Packaging Efforts for Inter- and Intra-Board Level Optical Interconnects

Ray T. Chen, Li Wang, Jinho Choi and Xiaolong Wang

University of Texas at Austin, 10100 Burnet Road, Bldg.160, Austin, TX, 78758

We demonstrate a flexible optical waveguide film with integrated Vertical-cavity surface-emitting laser (VCSEL) and positive-intrinsic-negative (PIN) photodiode arrays for fully embedded board level optical interconnects. The optical waveguide circuits with 45° micro-mirror couplers are fabricated on a thin flexible polymeric substrate by soft molding. 45° micro-mirrors on waveguide array for fully embedded board level optical interconnections are investigated both theoretically and experimentally. Smooth mirror surface fabrication is demonstrated by using microtome blade. Thin film VCSEL arrays and PIN photodiode arrays are directly integrated on to the waveguide film. Measured propagation loss of the waveguide was 0.3dB/cm at 850nm.

The speed and complexity of integrated circuits have increased rapidly in recent years, and this trend continues. As the number of devices per chip, the number of chips per board, the modulation speed, and the degree of integration continue to increase, electrical interconnects are facing their fundamental bottle-necks, such as speed, packaging density, fan-out, and power dissipation. Multichip module (MCM) technology is employed to provide higher data transfer rates and circuit densities [1]. However, the state-of-art technologies based on electrical interconnects fail to provide the required multi-Gbit/s clock speed and communication distance in intra-MCM and inter-MCM hierarchies [2]. Even if the transmission speed was left the same and data bus width expanded, it would probably mean more IC pins and other more interconnect layers problems [3]. Optical interconnect is a promising solution to overcome the electrical interconnect bottleneck problems since it has inherent advantages of high bandwidth, no capacitive loading and immunity to electromagnetic interference. In contrast to a electrical interconnect, the optical interconnection transmits information at a higher data rate, consumes less power, and occupies less real estate on the board. Recently many research groups have worked on board level optical interconnect systems and demonstrated their viability [4]-[6]. However, there are still some difficulties in packaging and manufacturing to overcome.

In this report we propose employing fully embedded optical interconnects (FEOI) at the printed circuit board (PCB) level, in a reliable and robust fashion. FEOI provide not only process compatibility with the standard PCB processes but also provide a reduced footprint on the PCB. This is accomplished by fully embedding all optical components such as light sources, channel waveguides and detectors among the other PCB electrical layers as indicated in Fig 1. The pulsed laser light from the VCSEL is normally coupled into the multimode waveguide through a 45° micro-mirror coupler. It propagates through the waveguide, then is reflected at the output interface of the waveguide by another 45° micro-mirror coupler, and finally is illuminated vertically on the active area of the photodetector. This process provides no interface problem between electronic and optoelectronic components as conventional approaches do, and additionally, real estate of the PCB surface is free to be occupied by electronics and not by optoelectronic components. The performance enhancement due to the employment of the optical interconnection is observed. In order to implement FEOI; the characteristics of four main components have to be investigated.

- thin film vertical cavity surface emitting laser (VCSEL) as optical transmitter
- flexible polymer waveguide as optical transmitting media
- 45° micro-mirror couplers
- thin film PIN photodiode as optical receiver.

0-7803-8557-8/04/$20.00©2004 IEEE

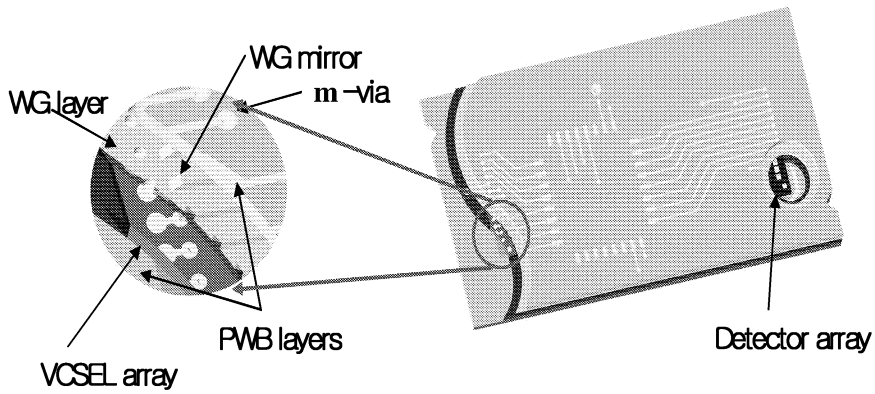

Fig. 1. Illustration of a fully embedded board level optical interconnect

Polymer-based waveguides are employed in this FEOI to provide the integrated optical circuitry. Polymers have exclusive advantages for use as optical layer waveguide on PCB. They provide ease of process, cost-effectiveness and high performance characteristics such as lower optical loss and thermal stability [1]. For integration of polymer waveguides into multi-layer PC boards to occur, the waveguides have to withstand more than 1 hour exposure of 180ºC and 350psi during the lamination. For this reason, the ultra-violet (UV) curable resin ZPU12-460 and ZPU12-450 (available by Zen Photonics) were chosen as the core and cladding materials. The refractive index of ZPU12-460 and ZPU12-450 are 1.47 and 1.46 at 850 nm. They are low loss, low birefringence and environmental stable. The polymeric foil Topas (cyclo-olefin-copolymer) from Ticona was chosen as the mechanical support for optical layer. The Topas film is highly transparent, has a low loss at 850nm and has a high glass transition temperature (150°C).

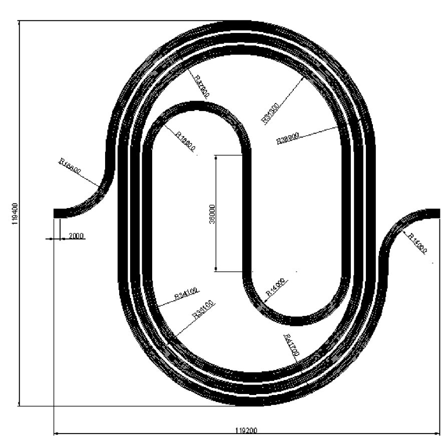

Fig. 2. The total length of 109 cm waveguide layout design

For board-level interconnection, the interconnection distance can be easily in the range of tens of centimeters up to 1 meter. We designed the two waveguide patterns: a 51 cm long and a 109 cm long pattern shown in Fig.2. Both had cross sections of 50µm×50µm to relax alignment tolerances and contained 12 waveguide channels with 250µm separation between individual channels.

Further details of the research work will be presented in the conference. This research is supported by DARPA, MDA, AFOSR, ONR, Sematech and the ATP program of the State of Texas.