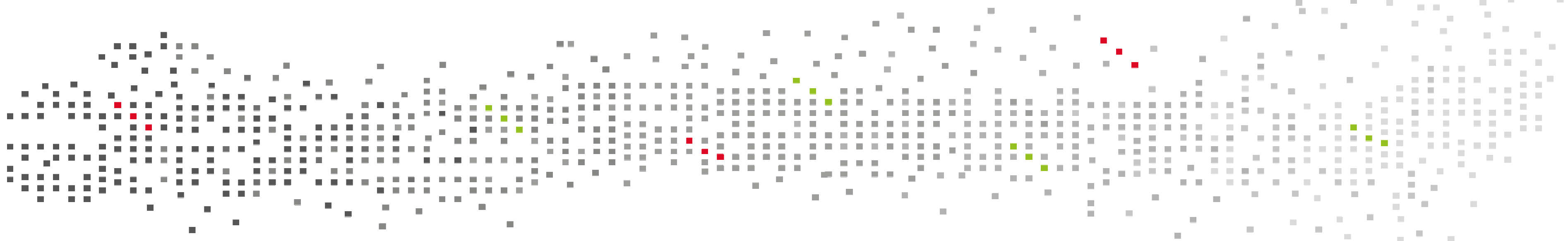


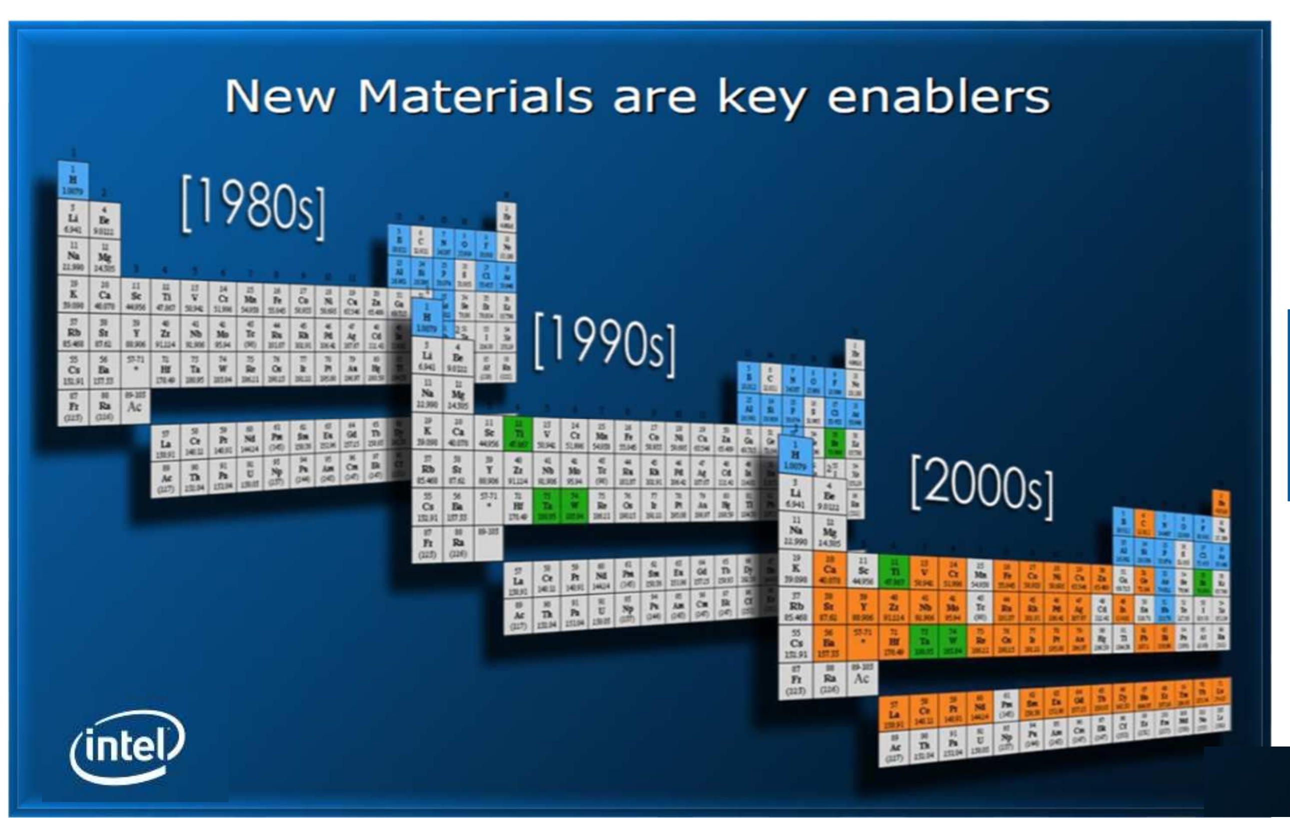
MICROELECTRONICS & NEW MATERIALS: CHALLENGES & OPPORTUNITIES

Bruno Mourey - CTO

OUTLINE

- Introduction – New Market Opportunities
- Integrating New Materials in the Process Flow
- Challenges and Opportunities
- Conclusions

