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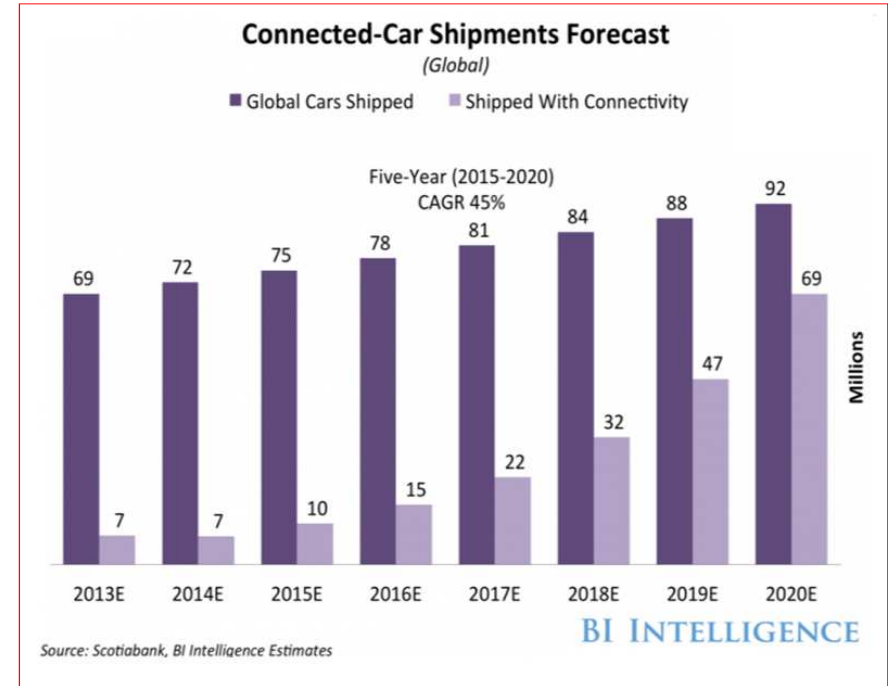
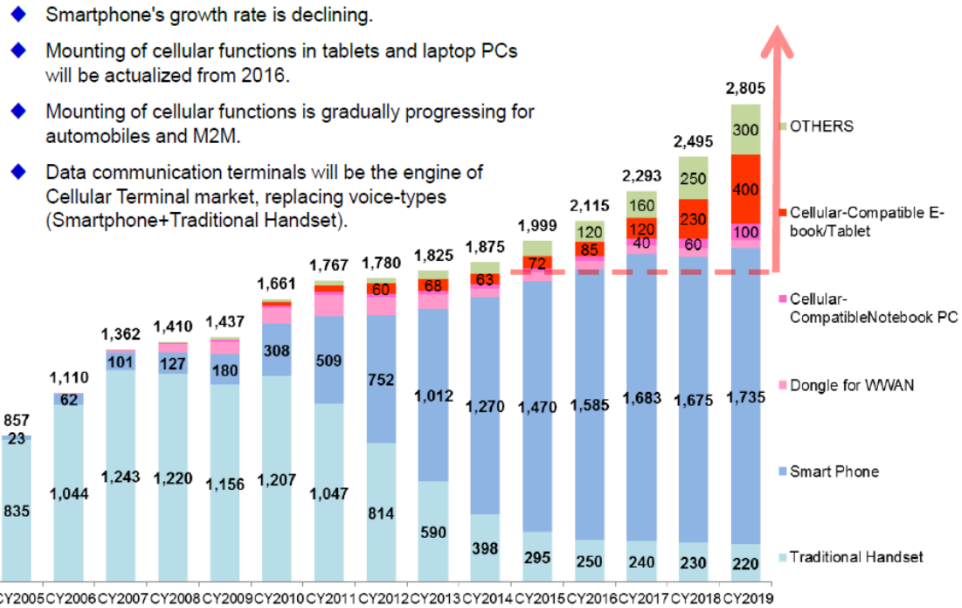


