AIM Photonics Design Enablement: A Design-Assembly-Test Platform Advancing the Silicon-Photonics Ecosystem

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Abstract: AIM Photonics design enablement platforms supporting photonic integrated circuit design, interposer-based assembly, and design-for-test for a 300 mm CMOS-compatible silicon-photonics foundry are presented.

1. Introduction

In this paper, we present the AIM Photonics design enablement platforms that support conventional photonic integrated circuit (PIC) design and extend to interposer-based assembly and test and measurement. The platforms are developed for 300 mm silicon-photonics processes manufactured in a prototype foundry at the Albany NanoTech Complex Albany, NY.

2. AIM Photonics Design Enablement

Customers need to think about their final product or assembled package early in the design phase since packaging can impact design considerations. It is important for customers to engage with AIM Photonics before finalizing PICs, interposer designs, and testing options and use the available design kits that are shown in Fig. 1. This will ensure compatible interfaces on the PIC and/or interposer chips, which are independently designed using their respective Process Design Kits (PDKs), as well as other required interfaces for a final package, including electronic integrated circuit (EIC) flip chip bond pads, fibers and fiber array units (FAUs), and customer-provided or AIM Photonics-standard printed circuit board (PCB) bond pads. The desired interfaces between various components will require specific design rules that affect the PIC or interposer design layout, thus providing true co-design for PIC design, packaging, assembly, and test.

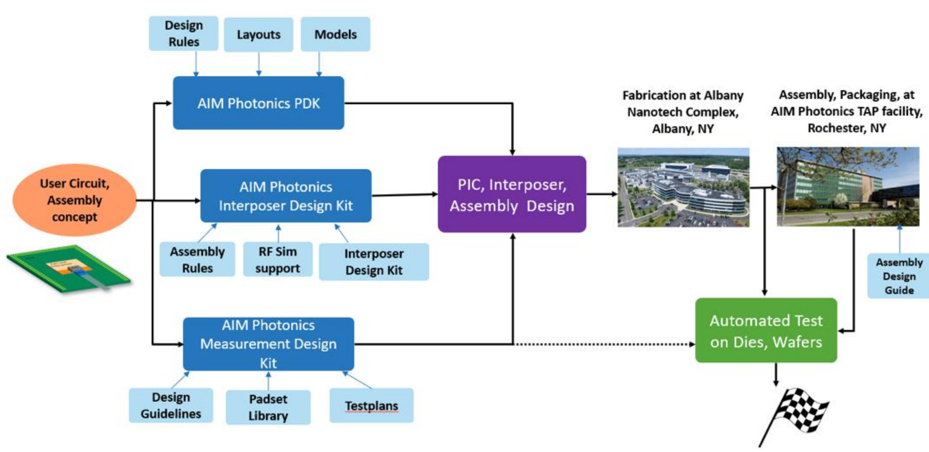

Fig. 1. AIM Photonics design Enablement offerings, including PIC Design-Assembly-Test

3. PDK for PIC Design

AIM Photonics has a legacy of developing PDKs for PIC design [1]. AIM Photonics PDKs contain component layouts, models, design-rule-checks, and schematic-driven-layout and is available on major EPDA platforms such as Cadence, Synopsys, Ansys, Luceda, and Siemens [2]. In addition to the baseline “ACT1” platform [3] with a mature

PDK and a Multi-Project Wafer (MPW) service operating since 2016, recent offerings include a low-loss 'Quantum Flex Platform' [4] and SiN [5] technology targeting sensor applications.

The Quantum FLEX Platform targets quantum computing applications and high-performance optical communication applications. The Quantum FLEX Platform PDK includes several novel features in the technology offering, including the introduction of various etched "trenches" that users can use in their designs. These trenches are specifically designed to enhance thermal isolation for thermo-optic devices, improve sensing, or lower optical coupling loss. The PDK also contains a variety of doping options, enabling the design of lateral and vertical junction modulators (Fig. **1**Fig. 2) and avalanche photodetectors.