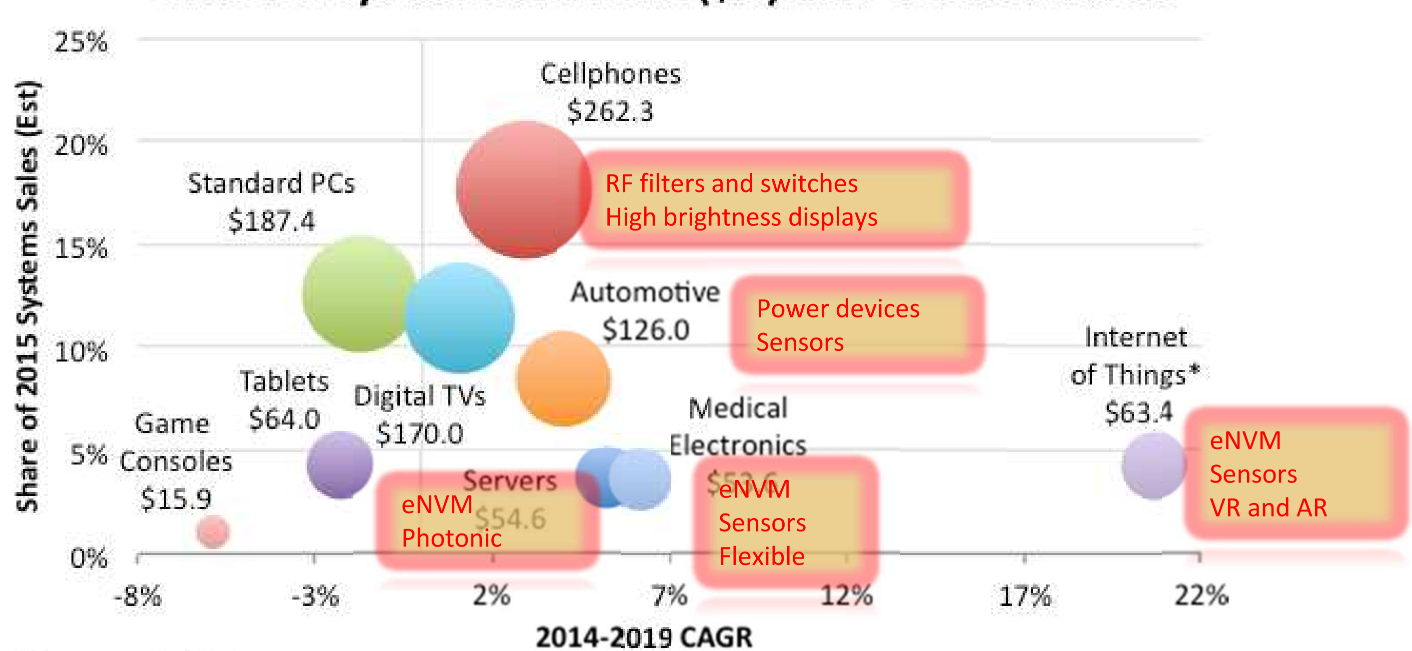
MICROELECTRONIC TECHNOLOGIES ARE GROWING THROUGH MATERIAL INNOVATION



New materials enable innovation by

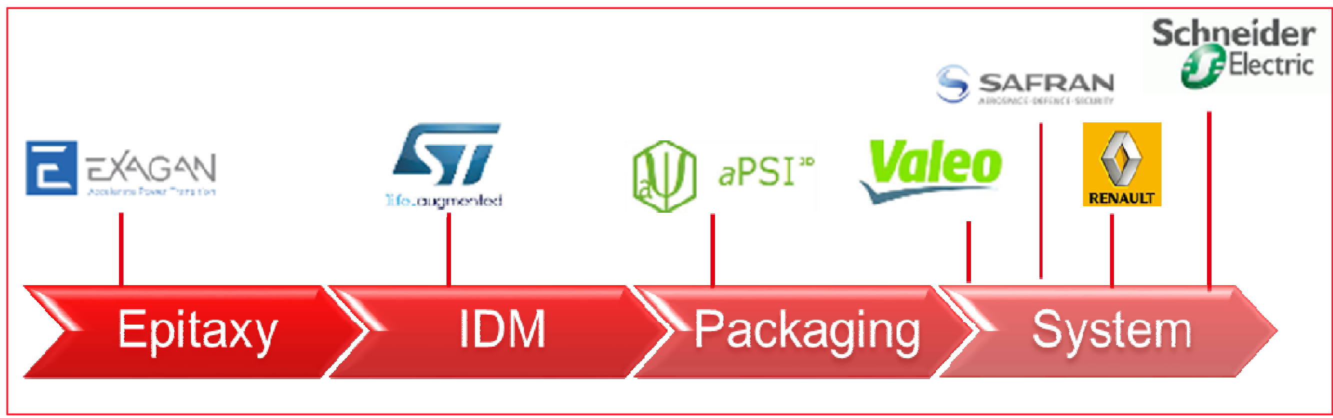
- Improving performance
- Opening new market opportunities

NEW MARKET OPPORTUNITIES ARE DRIVEN BY SCALING AND … NEW MATERIAL DEVICES



FROM MATERIALS TO SYSTEMS: AN INTEGRATED APPROACH

An example: Leti's Ecosystem in Power GaN



Integration of New Materials in Process Flows is Key for Best-in-Class, Application-Specific Devices

OUTLINE

- Introduction – New Market Opportunities
- **Integrating New Materials in the Process Flow**
- Challenges and opportunities
- Conclusion

LETI’S APPROACH TO MATERIAL INTEGRATION