RF DEVICES: BREAKTHROUGHS THANKS TO NEW MATERIALS

Jean-René Lequepeys

Leti Devices Workshop | December 3, 2017

CELLULAR RF MARKETS

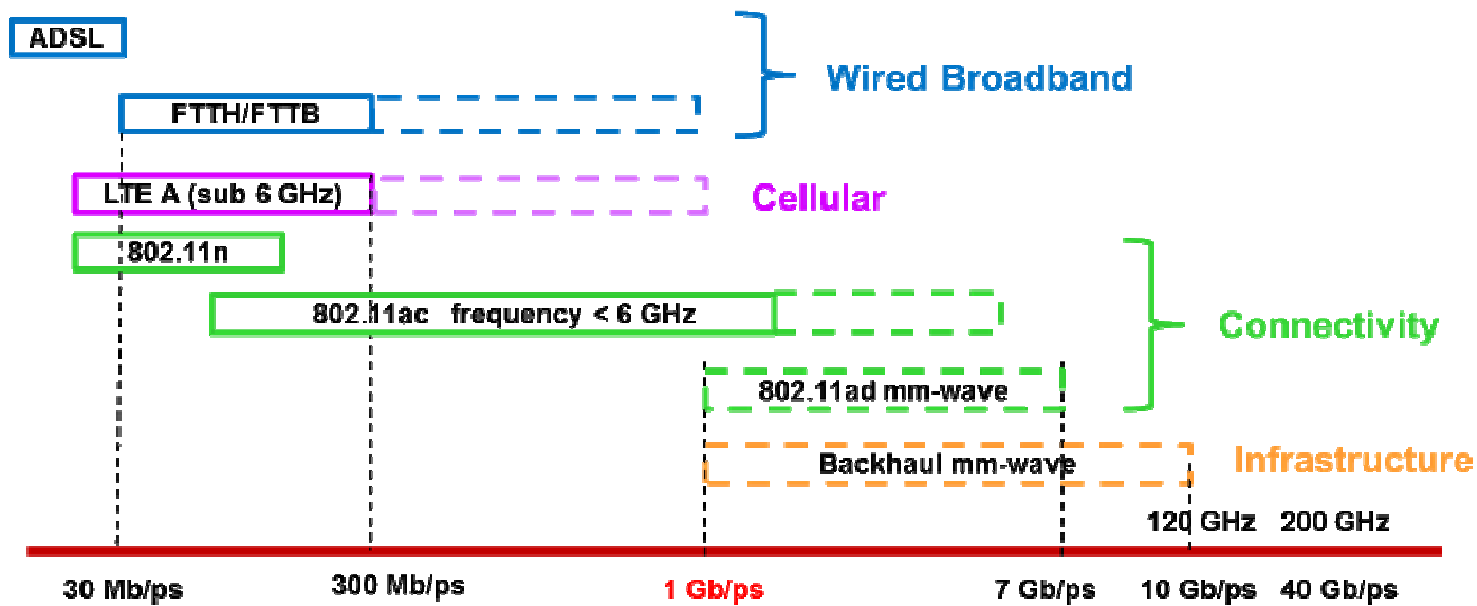


- RF cellular markets are **still progressing**
- Smartphones** remain the main driver
 - Declining growth rate but more complex RF content
- 5G** is bringing new RF applications and **new markets**
 - Connected-cars (V2X & V2V), IoT...



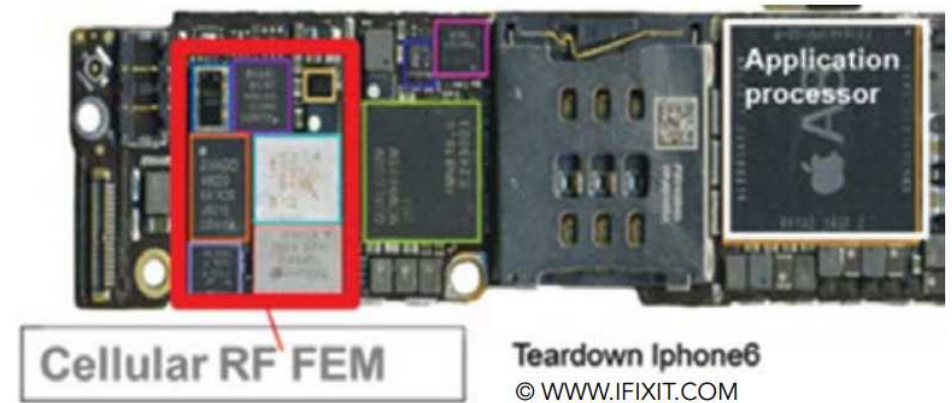
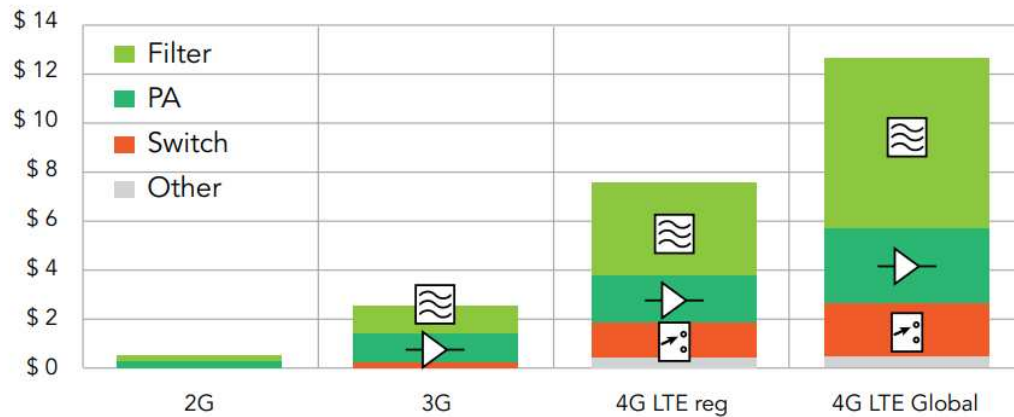
5G WIRELESS TECHNOLOGIES

