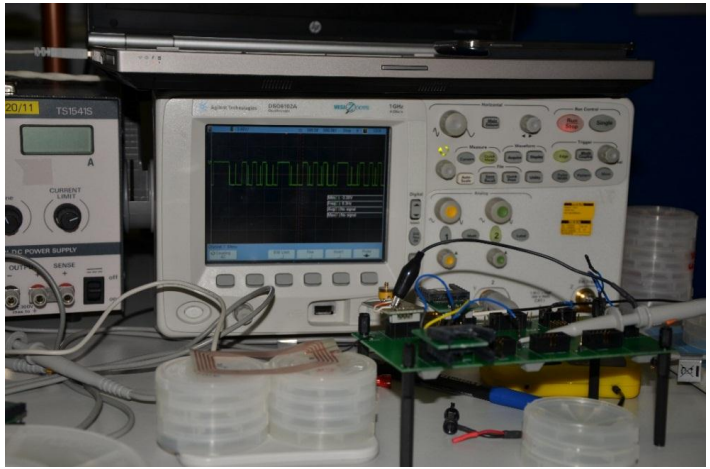
Base carrier frequency 13.56MHz

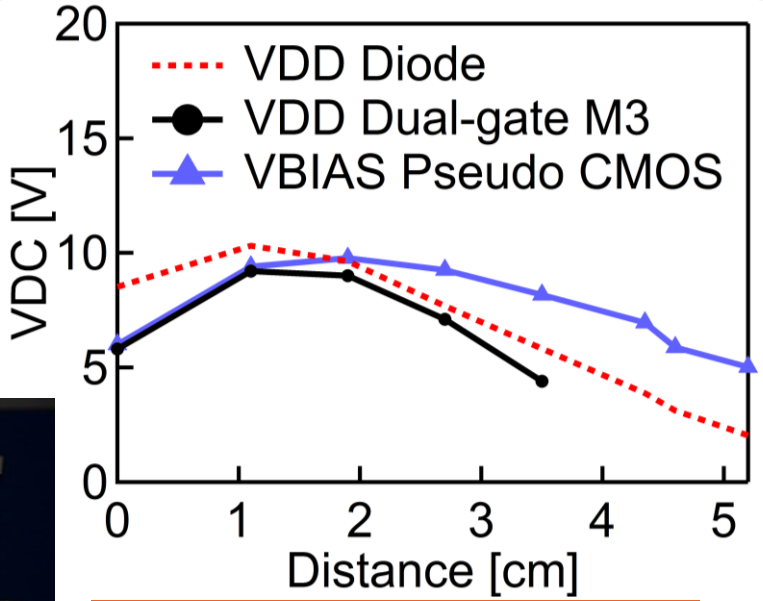
Standard	Data rate [kbit/s]
ISO14443	106
ISO15693	6.62 or 26.48



OXIDE NFC TAG - MEASUREMENTS







Data rate @ 1.1cm	
Diode-load	23.8kbit/s
Pseudo-CMOS	9.4kbit/s
Dual-gate M3	1.4kbit/s

Research done together with

KU LEUVEN

FLEXIBLE OXIDE NFC TAG – SUMMARY

	Diode-load	Dual-gate M2	Dual-gate M3	Pseudo-CMOS	[1] Zero-V_{GS}-load	[2] Diode-load
# TFTs/ inv	2	2	2	4	2	2
Area [mm^2]	2.70x2.98 (8.046)	3.91x3.87 (15.132)	2.70x3.14 (8.478)	4.69x3.36 (15.759)	7x10 (70)	3.9x1.5 (5.85)
# TFTs	218	218	218	436	1026	222
# VDD	2	3	3	3	2	2
Noise margin	<7.4% VDD/2	~36% VDD/2	~40% VDD/2	~24% VBIAS/2	~15% VDD/2	11.6% VDD/2
Data rate	71.6kbit/s	11.3kbit/s	25.8kbit/s	43.9kbit/s	0.05kbit/s	3.2kbit/s
ISO 15693	**Yes**	**Yes**	**Yes**	**Yes**	No	No
Carrier	PEN-film	PEN-film	PEN-film	PEN-film	Glass	Glass