- Direct Material Deposition
- Material Chip-to-Wafer Transfer
- Full Material Transfer

DIRECT MATERIAL DEPOSITION

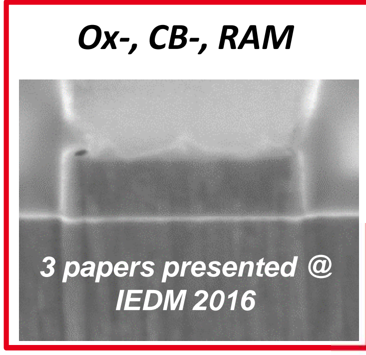
- **Benefits**
  - ✓ Simple
  - ✓ Cheap

- **Drawbacks**
  - ✓ Thermal Budget Limitation
  - ✓ Heterogeneous Epitaxy Availability

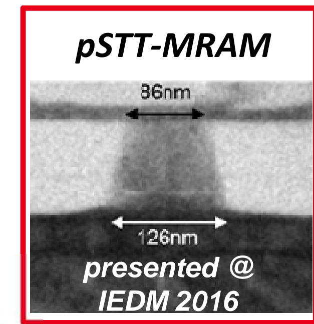
NVM MATERIAL DEVELOPMENT: IMPLEMENTING DIRECT MATERIAL DEPOSITION

- Target for 2017: to include a BEOL selector

Ox-, CB-, RAM



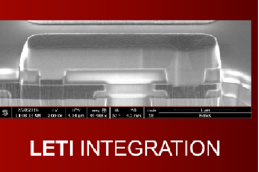
pSTT-MRAM



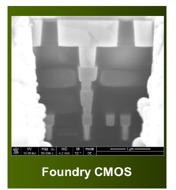
RRAM

MRAM

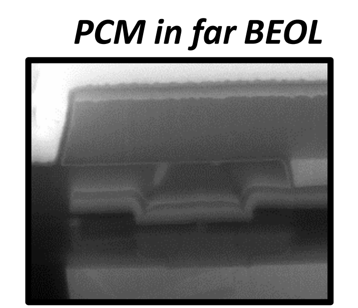
Project/Partner specific: NVM module plus 2 metal layers **fabricated at Leti**