- 5G priority is to use **sub-6 GHz cellular spectrum** to get Gigabit per second data throughput
 - Introducing CA + MIMO + 256 QAM
 - Waiting for mm-wave challenges to be solved (power consumption)



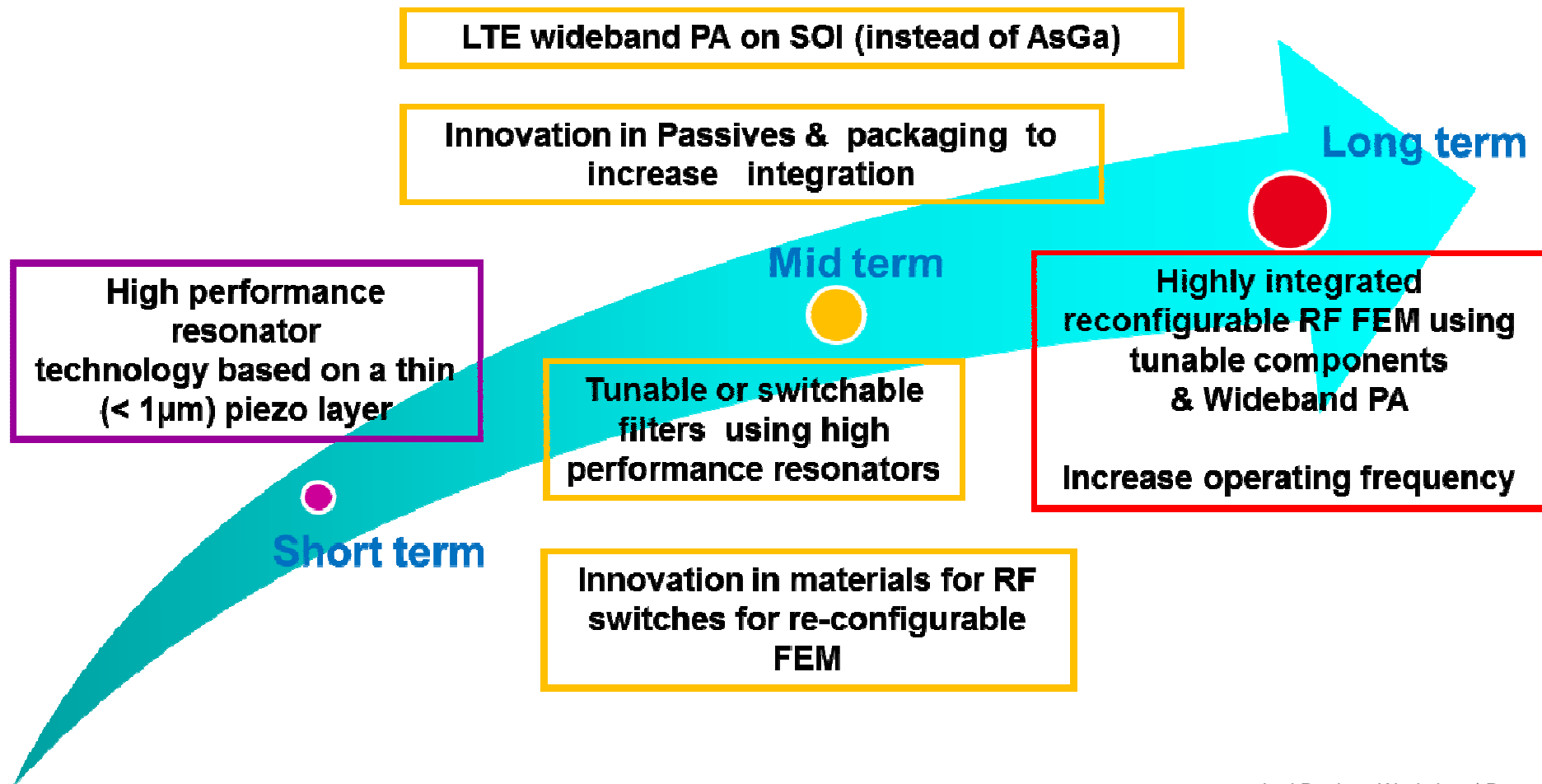
NEW REQUIREMENTS FOR 5G (LTE-A FEM EXAMPLE)