[1] H. Ozaki, et al., Symposium on VLSI Circuits Digest of Technical Papers, 2011
[2] B.-D. Yang, et al., ETRI Journal, Volume 35, Number 4, August 2013

RF POWER TRANSFER

FOR A LONGER LIFETIME AND HENCE LOWER REPLACEMENT COSTS OF ACTIVE TAGS

imec

COLD CHAIN LOGISTICS: REMOTE TEMPERATURE LOGGING

REMOTE, CELL PHONE POWERED, WIRELESS FOOD SENSORS

IMEC WIRELESS POWER TRANSFER

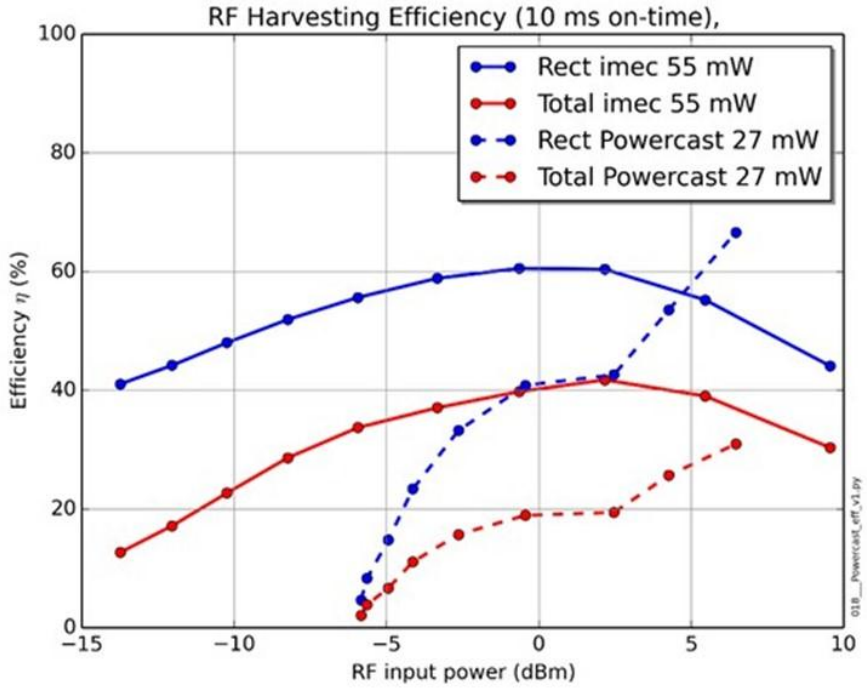
We have the technology

Transmitter: 3W EIRP, 868-915MHz

30µW continuous DC power
up to 5m distance

60mW DC power during 40ms
every 2 minutes
up to 12m distance

BENCHMARK IMEC- POWERCAST



Imec WPT system triples the distance that can be reached with Powercast system

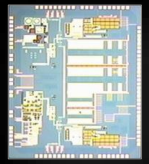
LOW POWER RADIO DESIGNS

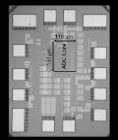
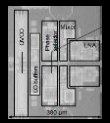
FOR A LONGER LIFETIME AND HENCE LOWER REPLACEMENT COSTS OF ACTIVE TAGS