Common CMOS test wafer, commercially outsourced, with 4 metal layers and all circuit test structures



PCM in far BEOL



MATERIAL CHIP-TO-WAFER TRANSFER

4-inch III-V Wafer

Carrier

- **Benefits**
  - ✓ Material cost efficiency
  - ✓ Use of available epi wafers (4 - 6 inch)
- **Drawbacks**
  - ✓ Limited to 10% surface usage (cost)
  - ✓ Complex integration

PHOTONIC INTEGRATED CIRCUITS:
AN IMPLEMENTATION OF CHIP-TO-WAFER INTEGRATION

Objectives

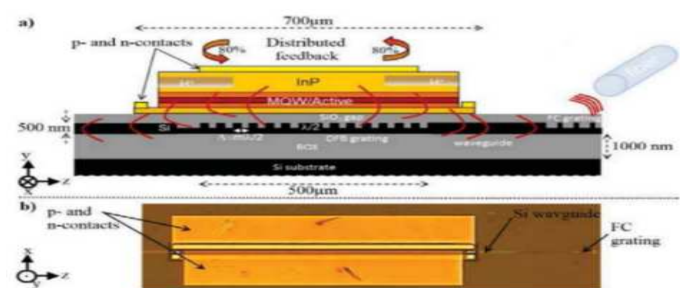
- Integration of III-V lasers on a Silicon photonic circuit

Requirements

- Full integration in 200/300mm fab
- Precise control of III-V quantum well/Si waveguide interface
- Laser processing on CMOS line

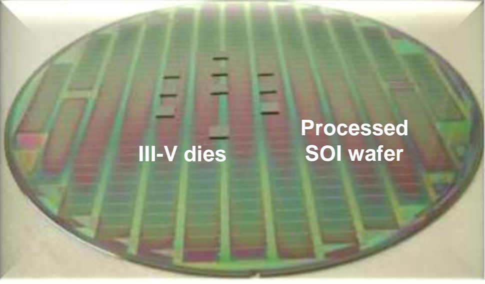
One solution: Collective direct bonding of InP dies on Si wafers

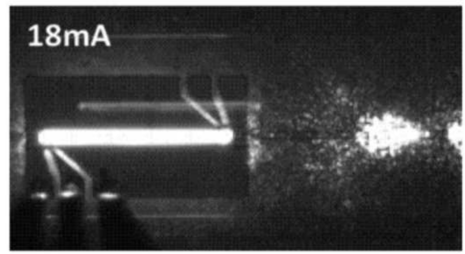
- Collective processes w/o any glue layer



Heterogeneously integrated III-V on silicon distributed feedback lasers

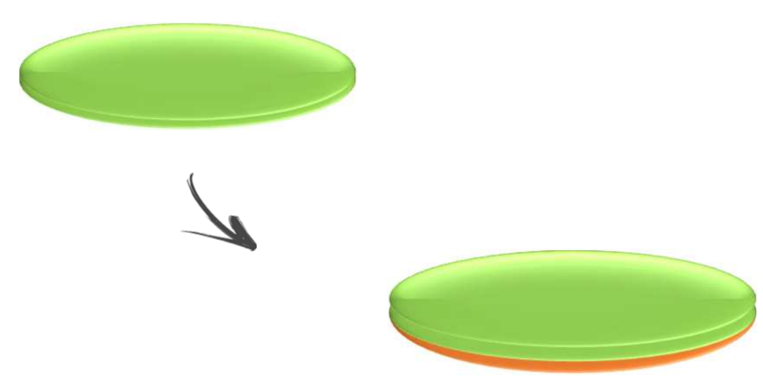
InP-dies bonded on Silicon CMOS wafer using direct bonding

