Performance Evaluation of Fully Embedded Board Level Optical Interconnection

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Summary

We have made a thin flexible waveguide film for fully embedded board level optical interconnections[1]. Fig. 1 shows the schematic diagram of a flexible waveguide film with optoelectronic devices. First, the master waveguide structures are formed on a silicon wafer using a standard photo-lithography process. SU8-2050 (MicroChem™) is used as the waveguide structures having 12 channel guides with a square shape cross-section (50 μm x 50 μm) and a total length of up to 100 cm.

45° total internal reflective (TIR) micro-mirrors are adopted to couple light from the VCSELs into the waveguide array, and then to the PIN photodiodes[2]. To get a soft mold with 45° micro-mirror couplers, the master waveguide structure is cut on both ends by a specially designed tool. PDMS (Sylgard 184, Dow Corning) is chosen as a soft mold material. The PDMS is poured on the master waveguide structure and cured. Surface relief waveguide patterns with 45° micro-mirror couplers are transferred from the master waveguide structure to the soft mold.

A flexible waveguide film is fabricated by the soft molding process. The core material (SU-8) is poured on the heated soft mold and then excess SU-8 is scraped out. The soft mold filled with SU-8 is covered with Topas™ 6015 (cyclo-olefin-copolymer) film, as a bottom cladding layer. The core waveguide structure is transferred from the soft mold to Topas™ 6015 film using a hot-press machine. A flexible waveguide film without the top cladding layer is exposed to UV light to cross-link the SU-8 and the surfaces of the 45° micro-mirrors are deposited with aluminum (Al) to ensure the total internal reflection. Finally, the top cladding layer is spin-coated on the film. Measured propagation loss of the waveguide is below 0.5 dB/cm for both TE and TM modes at 850nm.

Two 12-channel, 850 nm VCSEL arrays (2.5Gb/s and 10Gb/s) and a PIN photodiode array are used as I/O sources on a flexible polymeric waveguide film. The initial substrate thickness (200 μm) of the VCSEL is reduced to facilitate thermal management of the VCSEL and the fully embedded structure. Fig. 2 shows the L-I characteristics of two 12-channel VCSEL arrays. Apertures of optoelectronic devices are precisely aligned with I/O windows of the 45° micro-mirror couplers and fixed by a UV curable adhesive. The performance features of the 10 Gb/ses 12-channel VCSEL array are summarized in table 1. Fig. 3 shows an integrated VCSEL and PIN photodiode arrays. Conventional PCB lamination processes are applied to interpose a flexible waveguide film between PCB layers to form the fully
embedded structure in Sanmina-SCI. Further experimental results will be presented in the conference. This research is sponsored by DARPA, MDA, ONR and Sanmina SCI.

Figure 1. (A) A flexible optical waveguide film, (B) 12-channel VCSEL array, (C) 12-channel PIN Photodiode array, (D) 45° micro-mirror couplers.

Figure 2. L-I characteristics of 12 channel VCSEL array for the 10Gb/s (Both top contacts) and the 2.5 Gb/s (Top and bottom contacts).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Threshold Current</td>
<td>0.5 ~ 1.5 (mA)</td>
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<tr>
<td>Slope Efficiency</td>
<td>0.35 ~ 0.55 (mW/mA)</td>
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<tr>
<td>Central Wavelength</td>
<td>848 ~ 860 (nm)</td>
</tr>
<tr>
<td>Spectral Width(RMS)</td>
<td>0.45 ~ 0.6 (nm)</td>
</tr>
<tr>
<td>Forward Voltage (I_T=5mA)</td>
<td>1.4 ~ 2.0 (V)</td>
</tr>
<tr>
<td>Beam Divergence</td>
<td>27 ~ 32 (deg)</td>
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<tr>
<td>Reverse Leakage Current</td>
<td>5 ~ 20 (pA)</td>
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* Conditions: T_amb = 25°C, I_T = 2 ~ 5 mA

Table 1. Electro-optical characteristics of the 10Gb/s 12-channel VCSEL array.

Figure 3. Integrated VCSEL and PIN photodiode arrays on a flexible optical waveguide film.

References