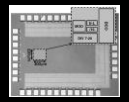
imec

Leadership in wireless and low power IP
ISSCC publications for > 10 years

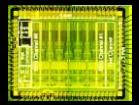

ADC

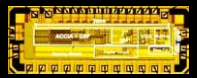

Scaldio1



Rx

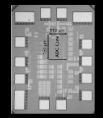

UWB TX

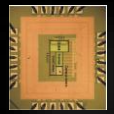

UWB RX

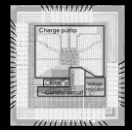

8-Channel EEG Readout ASIC

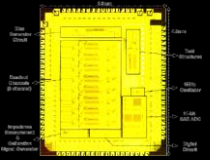

1-Channel ExG Readout ASIC

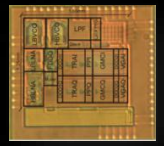

24-Channel EEG Readout ASIC

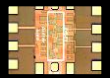

Gbps ADC


ADC

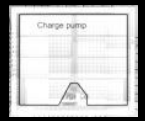

Power management


8-channel EEG Acquisition


Scaldio2A

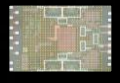

Wideband PA


RX FE

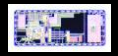

Integrated Power Management


ADC


Scaldio2B


Frequency synthesizer


Gbps ADC


Wake-up Receiver

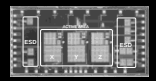

Fractional Charge Pump


Bio ASIP


Analog Signal Processor


Scaldio2C


Inductive Buck Converter


ULP capacitive sensor readout

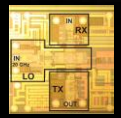

Cool BIO


BAN radio


Dry Electrode Readout ASIC

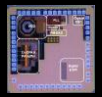


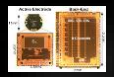
ADC ADC

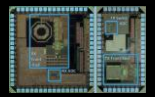

WiGig TRX


Flex ADC


Analog ECG signal processor


PAN Tx


8-Ch. Act. Electrode Readout for EEG


Event driven radio


UWB radio

CMOS Neural Probe

2.4GHz BT-LE/ Zigbee/802.15.6 radio

NTC processor

Energy Aware IC for Piezoelectric Harvesters

Analog MPPT DC/DC Buck Convertor

Analog Neural Signal Processing

Low-Power Implantable ECG Monitor

VCO lock detection

WiGig TRX

Scaldio2D

2004-7

2008

2009

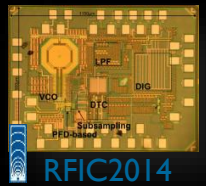
2010

2011

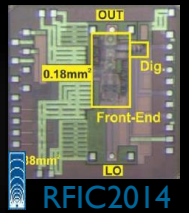
2012

2013

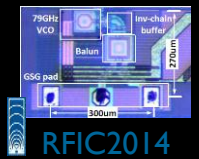
Leadership in wireless and low power IP
ISSCC 2014 and other 2014 publications



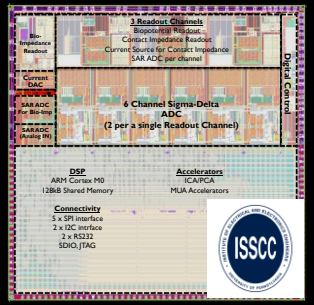
Frequency synthesizer



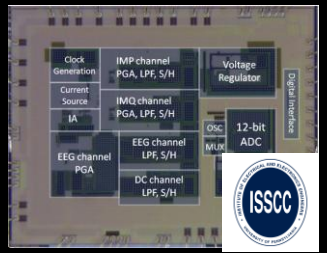
Polar TX



Injection LO

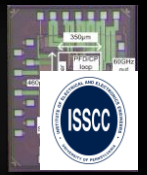


Multi-parameter Interface & Embedded Signal Processing For connected health

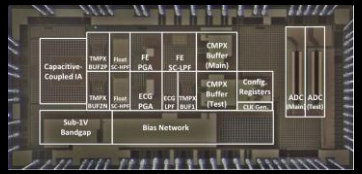


Digital Active Electrodes for Biopotential Recording from Dry Electrodes

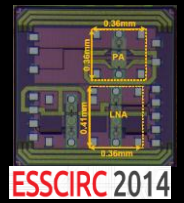
Radar TX



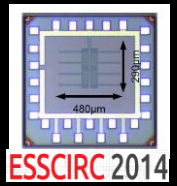
Subsampling PLL



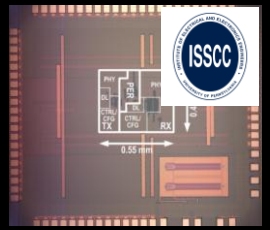
Analog Signal Processor for Cardiac Signal Analysis



