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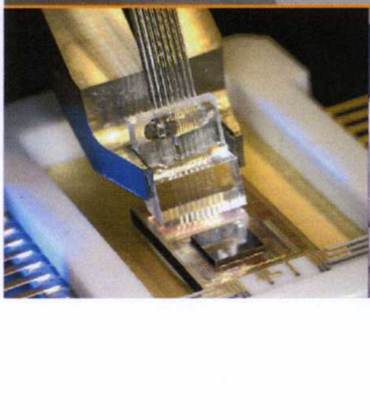
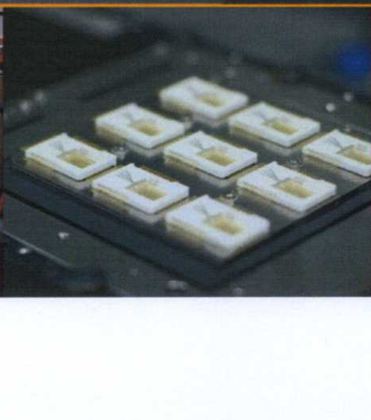
Scuola Superiore
Sant'Anna

Integrated Photonics at TeCIP Institute
2014





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INTEGRATED PHOTONICS TECHNOLOGY CENTER - INPHOTEC

"SI. PHO" SILICON PHOTONIC PLATFORM

Silicon waveguide technology is processed on 6" wafer scale, thin SOI layer 220nm active device and 3µm oxide buried material configurations.

Low loss high index contrast submicron size waveguide are fabricated by CMOS compatible process in order to realize dense Photonic Integrated Circuit; due to high line flexibility, fast prototyping and low/medium production can be achieved.

The technology available at "Inphotec center", with process capability guaranteed by industrial e-beam direct writing system, supports structures with minimum feature size in the range of 50 to 70nm, these conditions satisfy several approaches to process structures (es. coupling waveguide and single mode fiber):

- Lateral coupler with silicon taper and medium contrast layer
- Surface grating with different designs, shapes and materials in order to enlarge the bandwidth and reduce the coupling loss

The technology available can guaranteed realization of components with building block like:

- Ring resonator
- Thermal tuning structure by silicon embedded resistor or overlay metal
- Junction P and N for direct modulations
- WDM structure

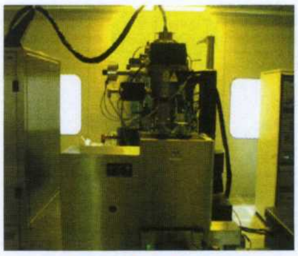
The Ion Implantations will be an outside service trough qualified industrial partner.

The PD, Germanium photo-detector integration will be also supported by an outside industrial partner.

The key equipments at "Inphotec" dedicate at Si.Pho platform are:

- Direct writing system by VB6 Vistec Reith
- Etching system by Omega-Mori with SF6 –C4F8 –CH2F2 gas mixture
- Si3N4 and Si Poly by LPCVD vertical and Horizontal
- UV exposure system front and backside alignment
- PECVD liquid system by TEOS, BTEOS and PTEOS for High Conformal coating
- Evaporations System for metal layer by lift-off
- Field Emission Sem Microscope low acceleration voltage
- Spectro ellipsometer for high accuracy determinations of n,k and thickness

VERTICAL FURNACE FOR POLY Si, Si_3N_4



VISTEC VB6 UHR

Glass on Silica" Platform

In silicon microphotonics the optical waveguide is one of the fundamental building block, the choice of the waveguide material defines the wavelength of signal and the integration density.
Glass on Silica is implemented in order to:

- Cover the full range of Photonic Integrated application
- Extend the wavelength range from visible up to 1600nm very wide transparency range
- Guarantee very low propagations loss

At "Inphotec" center the facilities can process wafers 6" size for glass on silicon integrations, through LPCVD stoichiometric Si3N4 for dielectric high contrast materials, depositions of SiO2 :Ge doped, SiOxNy low medium contrast by PECVD anneal deposition. The edge roughness and low stress structure will be achieved through advance etching system "helicon source plasma system". Upper cladding solutions for High Aspect ratio Structure with low stress material will be achieve processing thick glass layer by PECVD liquid source with Semicom standard precursors.
The summary of process capability available at the center are in the following table:

