Solving Technical Challenges of PICs through the Advancement of Integrated Silicon Photonics Solutions for the 21st Century

(Invited paper)

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ABSTRACT

In this paper, AIM Photonics describes how developing a widely accepted set of processes and protocols for the design, manufacture, and integration of silicon photonics systems not only advances this technology, but also presents a tremendous economic opportunity, with the overall global market estimated to grow to more than $795 billion by 2022. Integrated Photonics is finding use in a wide range of areas including: telecommunications, laser based radar, data communications, sensing, and many others. Integrated photonics dramatically improves the performance and reliability of electronic integrated circuits while significantly reducing size, weight, and power consumption. Integrated photonics will advance established industries and enable new ones in the 21st century in the same way that semiconductors fostered the revolution in computing, telecommunications and other fields over the past 40 years.

1. INTRODUCTION

This paper details various projects and results driving advancements of integrated silicon photonics. Recent successes are highlight in data comm, sensors, and manufacturing. AIM Photonics addresses challenges associated with key technologies and manufacturing of integrated silicon photonics. Automated electro-optical inline testing and automated fiber attach are two key volume manufacturing challenges being addressed. In addition, advancing transceiver technologies for communication, and sensors for bio medical and chemical detection purposes are presented. AIM Photonics has also worked the past two years to establish a silicon photonics Process Design Kit (PDK) to enable small to medium sized companies access to validated and tested devices for previously mentioned key technologies.

AIM Photonics partnership with EPDA industry leaders, large and small PIC companies, government institutes, and globally recognized university researchers has establish an ecosystem that provides complete access across the entire product cycle; design, research, development, proof of concept, prototyping, validation, and fast transfer to volume manufacturing. This allows AIM Photonics partners a low cost solution with quick cycles of learning, creating reduced time to market, all while advancing the broader silicon photonics manufacturing ecosystem.

2. HIGH DENSITY FIBER-CHIP INPUT/OUTPUT (I/O)

AIM Photonics and partners are developing the critical fiber-to-photonic chip coupling technology that will become the mainstay manufacturing solution at the Test Assembly and Packaging (TAP) Facility in Rochester, New York. Widespread commercial adoption of integrated photonics has been impeded by the challenges of realizing low cost scalable optical I/O packaging solutions. The fiber and fiber array connector envisioned in this PIC attach process would open a path to high volume manufacturing, with unprecedented coupling alignment tolerances for scalable, cost effective assembly. The significant reduction in the size of components, as depicted in Figure 1, will result in cost reductions for those components [1].

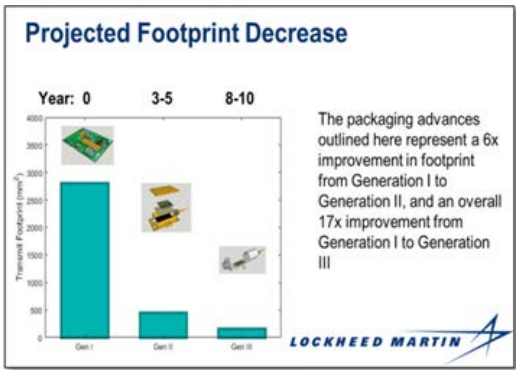

Figure 1. Timeline for reduction in packaging footprint. Credit: Lockheed Martin.

3. DEVELOPMENT OF UNIVERSAL TRANSDUCER COMPONENTS AND MICROFLUIDIC SYSTEMS

This project demonstrates photonics manufacturing processes for common detection elements of chemical and biological sensors and completed testing of photonics based components that detected simulants of the chemical warfare agent Sarin within tolerances approaching Department of Defense (DoD) requirements. This is the first time a sensor of this type, as shown in Figure 2, has been manufactured using a process that can be scaled for commercial production [1].