- Evolution from 3G to 4G has increased the RF content in smartphones **in size and cost!**

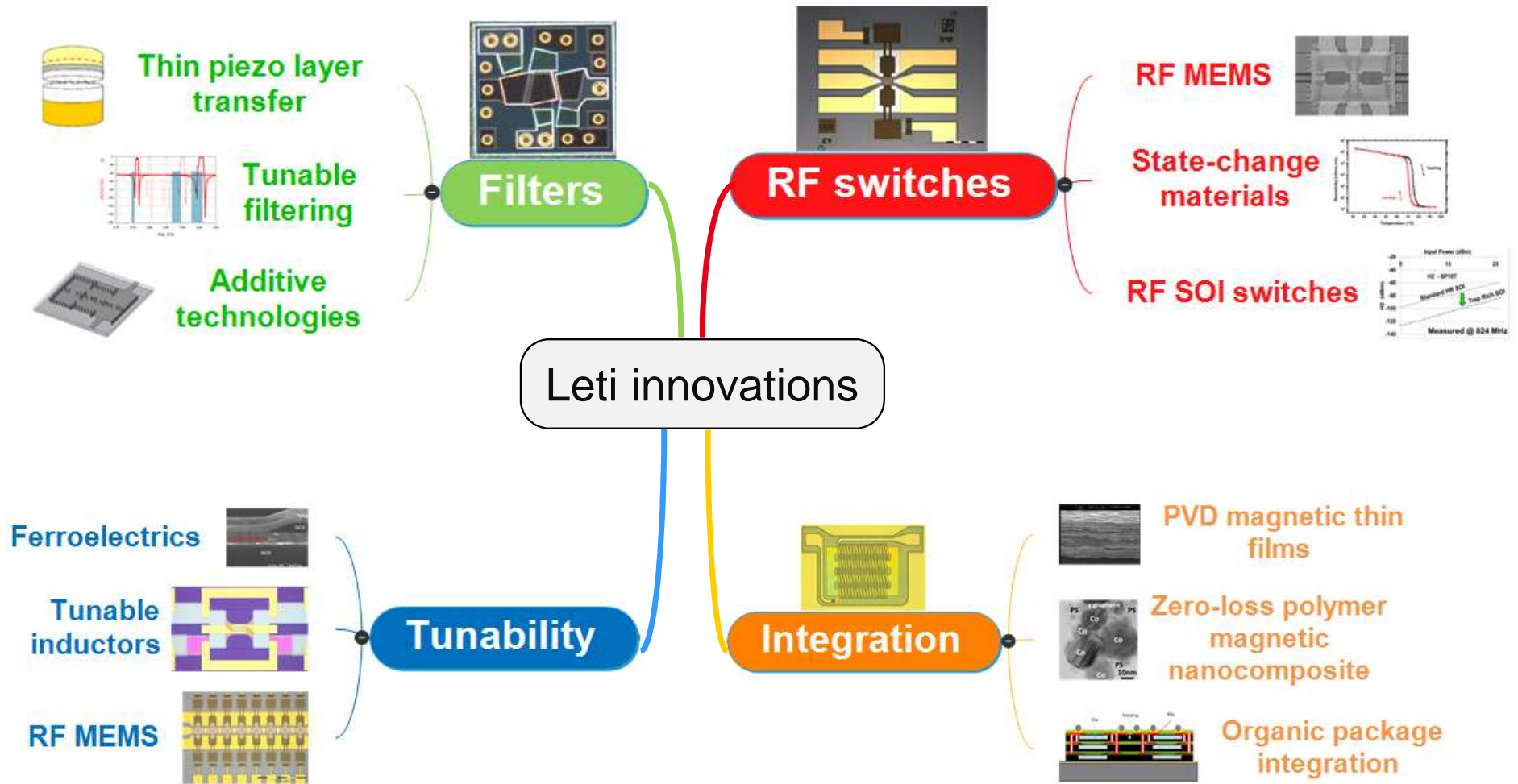


- New requirements are appearing for 5G
 - ✓ **Higher integration and lower cost**
 - ✓ Better **linearity** to support complex modulations