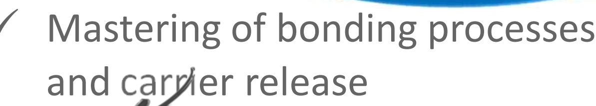




B. Ben Bakir Duprez et al. Invited talk ECS 2014

FULL SUBSTRATE MATERIAL TRANSFER





Benefits

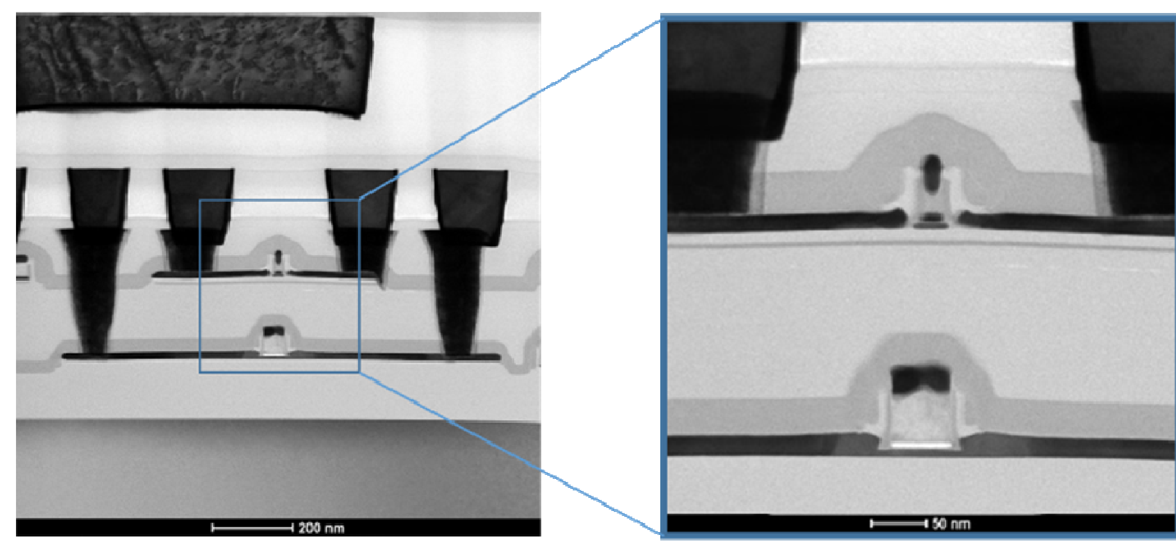
- ✓ No thermal budget limitation
- ✓ Heterogeneous epitaxy capability

Drawbacks

- ✓ Mastering of bonding processes and carrier release

COOLCUBE PROCESS FLOW: 3D MONOLITHIC INTEGRATION

AN IMPLEMENTATION OF FULL MATERIAL TRANSFER INTEGRATION



L Brunet, VLSI 2016

- ✓ **Nanometric lithography alignment** at wafer scale
- ✓ **No impact of layer deformation** during bonding and thinning

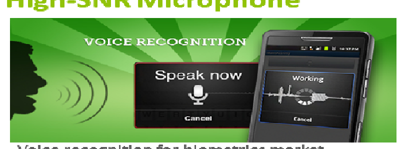
OUTLINE

- Introduction – New Market Opportunities
- Integrating New Materials in the Process Flow
- **Challenges and opportunities**
- Conclusion

3 CHALLENGES IN MATERIAL INTEGRATION FOR MORE THAN MOORE APPLICATIONS

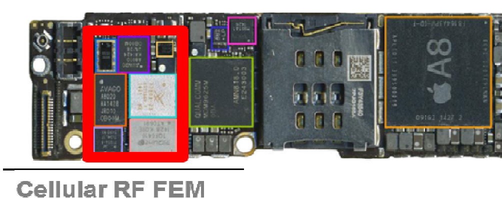
- Piezoelectric Materials for New Sensor/Actuator Applications

