Polymer-based Passive Photonic Components with on-chip Fiber Grooves and Thin Film Filters

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Abstract— **Passive photonic components based on polymer planar waveguides combined with integrated thin film filters are demonstrated. Etched on-chip grooves provide the possibility of automatic and passive fiber attachment with high coupling efficiency. 1x2 multiplexers show extremely low insertion loss (< 1 dB) and low crosstalk level (< -30 dB). Integrated polarization splitters exhibit more than 35dB TE/TM extinction ratio over a 20nm wavelength window.**

I. Introduction

Modern optical fiber based communication networks are in increasing demand for highly functional, small footprint, low power consumption, and low-cost optical modules. Photonic integration - monolithic or hybrid - is considered a key technology to achieving these requirements. The latter approach relies on planar light wave circuits (PLC) serving as integration platform. To this end various material platforms are being utilized. We have been developing polymer-based PLC technology (P2LC) which is attractive in several respects: flexible and potentially low-cost fabrication including passive alignment packaging [1]; applicability of different substrates and incorporation of heterogeneous materials because of low-temperature processes; easy micro-machineability, amongst others. We are pursuing a “toolbox” concept [2, 3] in which on-chip fiber grooves, thin film filters (TFFs), and 45° turning mirrors are involved as crucial elements. The toolbox also encompasses hybridized integration of active devices, in particular photo- and laser diodes. In this paper, we focus on passive fiber attachment and the integration of thin film filters for wavelength (de)multiplexing and polarization splitting.

II. On-Chip fiber attachment

Fiber/waveguide coupling has proven to be challenging for PLC due to the refractive index and/or the optical mode mismatch. The coupling issue becomes more serious with high-index contrast PLCs, based on e.g. silicon (SOI) and III-V semiconductors. The solutions are either expensive (with spot size converters) or bulky (with vertical grating couplers). For low-index contrast PLCs, such as silica or SiNx platforms, the coupling issue is less severe and can be solved by end-fire coupling with the aid of anti-reflection coatings. However, the end-fire coupling often suffers from poor mechanical support and the need for an extra sub-mount to hold the fiber in place.

On the polymer platform we have performed fiber/waveguide coupling by means of on-chip U grooves, as shown in Fig. 1. The U-groove width matches the fiber diameter and is etched down to the point where the fiber core and the waveguide centre are aligned. Horizontally, they are defined to the respective waveguides in a self-aligned manner thus providing virtually perfect lateral adjustment. In addition, the fiber/waveguide interface can be angled at 8° to reduce back reflection. The deep groove is etched by standard oxygen reactive ion etching utilizing a thin metal mask. The uniformity achieved across a whole 4-inch wafer is within 1µm for both width and depth.

With proper index-matching glue and waveguide tapering for mode matching, the typical loss per-facet for the U-groove based fiber/waveguide coupling is as low as 0.25 dB over a broad spectral range from 1300-1600nm. Together with a company partner an automated “pick-and-place” fiber attachment process is under development.

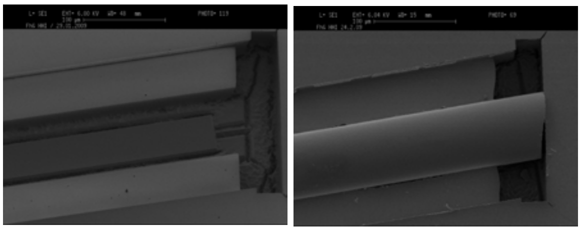

Fig. 1: SEM photos of U grooves with (right) and without (left) angled fiber inserted.

III. Thin film filters

Optical filters are key components in any optical network using different operating wavelengths. We have studied the implementation of filter functions using thin film filter elements. These are vertically inserted into dedicated slots crossing the PLC waveguide, as schematically shown in Fig. 2. The TFF slots are etched in the same process as used for the fiber U-groove formation but may also be simply formed by applying a dicing saw, subject to wafer and chip layout. The width of the slot needs to be well adjusted to the thickness of the filter platelet. The verticality of the mounted filter and its thickness are determining parameters for the excess loss. The thin film filters themselves are made by ion beam sputter deposition of appropriate dielectric layers onto a polymer film (same polymer material as used for the waveguide cladding) which again is spun on a sacrificial Si substrate. The total thickness of the eventual filter element measures between some 15-25 µm only, depending on the spectral requirements.