LNA & PA

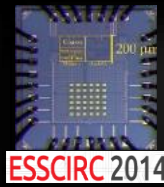


3.5GSps ADC

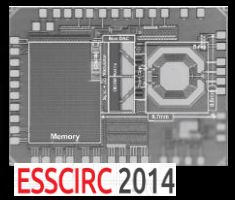


2.4GHz multi standard digital baseband IC

14b 300MS/s ADC

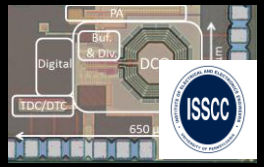


12b 200MS/s ADC

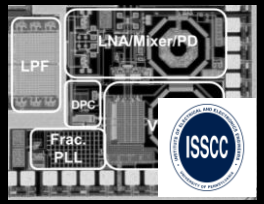


Digital TX Scaldio3B

400MHz 802.15.6 radio



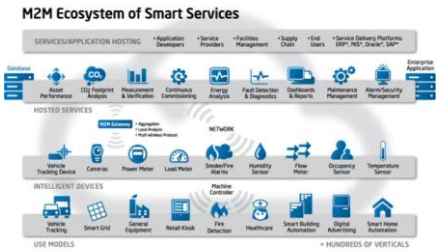
Sub-mW All-Digital PLL



Direct Phase Demodulation Receiver

SUB-GHZ RADIO

Multi-standard	• *IEEE 802.15.4g-SUN, Wireless MBUS, KNX-RF, IEEE 802.15.4k-LECIM*
Best-in-class performance	• 4mW Rx, 3-50mW Tx • -120 dBm sensitivity, *13dBm* output • Optimized power in all states
High level of integration	• Integrated PA and DC-DC conversion • AFE, DBB and ARM processor in one SoC
Differentiating features	• Long range, incl. outdoor operation • Autonomous operation: coin cell/harvested • Worldwide compliance: 779-960 MHz



BENCHMARK WITH COMMERCIAL SUB-GHZ ICS

2x lower Tx power than SotA

10x lower Rx power than SotA

Product		AT[illegible]	INFINEON	ADI	Silicon Labs	imec
		[illegible]A5340	[illegible]A5340	ADF7023	Si4455	**Target**
[illegible]bps)			0.5-50	1-300	0.5-500	**1-400**
		[illegible] / MSK / ASK	BPSK / O-QPSK	GFSK / ASK	(G)FSK / (G)MSK / OOK	(G)FSK / OOK	**(G)FSK / (G)MSK / OOK**
[illegible]DD (V)		3.6	3	3	3	3.3	**1.5**
TX	PDC (mW)	122.4	75	67.5	96.3	99	**50**
	Ptx (dBm)	12	10	13	13.5	13	**13**
	Tx efficiency	13%	13%	30%	23%	20%	**40%**
RX	PDC (mW)	61.2	27.6	36	38.4	33	**4**
	Psens (dBm @ kbps)	-116 @ 0.6 -97 @ 50	-110 @ 20 -106 @ 50	-120 @ 0.5 -100 @ 50	-116 @ 1 -106.5 @ 50	-116 @ 2.4 -108 @ 40	**-120 @ 1** **-103 @ 50**

ION SENSORS

FOR ADDITIONAL FUNCTIONALITY OF ACTIVE TAGS FOR FOOD, FLUIDS AND MEDICINE MONITORING FOR SAFETY AND AGAINST COUNTER FEITING