 - ✓ **Higher frequency and wider bandwidth** to target C-band
 - ✓ **Reconfigurabilty** to simplify RF architectures

LETI ROADMAP FOR 5G CELLULAR FEM

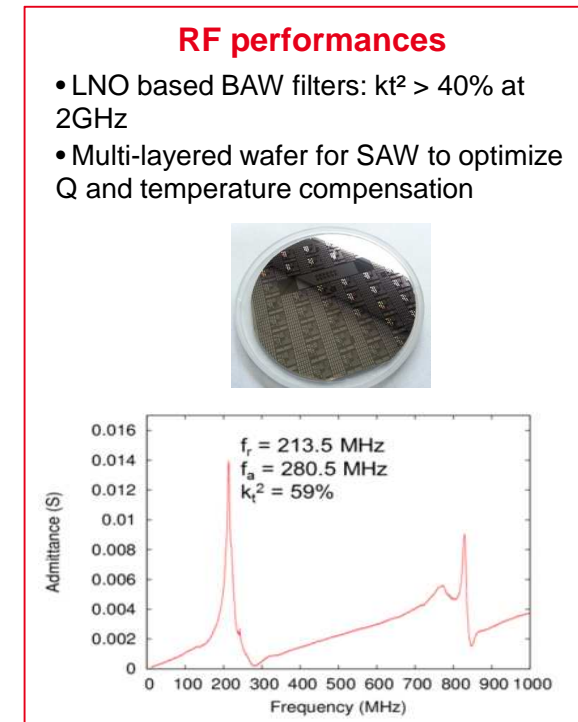
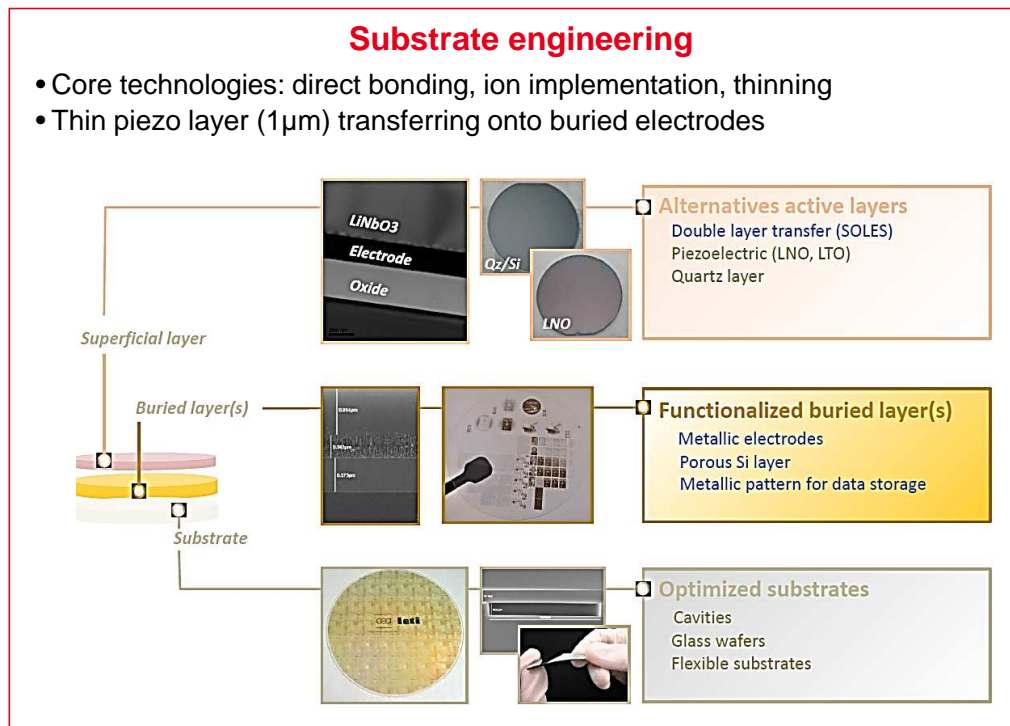