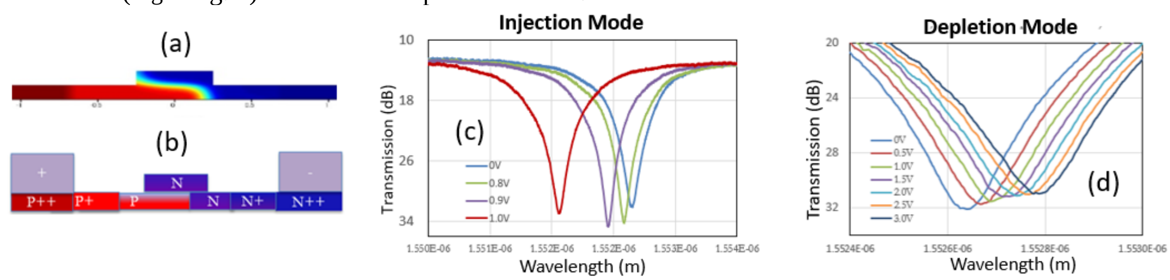

Fig. 2. Vertical Junction Modulator Demonstration in AIM Photonics Quantum Flex Technology. (a) Illustration of Vertical Junction Doping profile simulation (b) Component cross-section with doping levels indicated (c) Injection Mode data (d) Depletion Mode data

The Sensors PDK contains various SiN components such as couplers (Fig. 3), splitters, and waveguides targeting the 700 nm to 1600 nm range. In addition, sensor circuit designers can readily choose from a suite of ring resonator components with oxide, air, and water cladding options. Accurate compact models are offered that describe the measured characteristics of these resonators (Fig. 4).

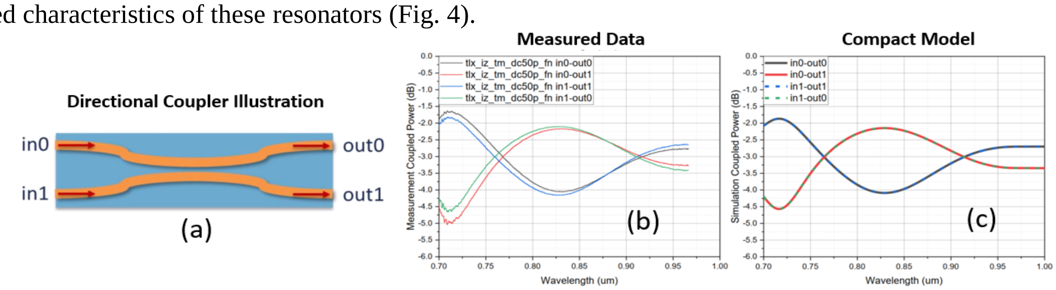

Fig. 3. Directional Coupler Component (a) Measured Data (b) and Compact Model (c) from Sensors PDK

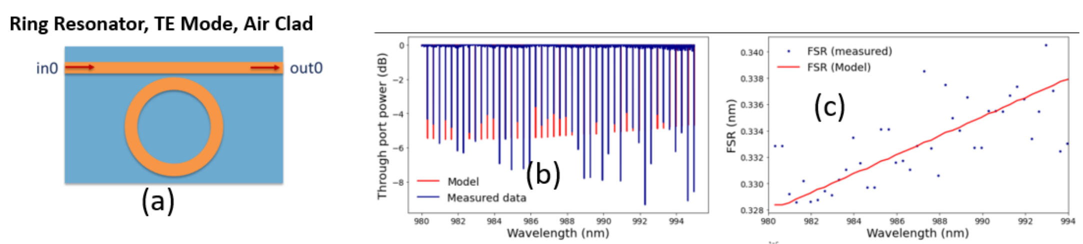

Fig. 4. Air Clad TE Mode Ring Resonator (a) Transmission Spectrum (b) Free Spectral Range (FSR). Blue= Data, Red=Model

4. Interposer Design Kit for Assembly

The Active Interposer (AI) platform includes design, assembly, and test of 3D packaged optoelectronic systems. The PDK has a full suite of components and assembly procedures as shown in Fig. 5 (a). Passive and active photonic components include Si and SiN waveguides, edge couplers, photodetectors, filters, and modulators in the C, L, and O bands. In addition, electronic components are included with wirebond and ball-grid array (BGA) pads, controlled impedance transmission lines, and on-chip capacitors and inductors. These electrical components can be used independently on the simplified Electronic Interposer (EI) platform without any photonics. Assembly processes supported include wirebonding, fiber attach, flip-chip CMOS/BGA attach, and 2.5D laser attach.