High-SNR Microphone



Voice recognition for biometrics market

- Materials for 5G RF Filtering Functions



Cellular RF FEM

- III-V Materials for AR/VR Applications

MARKET OPPORTUNITIES FOR PIEZO-MEMS

Sensor by function in mobiles and tablets

Revenues in US $ Millions	2 011	2 012	2 013	2 014	2 015	2 016	2 017

Axis: 6 000, 5 000, 4 000, 3 000, 2 000, 1 000, -

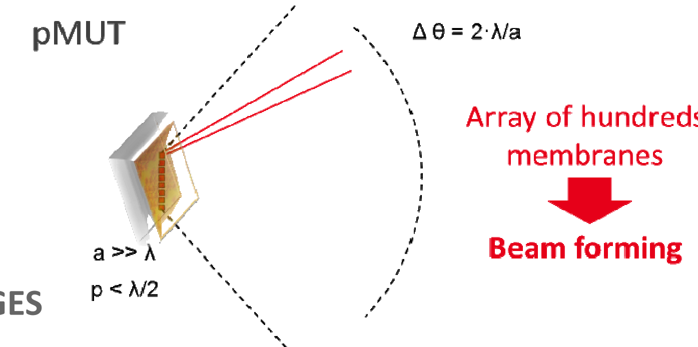
Legend: Gaz, Fingerprint, Pressure, Microphone, Magnetometer, Gyroscope, Accelerometer

Market report and forecast – data from IHS reports on sensors for mobile phone and tablets 2014

- FingerPrint
  QUALCOMM InvenSense Innovation in MEMS
- Microphones
  vesper
- Ultrasonic Sensors
  CHIRP microsystems
- Integrated Optic
  Wavelens
- Inkjet
  hp

IHS

PIEZO MATERIALS FOR PMUT ARRAYS @LETI



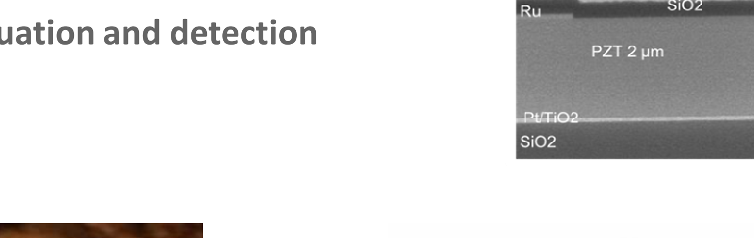
Array of hundreds membranes

Beam forming

(pMUT array)

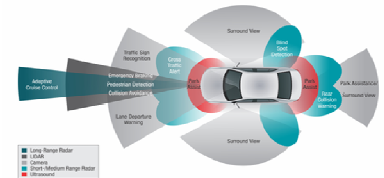
CHALLENGES

- Well control of PZT and AlN piezoelectric technology and integration
- Demonstration of high-frequency piezoelectric actuation and detection
- 3D integration with read/write electronics