Material	D RI*	Waveguide Size	Curvature
SiO2 (Ge)	0.7%	4.5X4.5 µm2	7 mm
SiO2 (Ge)	2.5%	2.5X2.5 µm2	1.2 mm
SiON	7%	2.2X2.2 µm2	300 µm
Si3N4	35%	submicron	7 µm

***D RI= ncore2-nclad2/2 ncore2**

BPTEOS Liquid source PECVD

Omega Mori

The line can support developing phase and medium productions, the key equipments to satisfy the technology are:

- Etching system by Omega-Mori with C4F8 –CH2F2 gas mixture
- Si3N4 and Si Poly by LPCVD vertical and Horizontal
- UV exposure system front and backside alignment
- PECVD liquid system by TEOS and BTEOS a PTEOS for high conformal coating
- PECVD High rate deposition for < Ge doped layer
- Evaporations System for metal layer by lift-off
- Field Emission Sem Microscope low acceleration voltage
- Spectro ellipsometer for high accuracy determinations of n,k and thickness

Integration "Silicon Micropackage" Platform

The silicon optical bench is a technology in which active and passive optoelectronic components are assembled on a silicon chip. Optical components based on SiOB are cost effective when compared to discrete optical elements, in particular considering the increase of an optical subsystem complexity. The common technology used to achieved high accuracy position of discrete elements is "silicon wet anisotropic etching". The anisotropic etching defines structure with high accuracy position (<±1.5µm in XYZ) related to silicon crystal plane {111} on silicon wafer (100); an example of structure that could be used for high accuracy position is the so called V-groove structure, this feature has an angle of 54° suitable for fiber, lens or other discrete component position. Other significant structure for this application is mirror at 45 °.

The silicon wet etch technology, based on 6" wafer, is a controlled etching with strong basic chemical components like KOH or TMAH (tetramethyl ammoniumhidroxide); the process is performed in a dedicated reactor.
The integrations of proper metal layers and dedicated technology of eutectic alloy Au-Sn 80/20 (fundamental building block) allow to manufacture silicon optical bench.

The line can support development and medium production, the key equipments are:

- Etching system by Omega-Mori with C4F8 –CH2F2 gas mixture
- Dedicated wet etch reactor
- Si3N4 and Si Poly by LPCVD vertical and Horizontal
- UV exposure system front and backside alignment
- Evaporations System for metal layer by lift-off
- Field Emission Sem Microscope low acceleration voltage
- Spectro ellipsometer for high accuracy determinations of n,k and thickness
- Extend range step measurement up to 1mm with 0,1um accuracy
- Critical dimension up to 1000um with 0,25um accuracy

Advanced Packaging Platform

The advanced packaging platform develops back end and packaging technologies for silicon photonics applications, starting from package design, process development up to engineering and prototipation.The line is actually operative inside a 70 square meters area, part in class 10.000 and part in class 1000.

The main equipment includes the following:
- 1 automatic die-attach FINETECH model PICO
- 1 automatic ball wire bonder K&S
- 1 manual wire bonder TPT model HB16
- 1 Automatic Alignment and Pigtailing Bench
- Vision microscopy

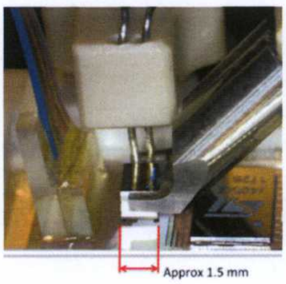
Automatic die bonder Finetech

Automatic ball bonder K&S

Automatic pigtailing/flip bench PI-miCos

The main technologies includes the following:
- Die bonding, Flip Chip Bonding
- Tacking, In situ reflow, Eutectic Bonding
- Wire bonding
- Vertical and Horizontal Alignment and Pigtailing for silicon photonics

In particular has been developed an innovative automatic bench for silicon photonics applications that includes the pigtailing of fiber arrays as well of active devices (laser pill/LAMP). The main characteristics are reported below



