Low-Cost Single Mode Optical Passive Coupler Devices with an MT- Interface Based on Polymeric Waveguides in BCB

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Abstract

The authors have demonstrated the feasibility of using Benzocyclobutene (BCB) waveguides for realization of low-cost single mode optical modules, for example WDM filters or power splitters, with multi-channel connector interfaces.

Key words:

Waveguides, Optical Couplers, and Benzocyclobutene (BCB) Dielectric.

1. Introduction

The introduction of new types of interactive multimedia services (Internet) raises the demand for substantially increased capacity of the existing telecommunications network infrastructure, which is only possible by wide use of optical fibers in switching, transport and access system equipment.

Planar waveguide technology is one of the technological areas, which can make an important contribution to the breakthrough of the optical solutions[1-3]. Silica-on-silicon has been the most widely-used waveguide material for telecommunications applications. However, full implementation of the "low-cost/high-volume" Fiber-To-The Home (FTTH) scenario requires introduction of less expensive materials and fewer step production processes, therefore polymer solutions have to be considered. A promising choice for fabrication of buried Single Mode (SM) waveguides for both passive and active components is benzocyclobutene (BCB)[4].

The purpose of this research study was to investigate whether Single Mode performance can be achieved in buried BCB waveguides as well as whether process window is suitable for standard batch manufacturing. Furthermore, the waveguides were applied for realization of low-cost optical splitter and WDM filter with an MT-connector interface (an optical interface for a commonly used ribbon fiber connector (MT = Mechanical Transfer), as illustrated in Figure 1.

The use of a "receptacle" type of the MT-connector interface makes it possible to achieve lower fabrication cost, higher compactness, and easier handling compared to pigtailed devices.

2. Waveguide Fabrication

Benzocyclobutene (BCB), commercially available under the name of Cyclotene™ from Dow Chemical, is a dielectric material developed for microelectronics applications. The family of BCB-materials has superior dielectric properties, low moisture absorption, good planarization properties, good thermal stability, and low shrinkage factor as compared to other polyimides[5-7].

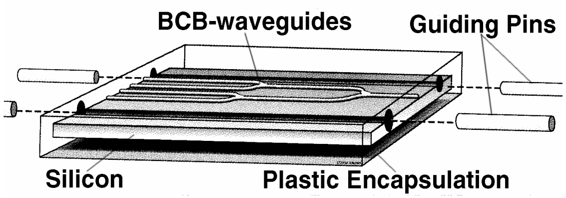

Figure 1. Schematic view of power splitter module.

Two types of BCB materials were used for manufacturing of buried SM waveguides. A dry etching was used for under and over cladding of the waveguides, and a photo-definable version, photo-BCB, as the core material.

The process parameters, and not only the chemistry of the BCB, infuence the index step between the core and the cladding. At this stage, a standard silicone wafer was used as a substrate for the waveguide. An e-beam fabricated lithographic mask was used for patterning of the waveguides. Three different types of waveguide structures were fabricated: straight waveguides, Y-splitter branches, and directional coupler structures. There were in total 44 different chips on the mask. The size of each chip was 6 mm x 14 mm.

Theoretical calculations were performed to determine optimal bending radii for the waveguide channels. The bending radius used in the Y-splitter and directional couplers was chosen to be 30 mm. Directional couplers had widths between 6 µm and 10 µm and different lengths and separation distances. A typical core layer thickness was 7µm, defined by spinning parameter of the photo-BCB.

3. Encapsulation of the Device

A transfer molding process was applied to encapsulate the waveguide structures and to form the optical MT-interface. A tool, previously developed at Ericsson for manufacturing of MT-connectors, was modified for the purpose. The material used was a thermosetting resin filled with silica. A photo of a prototype module with an MT-connector from a side view is shown in Figure 2.

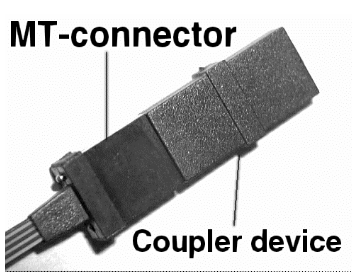

Figure 2. Splitter module connected to an MT - connector.