As an application example we demonstrate a 1x2 1310/1490 (or 1550) nm (de)multiplexer, as utilized in FTTH networks (Fig. 2). The total chip made on Si substrate measures 5 mm (length) by 1.3 mm (width). The input signals at wavelengths 1310 nm and 1490 nm (or 1550 nm) are launched into the input port. Using a long wavelength pass filter (LWPF), the optical signal at wavelength 1490/1550 nm will pass it to exit at output port 2 whereas the signal at 1310 nm will be reflected by the TFF to the output port 1.

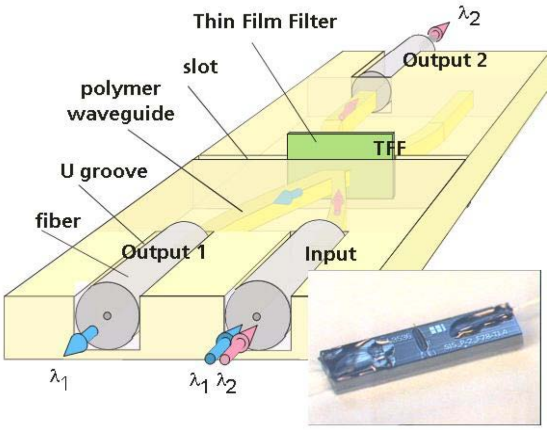

Fig. 2: The schematic of the 1X2 multiplexer

The polymer material used is commercially available and employed for qualified components. The buried waveguide core has a typical cross-sectional dimension of about 6 µm in both width and height to ensure single-mode operation. The waveguide loss is around 0.5 dB/cm at 1550nm and 0.4dB/cm at 1310nm. The full angle between the two waveguides is 16°, which efficiently suppresses back-reflection while keeping the slot loss at a minimum.

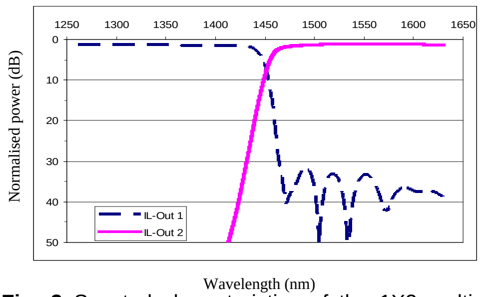

Fig. 3 Spectral characteristics of the 1X2 multiplexer, with the blue curve indicating the signal at output #1 (reflected) and the purple curve the signal at output #2 (transmitted).

The measurement result is shown in Fig. 3, displaying the filter performance of the LWPF. At 1310nm, the insertion loss at output port 1 is around 1.2 dB. The other channel at 1550nm exhibits an even smaller loss of 1.0 dB. The crosstalk level is below -30dB. Across the whole wavelength range, the back reflection into the input fiber (optical return loss) is well below -50 dB. If we subtract the loss from the fiber connectors and only consider the net insertion loss from the input fiber to the output fiber, the device itself features a loss well below 1 dB. The maximum polarization dependent loss is 0.5 dB.

IV. Polarization Beam Splitter

Polarization splitting is another key function, especially with polarization diversity type PLCs. There have been many integrated polarization splitters reported, using gratings, waveguide birefringence, photonic bandgap effect, and others. We propose, however, a fairly easy solution by again using a thin film element (PSTFF). The schematic architecture of the device is similar to Fig. 2. Depending on the characteristics of the PSTFF, one polarization will be reflected to output 1 and the other will pass through to output 2. The incident angle from the waveguide to the PSTFF, i.e. the half-angle between the two waveguides, can be varied to optimize the splitting ratio for a desired bandwidth.

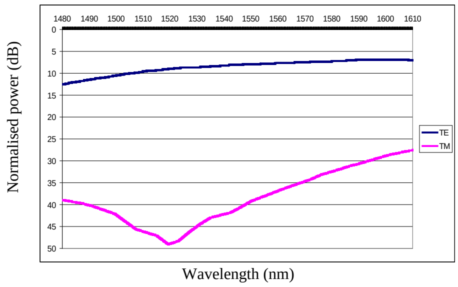

Fig. 4 Spectral characteristics of the polarization beam splitter at output 2 (transmitted). The blue curve indicates the TE polarization and the purple curve shows the TM polarization.

As an early result, Fig. 4 shows the spectra for TE and TM signals at the output port 2. At 1520nm, the splitting ratio is around 40dB with a 3dB bandwidth of ~20nm. Further studies are in progress to optimize the device in terms of smaller insertion loss, larger splitting radio and bandwidth.

V. Acknowledgement

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[3] N. Keil, Z. Zhang, C. Zawadzki, C. Wagner, A. Scheibe, H. Ehlers, D. Ristau, J. Wang, W. Brinker, and N. Grote, Electronics Letters, Vol. 45, Issue 23, pp. 1167–1168, 2009.