WHAT DOES EPITAXY STANDS FOR?

Epitaxy = mono-crystalline layer grown on a mono-crystalline substrate;
homo-epitaxy : layer A (Si) on substrate A (Si);
hetero-epitaxy : layer B (SiGe) on substrate A (Si)

\[ a_{(Si_{1-x}Ge_x)} = 5.43105 + 0.20050x + 0.0263x^2 \text{ Å} > a(Si) = 5.43105 \text{ Å} \Rightarrow \]

Strain accumulation inside the SiGe layer when grown on Si. 2 scenarii :

- \( e_{(Si_{1-x}Ge_x)} < e_c \) : pseudomorphic (i.e. strained) SiGe
- \( e_{(Si_{1-x}Ge_x)} > e_c \) : relaxed SiGe : misfit dislocations
THE 200MM/300MM EPITAXY TOOLS IN LETI

Specificity: growth on industry-compatible 200mm and 300 mm Si wafers

Reduced Pressure – Chemical Vapour Deposition of group-IV semiconductors (Si, SiGe(C), Ge, GeSn): 3 single wafer tools
- a 200 mm Epi Centura cluster tool from Applied Materials (2 chambers)
- a 300 mm Epsilon 3200 tool from ASM America (1 chamber)
- a brand-new 300mm Centura Cluster tool from AMAT (2 chambers)

Metal Organic – Chemical Vapour Deposition of III-V semiconductors: 2 tools
- GaN-based heterostructures: 200 mm Aixtron Crius tool (1 chamber) => B. Hoyt pres.
- GaAs/InP-based heterostructures: 300 mm AMAT Centura tool (1 chamber)
THE NEW CENT300 GROUP-IV EPITAXY CLUSTER TOOL

(i) top view, (ii) side view and (iii) 3D view of the cluster tool from Applied Materials.
THE SICONI LOW TEMPERATURE SURFACE PREPARATION CHAMBER

SICONI: low temperature surface preparation thanks to NH3 / NF3 remote plasma

Plasma generation

\[ \text{NF}_3 + \text{NH}_3 \xrightarrow{\text{RF}} \text{NH}_4\text{F} + \text{NH}_4\text{F} - \text{HF} \]

Reaction with surface oxyde

\[ \text{NH}_4\text{F} + \text{NH}_4\text{F} - \text{HF} + \text{SiO}_2 (s) \xrightarrow{} (\text{NH}_4\text{F})_2 \text{SiF}_6 (s) + \text{H}_2\text{O} \]

Salt sublimation @ 180°C

\[ (\text{NH}_4)_2 \text{SiF}_6 \xrightarrow{} \text{SiF}_4 + \text{NH}_3 \]
THE REGULAR CVD CHAMBER

RP-CVD chamber: regular temperature epitaxy of intrinsic and in-situ doped thin and thick SiGeC layers
- H2 (g) and N2 (g)
- SiH4 (g), Si2H6 (g) and SiH2Cl2 (g)
- GeH4 (g) and Ge2H6 (g)
- SiCH6 (g)
- N-type dopant: PH3 (g)
- P-type dopant: B2H6 (g)
- Etchant: HCl (g)
- Temp. Range: 400°C-1100°C
- Reduced Pressure (10 Torr – 600 Torr)
THE ELVIS LOW TEMPERATURE CVD CHAMBER

ELVIS chamber: low temperature epitaxy of intrinsic and in-situ doped thin SiGeC layers (Coolcube™)
- H2 (g) and N2(g)
- SiH4 (g), Si2H6 (g), SiH2Cl2 (g)
- Liquid Si source
- GeH4 (g) and Ge2H6 (g)
- SiCH6 (g)
- N-type dopant: PH3 (g)
- P-type dopant: B2H6 (g)
- Etchant: HCl(g) and Cl2(g)
- Temp. Range: 350°C-730°C
- Reduced Pressure (10 Torr – 600 Torr)

Coolcube™: very low temperature growth of raised sources and drains on the top devices
GROUP-IV SEMICONDUCTOR EPITAXIAL PROCESSES

Nanoelectronics:
- Selective Epitaxial Growth (SEG) of SiGe channels for pMOS devices
- High and Low Temperature SEG of Si, SiGe:B and Si:P raised sources and drains (CMOS)
- Epitaxial growth of SiGe/Si superlattices (SLs) for stacked nanosheets devices (CMOS)

Optoelectronics:
- SEG of Ge at the end of waveguides for near Infra-Red PhotoDetectors
- Smoothing thanks to $H_2$ annealing of Si waveguide sidewalls
- Epitaxy of thick SiGe layers encapsulated by Si (thick Ge layers encapsulated by SiGe) for mid (long-IR) waveguides
- Deep trench filling by Si:P and poly-Si:P ( imagers)
- Growth of thick GeSn layers for use as light sources and mid-IR PD

Substrates:
- Growth of SiGe Strain-Relaxed Buffers and tensile-strained Si for sSOI
- Growth of thick Ge layers for GeOI

MEMS:
- SiGe/Si stacks with SiGe as sacrificial layers
- Thickening of SOI substrates with intrinsic or doped layers
THE 300MM EPI CENTURA RP CHAMBER

Mono-wafer reactor:
- 300 mm substrate
- Growth temperature:
  - 400°C - 1100°C
- Operating pressure: 20 Torr
- F(H₂) = several tens of slms

- Domes and mobile parts: quartz
- 44 + 32 lamps (2kW)
- Temperature control: IR pyrometer
- Thermally activated decomposition of gaseous precursors on the surface =>

Top pyrometer

Bottom pyrometer