GLOBALFOUNDRIES Silicon Photonics

Vikas Gupta
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1  GLOBALFOUNDRIES Silicon Photonics Introduction

2  Key Differentiating Features
   • Monolithic Integration
   • Laser Attach
   • Fiber Attach
   • 2.5D Integration
   • CPO

3  Summary
Malta site – home of FinFETs, RF and Silicon Photonics

- **Market Segments**: Computing, mobile, wired and wireless infrastructure
- **Employees**: ~2,900
- **Differentiated Technologies**: 14/12LP, 12LP+, 12RF, 45RF Silicon Photonics
- **Operating since**: 2011
- **NY Gov’t grants**: $1.5B
- **Manufacturing capacity**: 500k (300mm wafers/year)
What is silicon photonics, and why use it?

SiPh has multiple advantages over “electrons” and alternative technology solutions:

- SiPh is fabrication of active & passive photonics components using silicon VLSI processes.
- Differentiates from indium phosphide (InP) by offering:
  - High-volume manufacturing
  - Higher level of integration
  - Compatibility with silicon processing
  - Lower cost ($/Gbps)
  - Lower power consumption

<table>
<thead>
<tr>
<th>Carrier</th>
<th>Active</th>
<th>Passives</th>
<th>I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic</td>
<td>Electrons</td>
<td>Transistors Diodes</td>
<td>Resistors Capacitors Inductors</td>
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<tr>
<td>Photonic</td>
<td>Photons</td>
<td>Lasers Modulators Detectors</td>
<td>Wave guides Phase rotators Heaters Spot size convertors</td>
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</table>

Performance

<table>
<thead>
<tr>
<th>Building block</th>
<th>SiPh</th>
<th>InP</th>
<th>SiN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive components</td>
<td>✗ ✗ ✗</td>
<td>✗</td>
<td>✗ ✗ ✗</td>
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<tr>
<td>Lasers</td>
<td>✗</td>
<td>✗ ✗ ✗</td>
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<tr>
<td>Modulators</td>
<td>✗ ✗ ✗</td>
<td>✗ ✗ ✗</td>
<td>✗</td>
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<tr>
<td>Switches</td>
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<td>✗ ✗ ✗</td>
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<tr>
<td>Optical amplifiers</td>
<td>✗</td>
<td>✗ ✗ ✗</td>
<td></td>
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<tr>
<td>Detectors</td>
<td>✗ ✗ ✗</td>
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Images: OFC
Photonics application space

GF SiPh solutions target broad range of applications

Source: Adapted from Yole Silicon Photonics and PIC devices, 2019
GF Silicon Photonics helps you harness the power of light for optical Transceiver applications.

- **Driver**
  - SiGe 8XP, 9HP

- **Transimpedance amplifier**
  - SiGe 8XP, 9HP
  - 45CLO monolithic

- **Photonics IC**
  - (modulator & photodetector)
  - 90WG, 45CLO

- **Laser**
  - Integration into PIC
45CLO feature set
Focus on data com & co-packaged optics

Legend:
- CMOS
- Optical

- MZI modulators
- Ring modulators
- Ge EPI PD
- Waveguides, passives
- BEOL passives, inductors, VNcap
- RF CMOS, standard cell, GPIO, ESD, eFuse, TIA, driver, precision resistor,
- Top grating couplers
- Edge fiber couple, passive or active align
- Direct laser attach
- Polarization splitter & polarization rotator
- Ridge, Rib WGs, Bends, tapers, Directional couplers, cross WIC, gratings, absorbers
- Thermal phase shifters standard & undercut
- 4x MUX/DeMUX tunable
The value of monolithic integration
Cost efficiencies combined with performance advantages

<table>
<thead>
<tr>
<th>Electronic technology for hybrid integration</th>
<th>GF monolithic CMOS - SiPh</th>
</tr>
</thead>
<tbody>
<tr>
<td>14FF</td>
<td>22FDX®</td>
</tr>
<tr>
<td>nMOS Ft</td>
<td>270GHz</td>
</tr>
<tr>
<td>Supply V</td>
<td>0.8V</td>
</tr>
<tr>
<td>Substrate</td>
<td>BULK</td>
</tr>
<tr>
<td>Mx res &amp; rap</td>
<td>High</td>
</tr>
<tr>
<td>Parasitic load</td>
<td>5-30fF</td>
</tr>
<tr>
<td>ESD cap</td>
<td>~50fF</td>
</tr>
<tr>
<td>Estimated TIA 3dB BW @1kΩ gain</td>
<td>24 GHz *(70fF)</td>
</tr>
</tbody>
</table>

High-performance, 45 nm SOI RF-grade CMOS FETs integrated with SiPh devices on chip

- Dense channel integration & **reduced packaging costs**
- Significant TIA bandwidth boost due to **low input capacitance**
- **ESD elimination** further reduces input capacitance to ~20fF
Laser attach development
On-chip placement is a game changer

- Silicon does not intrinsically lase; III-V based material needed for laser
- GF approach: Passively place InP laser in laser trench using fiducial marks
- Laser placement on SiPh chip has potential to significantly reduce packaging costs for Datacom, LiDAR & photonic computing applications
Passive fiber attach using V-grooves

Significant value add for high-count fiber arrays where active alignment of fibers is not possible

- Low loss, broadband, passive alignment of SMF

Needed for co-packaged optics (CPO), which minimize distance between optical & electrical chips
Enabling Reflow compatible bump features

2.5D Packaging integration

Support for Copper Receiver pads, Laser attach bond pads, Copper Pillars and Copper u-pillar bumps
# Packaging Standardization – many variations using GF PIC technology

## CPO JDF*

*From Co-Packaged Optical Module Discussion Document - Facebook 9/2019*

<table>
<thead>
<tr>
<th>Company</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Packaging approach</td>
<td>2.5D - Si Interposer &amp; cavity laminate</td>
<td>2.5D – organic Interposer</td>
<td>Fan-out package &amp; cavity laminate</td>
<td>Complex dual side Organic packaging w/ cut-out</td>
</tr>
<tr>
<td>Laser source</td>
<td>Off module</td>
<td>On Module</td>
<td>Off Module</td>
<td>On Module</td>
</tr>
<tr>
<td>Fiber Attach</td>
<td>GF passive</td>
<td>GF Passive</td>
<td>GF Passive</td>
<td>GF Passive</td>
</tr>
<tr>
<td>Fiber count per PIC (SMF)</td>
<td>24</td>
<td>16</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Other key PIC features supporting Co-package</td>
<td>Flip chip compatible, Cu u-pillars,</td>
<td>Laser cavity w/ multiple direct laser attach on PIC, Cu-P receive pads</td>
<td>Cu u-pillar receive pads, backside grind, Reflow compatible</td>
<td>Cu-P receive pads, Reflow compatible, 2-sided PIC FA</td>
</tr>
<tr>
<td>Packaging portable to Microelectronic OSATs?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

*Figure 3: Example of an optical module for CPO applications
Figure 3: Example schematic of a 3D IC CPO assembly
Summary

• GF Silicon Photonics technology is based on monolithic integration of RF CMOS and optical devices brings unique performance advantages
  • Reduction of interconnect parasitics
  • Close proximity of CMOS and SiPh allow to build high bandwidth dense transceivers
• GF Silicon Photonics technology has differentiating packaging solutions integrated into the technology to allow for efficient and cost effective packaging solutions extendable to co-packaged optics requirements.
Thank you

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