Ultrasonic gesture recognition

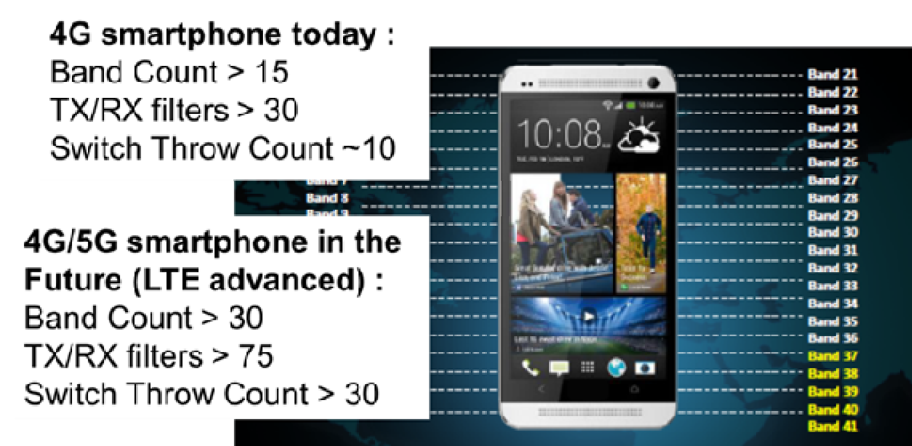
Imaging and biological monitoring

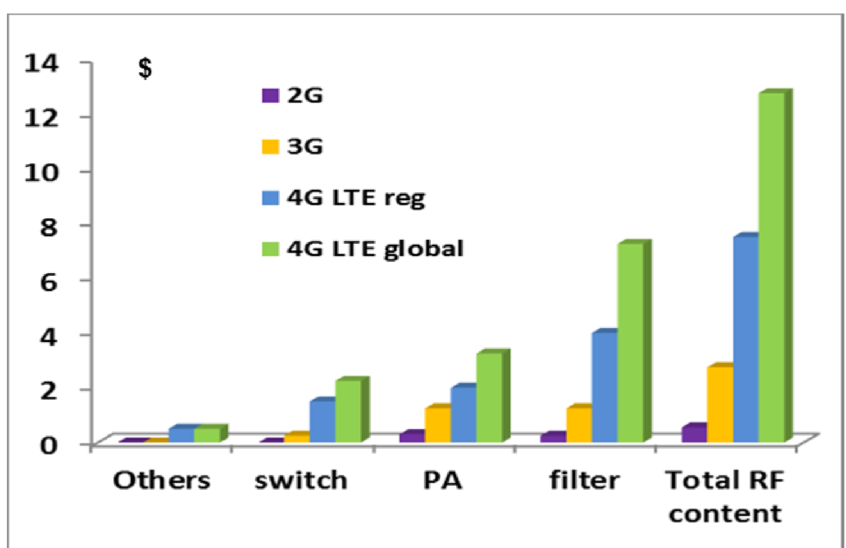


Ranging / obstacle avoidance: Autonomous vehicles, Robotics, Drones

5G MOBILE MARKET

LARGE INCREASE OF RF FUNCTIONS IN MOBILE PHONES DUE TO EVOLUTION OF COMMUNICATION STANDARDS

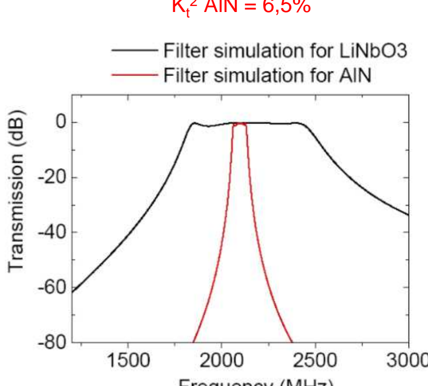




PIEZO MATERIALS FOR RF APPLICATIONS

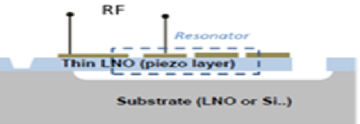
CHALLENGES

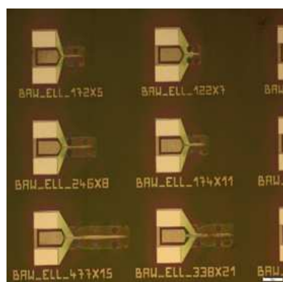
- High-performance resonator technology bandwidth
- Reconfigurable filters and PA
- Increasing the coupling coefficient (kT^2): AlN ➔LNO



SOLUTIONS

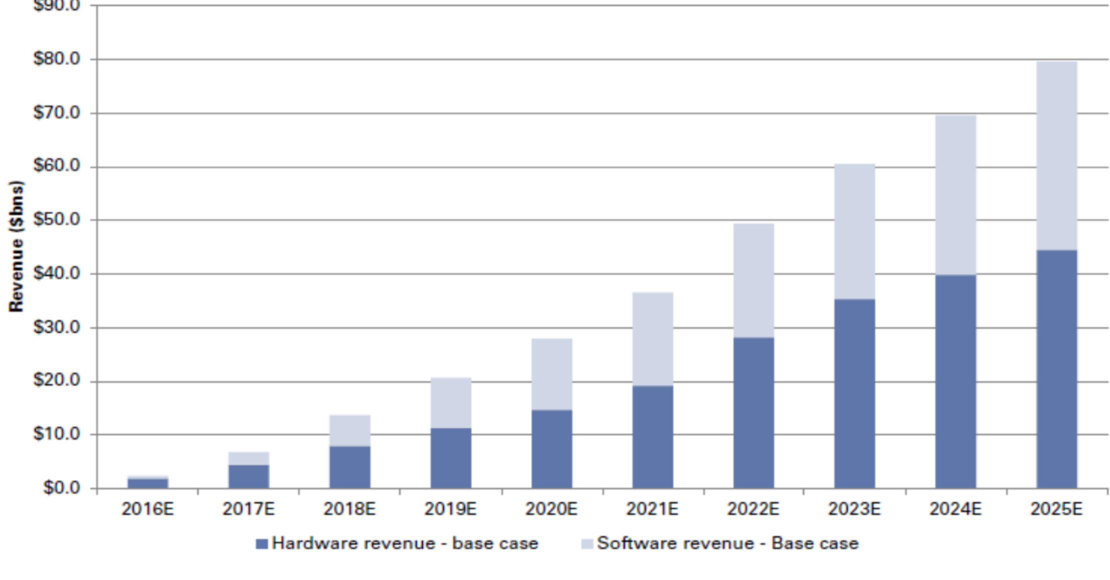
- Thin LNO on top of a cavity using full substrate material transfer technology
- Two options: SAW, BAW
- Generic process on thin LNO, targeting different frequency bands (up to 6 GHz)