For alignment of the waveguides to the interface, the following technique was chosen. V-grooves were etched on the silicon substrate with a standard potassium hydroxide (KOH) process. In the molding tool, these V-grooves were pushed against two metal pins, thus, forming the precise holes for the guiding pins of the MT-interface.

In this case, the alignment precision depends on the accuracy in the lithographic procedures for patterning of waveguides and KOH etching for V-grooves, which makes the mechanical stability of the plastic material less important. This technique has a potential of achieving single mode performance, approximately ±0.5 µm alignment precision. The polishing of the MT-interface with BCB waveguides on the silicon carrier was performed with a modification of the standard procedure used for optical connectors.

4. Characterization Methods and Results

Optical loss measurements were performed on both encapsulated and non-encapsulated straight waveguides. The directional coupler structures were also optically evaluated. The optical loss for different waveguide widths was measured in a spectrum analyzer (Anritzu Corp.) in the wavelength range of 0.6-1.6 µm. The light from a white light source was butt-coupled to the waveguide using a single mode fiber with an index matching gel. At the output, the BCB waveguide was connected to a multimode fiber (NA = 0.25) using the index matching gel.

Attenuation measurement in waveguides cannot be easily performed using the cut-back method. This fact is due to the difficulties in cutting the waveguide carrier and the problems to obtain reproducible in and output coupling.

5. Straight Waveguides

On straight waveguides with widths up to 12 µm, single mode performance was established. A typical curve for the optical loss as a function of wavelength for a 6 µm waveguide is shown in Figure 3. Loss measurements of encapsulated straight waveguides with polished endfaces gave almost the same loss as the non-encapsulated waveguides.

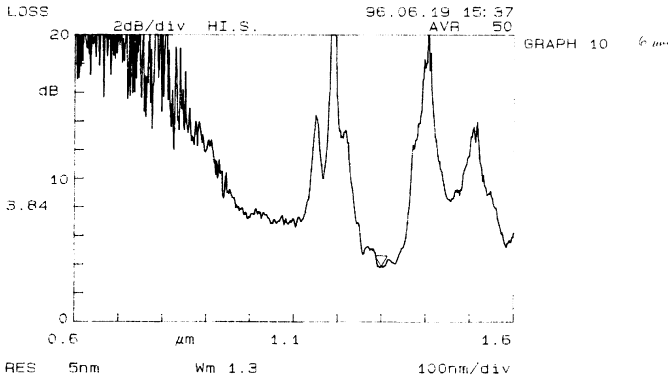

Figure 3. Typical loss curve for BCB waveguide.

6. Directional Coupler Characterization

In Figure 4, example of results from the characterization of the directional couplers are given. The directional couplers had the same interaction length but different separation between the waveguides in the coupling region. The results are shown as a function of the waveguide separation.

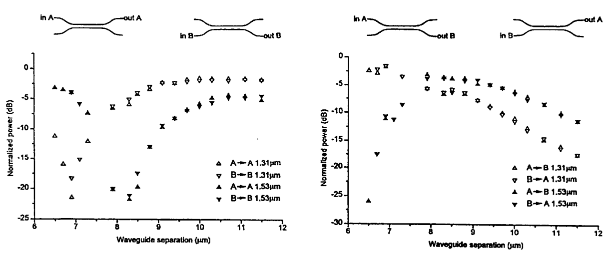

Figure 4. Evaluation of directional coupler.

For each directional coupler, light was launched into one of the two input waveguides channels. The optical output power was measured from the same waveguide (left hand diagram) and from the other waveguide (right hand diagram). The left hand diagram shows that the directional coupler with a waveguide separation of 6.9 µm operates as a WDM filter at the wavelength 1.31 µm and 1.53 µm into two different output ports.

7. Conclusions

The following conclusions were reached regarding feasibility of using BCB waveguides for optical passive branching devices:

- They can provide single mode performance while using uncomplicated standard processes,
- They can be applied for realization of straight waveguides, power splitters, and WDM filters, and
- They allow the use of plastic encapsulation and standard methods of interface polishing.

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