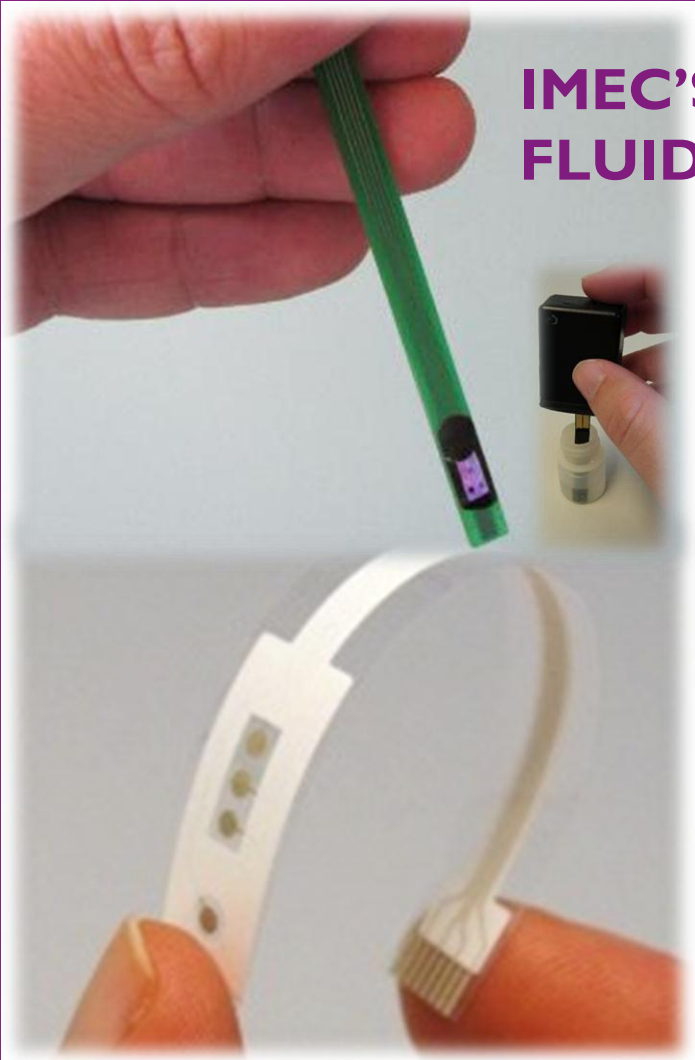
imec

ION SENSOR; APPLICABLE IN MANY AREA'S

PERISHABLES

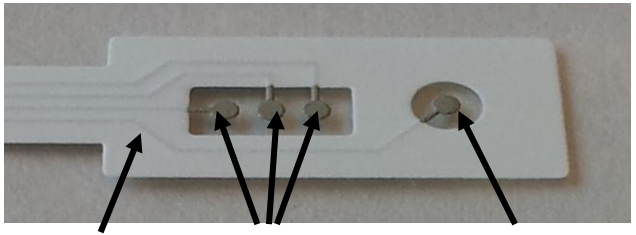
WATER QUALITY

WEARABLE PATCH

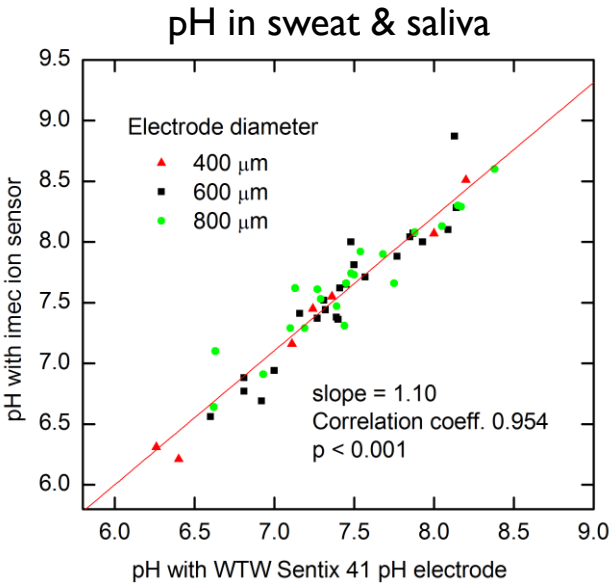


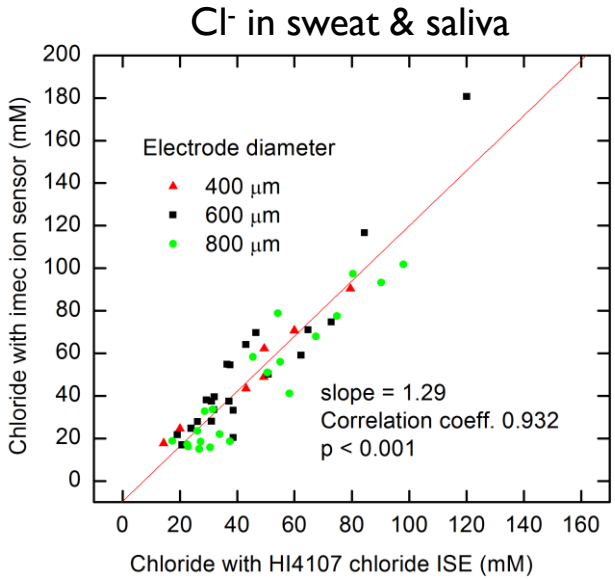
IMEC'S ION SENSOR PLATFORM FOR FLUIDICS ANALYSIS