AR/VR MARKET OPPORTUNITIES

- Main Challenges for Microdisplays
  - **Brightness and Resolution**



Source: Goldman Sachs Global Investment Research

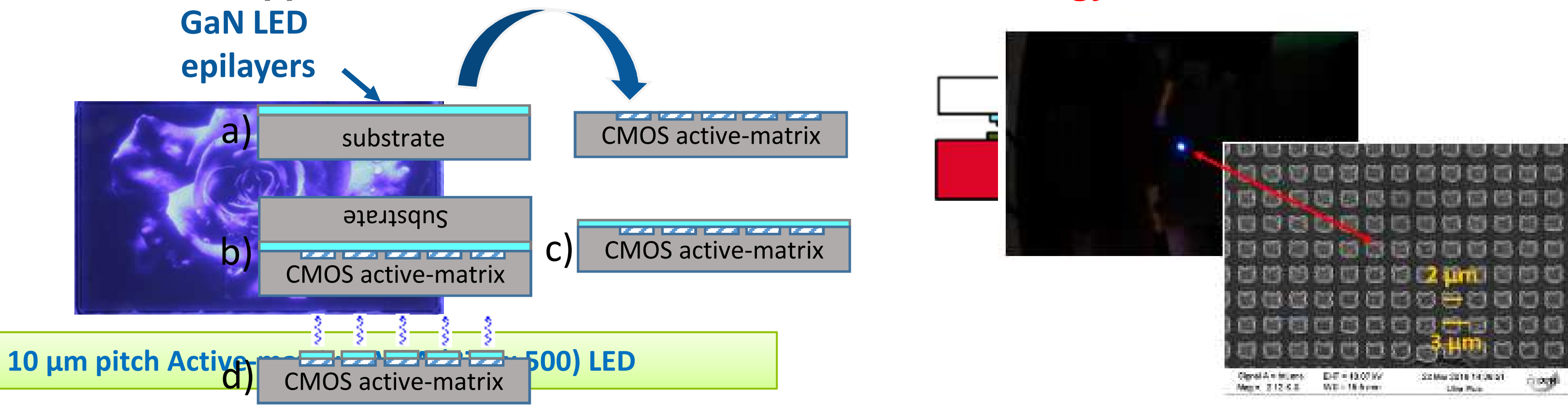
LED MICRODISPLAYS @ LETI

CHALLENGES

- Integration of GaN materials on CMOS wafers for high brightness
- Fine pitch

SOLUTIONS

- First approach: hybrid interconnection of processed GaN wafer on CMOS wafer
- Novel approach: **Full GaN Substrate Transfer Technology**



CONCLUSIONS

- New market opportunities will be driven by the introduction of new materials and innovative material integration technologies
- Leti is a leader in new material development and full integration processes (from concept to demonstration) that enable new applications thanks to innovative devices
- Leti is connected to industrial partners over the entire value chain
- There are many opportunities to collaborate (from equipment manufacturers, fabless and IDMs to end users) to innovate and provide solutions

NEW MATERIAL VS APPLICATIONS

	III V	Piezo	Magnetic	Chalcogenide
Display	X			