OUTLOOK ON WAFER SURFACE SCIENCE & ENGINEERING CAPABILITIES

Prototyping Pilot Line Workshop | Véronique CARRON, Head of SURF Department | 28/06/2019
120 people dedicated to wafer surface treatment
- Technicians
- Engineers
- Experts on 7 areas of competences: bonding, wet processes, TTH, implantation, CMP, grinding & epitaxy
- 10 PhD students

>150 tools from <200m to 300mm
- Industrial grade 200/300mm toolset
- <200mm capabilities
- 24/7 operations

3 types of activities
- Basic operations / mature processes ➔ Speed, efficiency
- Engineering / process tuning & integration for on going LETI programs
- Long term R&D in collaboration with academics, tool suppliers

IP & Communication
- > 20 patents / year
- Contribution to 100 publications in 2018

Our goal is to support and anticipate new applications and products through the development of new unit processes, materials and equipment technologies
OUR 7 AREAS OF EXPERTISE

WET
- Contamination control & cleaning
- Surface preparation
- Wet etching

TTH
- Annealing and oxidation atmospheric or low pressure furnace and RTP
- UV Nanosecond Laser Annealing
- High temperature deposition
  ➔ Poly-Si, a-Si, Si$_3$N$_4$, Low stress SiN, Si Dots

CMP
- Front End Applications
  ➔ SiO$_2$, Si, SiN etc.. Polishing
- Back-End Applications
  ➔ Cu, W, GST, magnetic materials etc...

Grinding
- Dry Polishing (200 / 300mm)
- Edge trimming and dicing (200 / 300mm)
- Grinding : Si, Ge, GaAs, InP, GaN, sapphire, polymer, metal, glass...

Epitaxy (Group IV)
- SiGeC RP-CVD : intrinsic or in-situ doped Si/SiGeC heterostructures for nanoelectronics & optoelectronics

Implantation
- All species implant for doping, Smart Cut™ and material modification applications :
- Plasma Immersion & ion implantation
- Temperature controlled Implant

Bonding
- Si/SiO2, Metal/Metal etc.. Direct Bonding
- Thermocompression / Eutetic and Anodic bonding
- Polymer bonding / Temporary bonding
- WTW or DTW bonding

More Moore
- FDSOI & Quantum
- Substrate
- Photonic
- Lighting
- Display

More Than Moore
- Power
- Sensors
- Imager
- 3D
UNIT PROCESS EXPERTISE: GROUP IV EPITAXY

- Investigated materials in 200 & 300mm
  - Column IV epitaxy of undoped/in situ doped: Si, Ge, Si-Ge, SiGe:C, Ge-Sn, strained or relaxed...
  - Blanket or localized & selective epitaxy
  - In situ surface preparation (Siconi)
  - Low temperature epitaxy (≤500°C) with

- Large panel of applications

- Selected tool Set
UNIT PROCESS EXPERTISE: THERMAL TREATMENT

- **Furnace & RTP**
  - Anneal and oxidation @ atmospheric or low pressure
  - High temperature deposition: Poly-Si, a-Si, Si$_3$N$_4$, Low stress SiN, Si Dots

- **Ge condensation module**
  - SiGe up to 70% Ge

- **Nano second laser annealing module with** SCREEN
  - UV 308nm – 80-180ns laser
  - From process to simulation of laser/structures interactions

- **Selected tool Set**
  - SCREEN LT-3100 platform 300mm UV-NLA
  - ASM VT412 200/300mm Oxidation & Annealing
  - HELLER 200/300mm Microbumps reflow for 3D IC
  - 2 Levitech RTP LEVITOR tools in 200 & 300mm
FOCUS : « COLD » PROCESSES FOR 3D MONOLITHIC INTEGRATION : COOLCUBE™

Low Temperature Epitaxy for top device

Surface Annealing with UV-NLA

For more details

➤ S. Kerdiles / JM Hartmann presentation in this WorkShop
UNIT PROCESS EXPERTISE : BONDING

- Direct bonding, a historic collaboration with
  - From basics mechanisms to applications
  - From Si to metals through III-V
- Metallic bonding
  - Direct vs eutectic vs thermo-compression bonding
- Polymer bonding
  - Temporary bonding
  - Flexible substrate bonding
- Chip to wafer bonding
  - Pick & place, collective bonding, self alignment
- Selected tool set

Gemini 200/300mm WtW high precision bonding
580CB 200mm WtW covalent bonding
EVG 560&850DB 200/300mm Debonding tool

Bonding defects and water diffusion after Si/Si direct bonding

AlGe eutectic bonding

20nm thick Si transfer on polymer

Collective III-V dies bonding

P. Montmeat et al. MAM 2017

FC1 for die bonding with precision

M. Tedjini et al. APL 2016
FOCUS: 3D STACKING ET HYBRID BONDING FOR 3D IC

Wafer to Wafer Bonder EVG GEMINI

Chip to Wafer Pick & Place SET FC1

Coupling between CMP – Bonding - Métrology

1µm pitch
UNIT PROCESS EXPERTISE: BONDING

Wafer Bonding

No intermediate layer
- Direct bonding
- Anodic bonding

With Intermediate layer
- Conductive layer
- Mixed surface
- Insulating layer
- Direct bonding
- Thermo-compression bonding
- Eutectic bonding
- Polymer bonding
- Direct bonding
- Direct bonding
- Glass frit bonding
- Polymer bonding