OUR DISRUPTIVE RF DEVICES TOOLBOX



RF FILTERS BASED ON THIN PIEZO LAYER TRANSFER

- **Concept:** highly efficient piezo materials (LTO, LNO, quartz...) transferring on Si to enhance performances of filters and resonators
- **Leti added-value = know-how unique in the world**

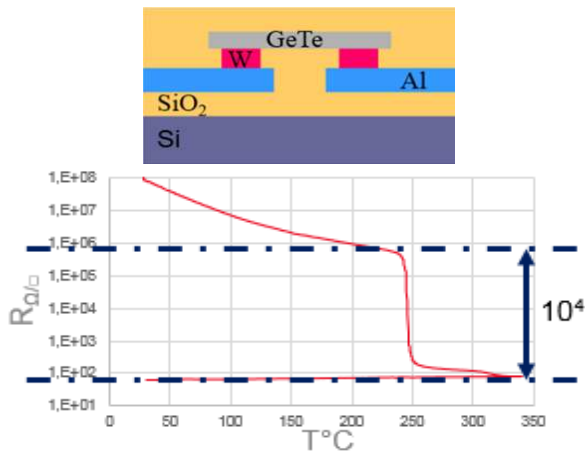


RF SWITCHES BASED ON PHASE-CHANGE MATERIALS

- **Concept:** use morphable low-cost materials to get bistable and low-loss high-frequency switches with good power handling capabilities
- **Leti added-value = a 2D material industrial manufacturing process**

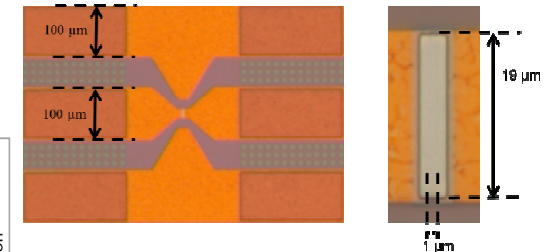
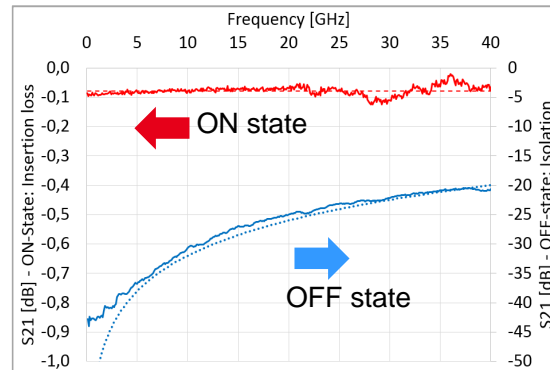
Resistive switching

- Switch between two states to get high R_{off}/R_{on}
- Materials = GeTe, VO_2
- 2D materials = MX₂ (M= Transition metal like Mo, W; X= Te, S, Se, Te)



Promising first results

- $R_{ON}=1 \Omega$ measured $\rightarrow |S21| < 0.1dB$
- $C_{OFF} = 4fF$
- 200nm process



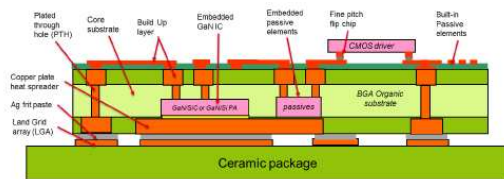
	SOI	MEMS	PCM
Insertion loss	2 dB	0.25 dB	<0.1 dB
Isolation	20 dB	40 dB	>30 dB
Actuation	2.5 V	40 V	< 5 V
$R_{ON} \times C_{OFF}$	120 fs	4 fs	4 fs

TECHNOLOGIES FOR HIGHER INTEGRATION

- **Concept:** integrating high-Q passives in low-cost packaging and using advanced magnetic materials to minimize the size of inductors or antennas
- **Leti added-value = ability to implement breakthrough materials at large scale**