A fully packaged EI demonstrator with flip-chip CMOS and BGA is shown in Fig. 5 (b). Assembly is a two-step process where the CMOS chip with copper pillars at a 60µm is flipped onto an EI chip to form high-density electrical connections. It is then attached to a control PCB with an 800µm pitch BGA. In Fig. 5 (c), we present a 2.5D laser demonstrator with a commercial DFB laser. This laser is flip chip attached directly inside a trench in the silicon photonics which enables edge coupling between them. The coupling efficiency between laser and silicon photonics chip was estimated to be ~3dB. The demonstrator exhibits a clean lasing spectrum with a >50 dB SMSR and an on-chip power in the silicon photonics waveguide exceeding 10dBm with a drive current of 100mA.

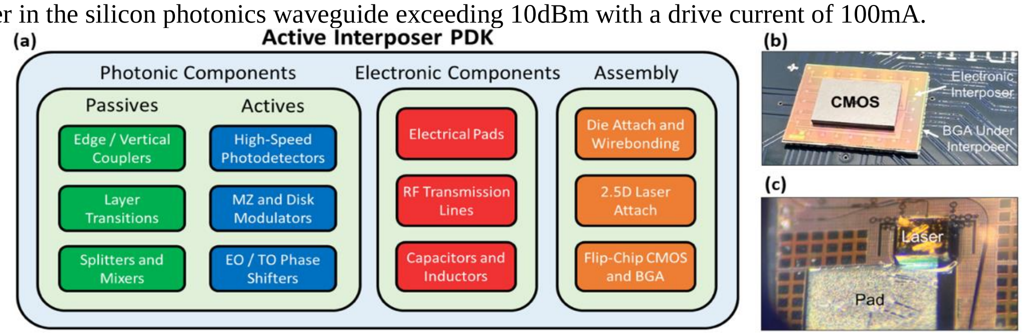

Fig. 5. (a) Organization of the Active Interposer PDK at AIM Photonics. (b) Picture of an Electronic Interposer Demonstrator with Flip-Chip CMOS and bottom Ball-Grid Array (BGA). (c) Micrograph of III/V DFB Laser Flipped into Trench in Silicon Photonics.

5. Measurement Design Kit for Design-for-Test

AIM Photonics offers a test service that includes measurements of optical, electro-optic, and advanced RF performance of PICs that are manufactured internally or in external foundries [6]. A comprehensive equipment set supported by a 300 mm prober with automated optical alignment is housed at AIM Photonics' facilities in Albany, NY, and Rochester, NY.

To ensure that customer designs are compatible with the test equipment at AIM Photonics, a "Measurement Design Kit" (MDK), analogous to the PDK, is introduced that includes a padset component library and measurement design guide (MDG). A parametric cell that lets users create various electro-optic padset configurations consistent with the test setup is included in the MDK library, as shown in Fig. 6.

Fig. 6 (a) Electro-optic automated prober with probes connected in the padset shown in (b) (c) Example of an eye diagram of a Mach-Zehnder Modulator with 5GBaud NRZ input measured at TAP facility, AIM Photonics, Rochester, NY

For customers that want to perform measurements at their own facility a set of testplans based on the Python-based SweepMe! measurement platform [7] are also included in the MDK. These testplans are currently applicable for on-wafer vertical coupling-based measurements using a 300 mm semi-automatic prober from MPI Corporation and instruments and drivers within the Keysight Photonic Application Suite. Support for additional configurations will be added in the future.

6. Acknowledgements

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