Almost all wafer bonding technologies are being addressed at Leti

For more details see other presentations of this workshop

- F. Fournel for LETI expertise on bonding technologies
- T. Wernicke for EVG vision on recent trends in Wafer Bonding Technology
- Y. Lamy (LETI) & V. Renault (SOITEC) for Substrate Innovation Center
**UNIT PROCESS EXPERTISE: IMPLANTATION & FRACTURE**

- **Beamline implantation:**
  - Three beamlines systems 200 & 300mm
  - From 0.2 ke.V to 250 ke.V
  - Standard & exotic species available
  - Si & III-N doping expertise (experiments & modeling)

- **Plasma doping for 2D & 3D structures**
  - 200-300mm Pulsion®

- **Large Smart Cut™ expertise with**
  - Transfer thin crystalline layers onto a foreign substrate
  - From basic physics studies with to technology

*And possibility to implant others species on demand…*

![SiO1 on Si (2*)](image1)
![GaAs on Si (2*)](image2)
![InP on Si (2*)](image3)
![GaN on sapphire (3*)](image4)
![and others...](image5)

1. Cocco et al., Phys. Lett. 36 p144
2. M. Malgras et al., Electron. Lett. 34 p458
3. V. M. Seto et al., ECS PV 2006-40 p119
4. V. M. Seto et al., Proc. Letters 43, 2415
6. Workers et al., accepted in JAP (2015)

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**Si fracture post H2 implantation**

Nanoplatets → μcracks → Full wafer

D. Massy et al. PRL 2018
UNIT PROCESS EXPERTISE: CHEMICAL MECHANICAL POLISHING (CMP)

- Planarization technology as an enabler for all Leti applis
  - Heterogeneous integration (3D, LED, hybrid bonding…)
  - Advanced CMOS (Gate last, SAC, STI, Coolcube™, BEOL, W…)
  - Advanced materials (III-V, perovskites…)
  - Substrate fabrication

- From coupon samples to 300 mm wafers

- Consumable benchmark and development with suppliers

- Last CMP 300mm tool generation
  - Advanced CMP options (End-point / RTPC / Clean / Uniformity control…)
  - Multiscale wafer and consumable characterization (Interferometry, AFM, confocal microscope..)
  - JDP with

  ![Ebara F-REX300 300mm](image)

Within die topography optimization through process and design rules (Interferometry)

Uniformity control @ wafer scale: 2nm on 300mm

1st Leti Prototyping Pilot Line workshop | V. Carron | 28 June 2019
UNIT PROCESS : WAFER THINNING AND DICING

• **Process :**
  • New material grinding : Si, Ge, GaAs, InP, GaN, sapphire, polymère, metal, glass…
  • From samples up to 300 mm
  • Consumables test (wheels, resists, …)

• **Equipements :**
  • 1 Disco full auto 200/300 grinding with dry polishing
  • 1 Disco Edge trimming & dicing full auto 200 mm / 300 mm
  • 2 Disco 200/300 mm
  • 2 Okamoto : from samples up to 200 mm
UNIT PROCESS EXPERTISE: WET PROCESSES

- **Surface preparation, cleaning & Selective etching**
  - For all Si technologies
  - On Ge, III-V and III-N materials
  - For packaging & 3D integration
  - From manual wet benches to advanced 300mm tools

- **Contamination Management**
  - Backside & bevel cleaning
  - Classical contaminant & noble metals
  - Particles removal

- **Selected tool set**

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**SiGe selective etch for SiGeOI substrate**

- Low Ge% SiGe
- \( \text{Si}_{0.3}\text{Ge}_{0.7} \)

**Surface preparation for epi. Regrowth on SiGe**

**Selective etching for µbump**

**AsGa passivation mechanisms in \( \text{H}_2\text{O}_2 \)**

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J. Widiez et al. ECS trans 2016

PE Reynal, SPCC 2018

M. Rebaud et al. UCPSS 2016
OUR COLLABORATION OFFER

New products & applications
- Collaboration thru LETI’s Silicon Product Divisions (DCOS, DOPT, DTBS)

Mature Processes & Technologies
- Wafer service thru LETI 3S (Silicon Specialities Solutions)
- IP licensing
- Technology Transfer

New Materials & Process Development
- Collaborative bilateral research on specific project
- Common laboratories
- Affiliation program

New Equipment Engineering
- Specific Joint Development Program

A full range of business models to meet our partner’s needs
CONCLUSION

- A State of the Art 100-200-300mm tool set & technologies in Surface Science & Engineering Processes

- Strong expertise in
  - Epitaxy
  - Implantation
  - Thermal treatment
  - Bonding
  - CMP
  - Grinding / Dicing
  - Wet Processes & contamination management

- At the heart of the SOITEC-CEA « Substrate Innovation Center »

- Access to
  - Specific process realization & developments for your needs
  - Collaborations on new tool capabilities
  - Consumable tests for Wet, CMP, Polymer Bonding, Grinding…