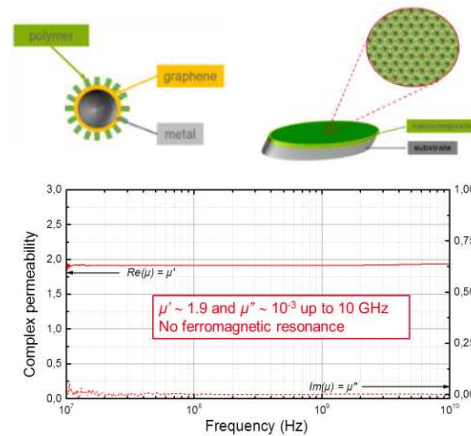
RF passives in organic interposer packaging

- Solution for thin RF modules <600μm
- High-Q passives (inductors, capacitors...) in organic package RDL
- Breakthrough materials to enhance performances = nanoparticles-based dielectrics and magnetics



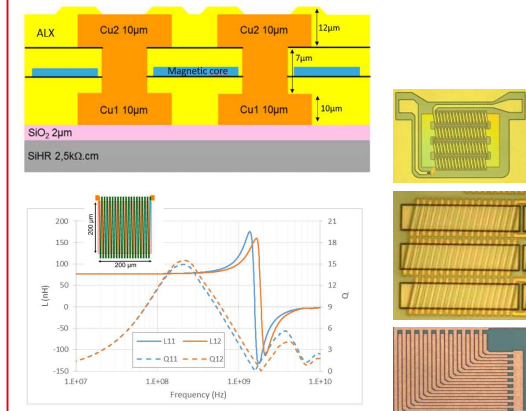
Metal polymer nanocomposites

- High loading rate demonstrated > 50%
- High permeability ($\mu=2$) up to 20GHz,
- Zero loss (non conductive, no FMR)
- +30% on inductor Q-factor (with $\mu=2$) thanks nanoparticles encapsulation



Magnetic core inductors

- Miniaturization of dc-dc converters and common mode filters
- Low cost process based on polymer
- Density of 2000nH/mm², Q>15
- 10x in down sizing for HF inductors

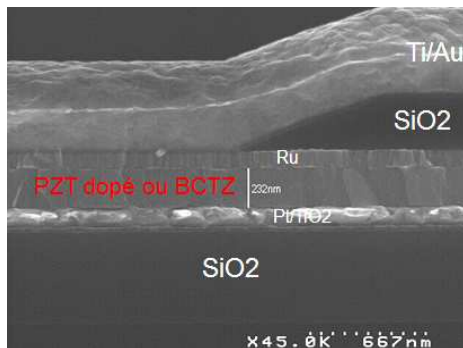


TUNABILITY FOR RECONFIGURABLE RF FEM

- **Concept:** tunable RF components based on morphable materials or MEMS technology
- **Leti added-value = broad portfolio of solutions for tuning**

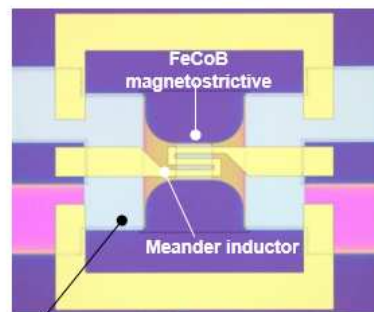
Ferroelectric tunable capacitor

- Impedance matching or tunable filters
- Doping elements into ferroelectrics to enhance the tuning ratio and to get lower losses (better Q-factors)
- Sol-gel low cost process
- **Tuning ratio > 7:1, Q > 50 @ 1GHz**



Innovative concept of tunable inductor

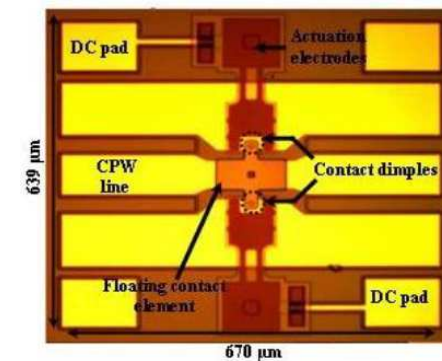
- Frequency-agile antennas
- piezo → stress on magnetostrictive → change of μ → change of L value
- Ultra low loss magnetostrictive core
- $L_{\max}/L_{\min} \geq 3$ (L between 1 to 20 nH), $Q > 20$, $V_{\text{actuation}} \leq 20V$