- Solid & flexible sensor, miniaturized and low cost
- Hand-held sensor demo
- Multiple ions: pH, Cl, Na^+, K^+
- 2-10 pH range, 0.1 – 1 M Cl^- range
- One drop of saliva, blood, urine, sweat, water or other liquid suffices



IMEC ION SENSORS... SIGNIFICANT CORRELATION WITH COMMERCIAL HIGH-COST SENSORS



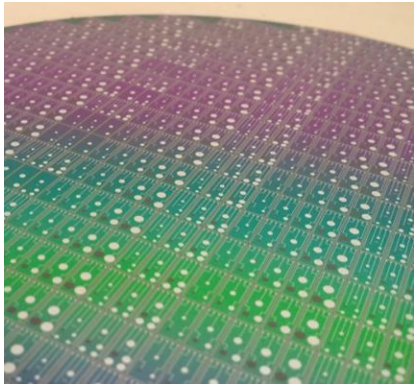


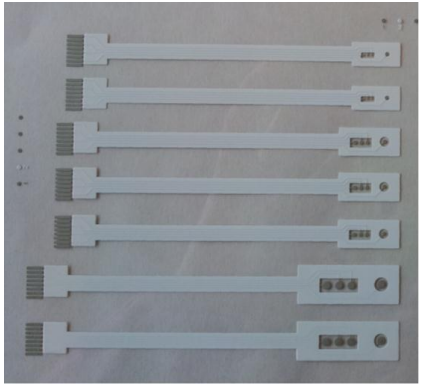
Similar response for different electrode diameters!

PORTABLE ION SENSOR BENCHMARK

	Imec, 2014 	Commercial pH sensor 	Commercial Cl^- sensor 	Commercial Na^+ sensor 	Commercial K^+ sensor 
Technology	Microfabricated solid-state electrodes	Glass membrane, ISFET	Solid state ion selective membrane	Solid state ion selective membrane	Solid state ion selective membrane
Range	pH: 2 - 10 Cl^-: 10^{-4} – 1 M Na^+: under development K^+: under development	pH: 0 - 14	Cl^-: 10^{-5} – 1 M	Na^+: 10^{-6} – 1 M	K^+: 10^{-6} – 1 M
Sensitivity [mV/decade]	pH: 59 - 61 Cl^-: 53 – 56 Na^+: under development K^+: under development	58 - 60.5	52-60	52-60	52-60
Life time	Tests running	~1 year	~1 year	~1 year	~1 year

TOWARDS MASS-PRODUCIBLE ION SENSORS



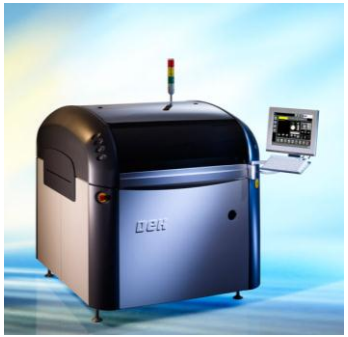


Base:

- AgCl electrodes
- pH electrodes
- Insulation

Screen printed or photolithography

Now: electrodes manually modified with pHEMA or ion-selective membrane



Investigate feasibility manufacturing by screen-printing or inkjet printing

CONCLUSIONS

Logistics is a large growing market towards 2020

A few large challenges for RFID are:

- lower tag price (compared with bar code); especially at unit level

- more functionality, including small sensors that can measure e.g. the quality of food, liquids, medication

- longer life time of active tags, reducing replacement costs

Holst Centre and imec work on several technologies which can help to overcome these challenges.