- Optoelectronic diodes alignment – active (sub μm)
- Fiber Array Pigtailing - active (sub μm)
- Optoelectronic flip-chip - passive (+/- 3 μm)
- Complete vision assisted automatic prealignment and processing
- UV and thermal curing
- Robot handling (load/unload, revolving, UV supply, epoxy application)
- High speed complete integrated processes (example: 8-way fiber array on grating pigtailing plus laser active flip chip on grating: up to 5 pieces/hr)

CNIT SILICON PHOTONICS DESIGN CENTER

Photonics on Silicon is the future solution for improving performance and power consumption in processing and communication devices for the Internet of the Future. Up to now silicon photonics can support all almost functionalities required to make a communication link: modulator, waveguide, mux/demux, filtering, detection. Monolithic integration of a laser source on silicon has remained a challenge with this material just as with other group IV materials, as they have very poor emission properties.

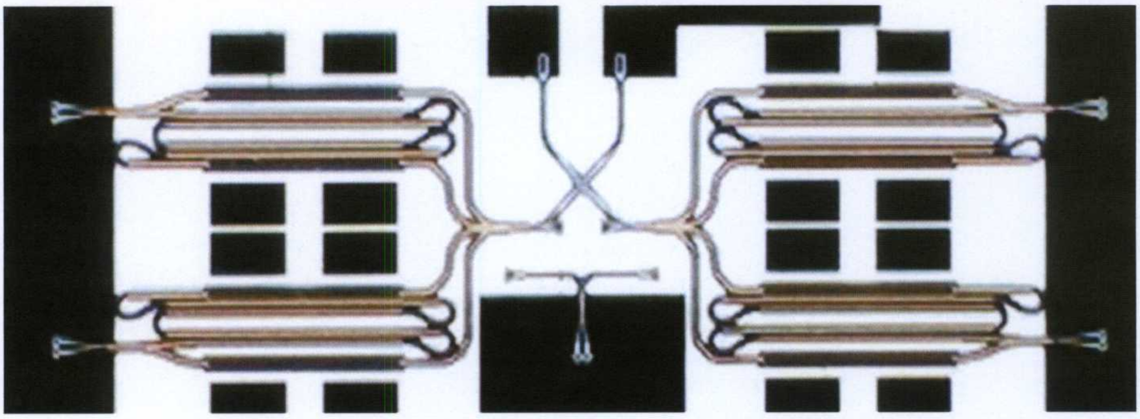
In order to answer the upcoming demand of silicon photonics integrated components, the TeCIP Institute, in collaboration with CNIT, is introducing its new professional design center, operating in partnership with the CNIT Photonic Networks National Laboratory in Pisa.

The Silicon Photonics Design Center will provide from basic design of passive and active photonic building blocks to creation of design libraries compliant with microelectronics IC design environments. The target is to develop performing and power efficient photonic circuits suitable for photonic-electronic integration.

Design capabilities will include mode solvers, FDTD 3D, filter synthesis and analysis, electrical and RF simulations for actives, circuit design, thermal and stress analysis, mask design tool sets.

The Center will be supported by a fully equipped characterization lab for data providing and internal design validation. The characterization lab will include electrical and optical on chip and on wafer testing capabilities.

CNIT is a non-profit Consortium, currently joining 37 major Italian Universities, whose main purpose is to foster research activity and provide networking support to specific projects in the area of telecommunications. CNIT Photonic Networks National Laboratory in Pisa has been established as a part of a broad agreement with Scuola Superiore Sant'Anna, to create a world-class Center of Excellence in Photonic Networks and Technologies.



The realization of the photonic integrated circuits designed by SPD Center will be carried out at the 800 sqm fully equipped cleanroom of the TeCIP Institute of Scuola Superiore Sant'Anna, operating from January 2015, possibly in in partnership with external fabs.

The Director of the Silicon Photonics Design Center is Marco Romagnoli, one of the scientists realizing the first monolithic Ge-on-Si electrically pumped laser, a major technical and scientific achievemen in the perspective of full integration of photonics and electronics with CMOS technology.