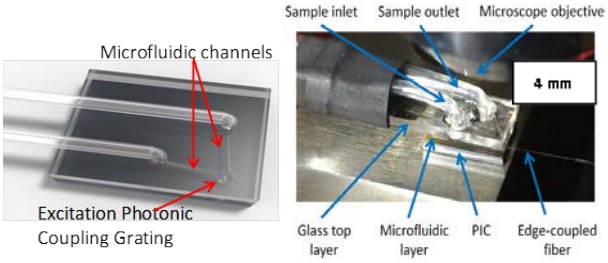

Figure 2. Schematic (left) and fabricated device (right) for microfluidic-enabled PIC for SERS. Credit: Carl Meinhart, University of Rochester.

4. HIGH CAPACITY PHOTONIC INTERCONNECTED SYSTEMS

AIM photonics recently completed set of key design deliverables, which were implemented with the assistance of products from member companies working in the AIM Photonics Data Communications Key Technology Manufacturing Area, in developing very high speed photonics-based digital and data communication links. By replacing electronic switches, which have been a major communication bottleneck and power sink in data centers, this technology will increase capacity tenfold and reduce energy consumption-per-bit transmitted by a factor of 10.

Another recent accomplishment is the completed installation of inline controls and test equipment to permit optical and electrical testing of photonic components. Such testing is a key to the improving photonics manufacturing processes. Inline testing significantly improves yield and reduces scrap loss. This will advance the development of (PIC) technology area for AIM Photonics members and other organizations by reducing cycles of learning and product development costs. The test system, shown in Figure 3, is the first of its kind [1].

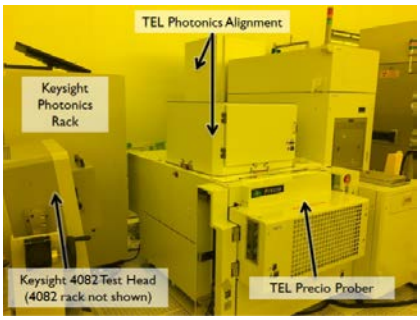

Figure 3. Newly installed electrical optical test equipment in the SUNY Poly cleanroom. The tools, part of the Inline Test Development project, will reduce the time to detect a misprocessed wafer from 4 months to a few days. Credit: AIM Photonics

5. PHOTONICS PROCESS DESIGN KIT COMPONENT LIBRARY

Analog Photonics, LLC and SUNY Poly expanded the comprehensive set of publicly available silicon PIC components in the integrated photonics process design kit (PDK). Continued development of the PDK is an essential enabler for both the baseline technology and the efficient design of products that will ultimately be manufactured. Work in 2017 provided new capabilities in optical integration, enabling reductions in the time to market, product development risk, and investment. Combined with Multi-Project Wafer (MPW) runs, this PDK will give AIM Photonics members access to silicon photonics components for the development of 100G, 200G and 400G+ optical transceivers or systems used in data centers, metro and long haul optical networks. Some features of the APSUNY_PDK are:

- 50Gbps modulation with less than one volt peak to peak drive. Low voltage drive at high bandwidth is key to enable low power applications and work with CMOS/BiCMOS drivers.
- Digital detectors with greater than 45GHz bandwidth and high responsivity, ideal for C-band receivers.
- Both polarization support for standard and low-cost single mode fibers, eliminating the need for expensive polarization maintaining fibers.
- Lower loss crossings and propagation with seamless dielectric transitions and <1% mismatch between the outputs of a 3dB splitter, leading to a high common mode rejection ratio (CMRR) [2].

6. TEST, ASSEMBLY, AND PACKAGING (TAP) FACILITY PROCESS DEVELOPMENT

The planning, construction, and implementation of the TAP Facility is near completion. Validation and testing of products for the facility are performed in advance with the help of industrial partners and their design teams. The TAP Facility, which represents an investment of $194 million by New York State for facility upgrades, equipment, installation, and lease costs, will open in the second half of 2018 [3].

7. CONCLUSIONS

Prior to the establishment of AIM Photonics, the growth of the integrated photonics industry was impeded by an immature manufacturing and design ecosystem. The ecosystem being created by AIM Photonics harnesses the combination of the nation's leading experts in photonics integration from both industry and academia.

ACKNOWLEDGEMENTS

AIM Photonics also recognizes its members and partners who are instrumental in driving the technology advancements through this national network for manufacturing innovation for integrated photonics.

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