Membrane with PZT actuators at both sides

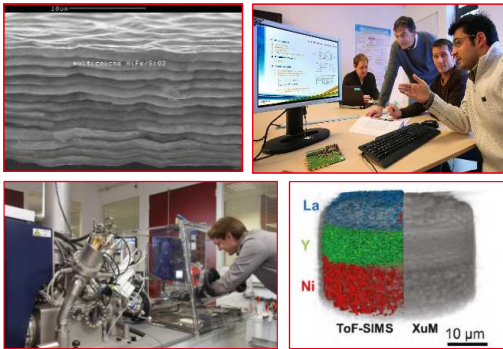
RF MEMS

- RF switches, tunable capacitors, compact mmW tunable phase shifters
- 20 years background
- **Hermetic thin film packaging ensuring long-term reliability**
- **Ex : tunable capacitor (tuning ratio = 33:1 up to 20GHz, Q > 120 @ 10GHz)**



YOUR PARTNER TO ADDRESS YOUR RF DEVICES ROADMAPS

Material research

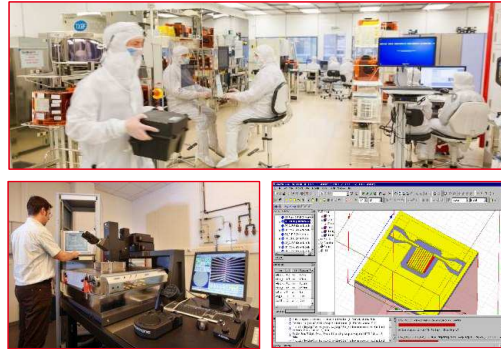


- ✓ Ability to work with breakthrough materials and to deal with contamination
- ✓ Joined developments with tools suppliers
- ✓ Physical understanding. Broad range of characterization tools

Long-term

Vision & breakthrough to gain competitive advantages

Validation & scaling

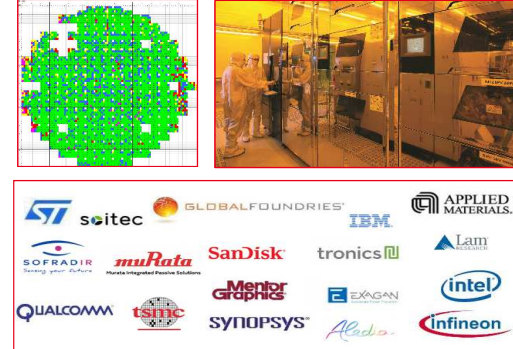


- ✓ 25 years background on 200mm silicon integration
- ✓ Ability to stabilize a process
- ✓ Ability to transfer to foundries for mass-production

Mid-term

Speed-up innovations time-to-market

Industrial transfer



- ✓ Use existing patents portfolio
- ✓ Strong links with foundries
- ✓ Know-how on technological and knowledge transfers

Short-term

Transfer of existing know-hows

FOR MORE INFORMATION

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Meet our two representatives abroad

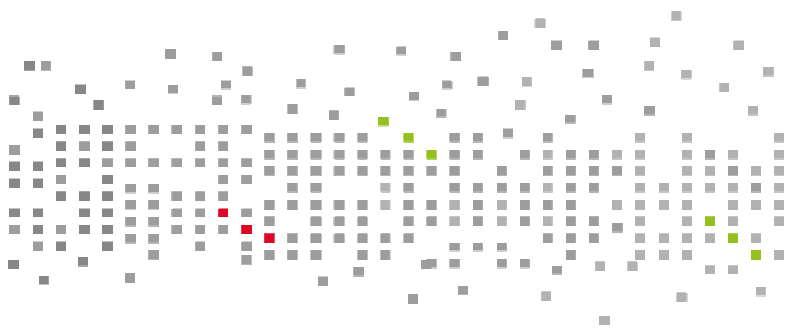


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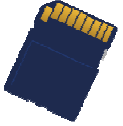
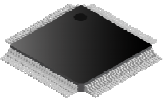













































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PLANCHE DE PICTOS

										
	DISPOSITIFS MÉDICAUX	INTERNET DES OBJETS	CAPTEURS	IMAGING SENSOR	SERVEURS ET CALCUL INTENSIF	NANO ÉLECTRONIQUE	COMPOSANTS PHOTONIQUE	ÉNERGIE ÉLECTRONIQUE DE PUISSANCE	SÉCURITÉ	RF
										
										
										
										
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