Compact SU8-silica Hybrid Thermo-optic Switch with Low Power Consumption

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Abstract— We propose a novel Mach-Zehnder interferometer (MZI) type thermo-optic switch based on SU8-silica hybrid waveguide structures. The switch consists of a 1×2 power splitter, two transmission arms and a 2×1 power combiner. The input/output waveguides and the power splitter/combiner are realized by the conventional silica waveguides, while the two arms for the MZI consist of SU8 strip waveguides. Such hybrid SU8-Silica waveguide strucutures combines the advantages of the low propagation loss of the silica waveguides and the large thermo-optic coefficient of SU8. Due to the high thermo-optic coefficient of SU8, the length of the transmission arm can be dramatically reduced.

1. INTRODUCTION

Optical switch is one of the key devices for optical communication system. Optical switches based on planar lightwave circuits (PLCs) have attracted extensive research interests due to compact structure, being integrated easily with other devices and large-scale production. Various material systems such as silica, silicon, and polymer have been employed to realize optical switches. Among them, silica-on-silicon [1] is considered to be one of the most attractive platforms for PLCs due to its low propagation loss and high coupling efficiency to optical fibers. However, the thermo-optic coefficient of silica is very small resulting in large dimension and high power consumption. A silicon-silica hybrid waveguide structure that utilizes a silicon waveguide as a TO phase shifter has been demonstrated [2]. It exhibits an extremely low power consumption but the fabrication processes are quite complicated.

Polymer based PLCs [3, 4] have a simple fabrication technology and the merits of low cost and high thermo-optica coefficient. Therefore, it is an important branch in modern integrated optics. In this paper, we propose a novel Mach-Zehnder interferometer (MZI) type thermo-optic switch based on SU8-silica hybrid waveguide structures. Small dimension and low power consumption can be achieved since then.

2. DESIGN AND ANALYSIS

The schematic of the SU8-silica thermo-optic switch is depicted in Fig. 1. Fig. 1(a) shows the top view of the device, which consists of a 1×2 power splitter, two transmission arms, and a 2×1 power combiner. Figs. 1(b) and (c) illustrate the cross section of the silica waveguide region (AA' cross-sction) and the SU8-silica hybrid waveguide region (BB' cross-section), respectively. Both the splitter and the combiner are based on multimode interference (MMI) coupler. The two transmission arms are designed to be asymmetric so that the function of switching can be realized while the two arms are heated. Buried silica waveguides which is the most popular platform for PLCs are considered in this paper. The refractive index of the substrate, core and upper-cladding are 1.45, 1.46, and 1, respectively. To be compatible with standard SMF-28 optical fiber and commercial laser diodes and photodetectors and minimize the polarization dependence, buried silica waveguides with a core size of $6 \times 6\,\mu m^2$ has been considered in this work.

For the purpose of reducing the coupling loss between the silica waveguide and SU8 waveguide, we have to optimize the SU8 waveguide dimension parameters, H, W, and h_{sub} (as shown in Fig. 1(c)). Mode solution is utilized to calculate the mode distributions for the silica waveguide and the SU8-silica hybrid waveguide. Overlap integral is then used to determine the coupling efficiency. Fig. 2(a) shows the coupling efficiency for waveguide with different H and W (at each H and W, h_{sub} is optimized to obtain a highest coupling efficiency). From Fig. 2(a), we can find that the coupling efficiency decreases while the W/H increases. Besides the couping efficiency between the silica waveguide and the SU8-silica hybrid waveguides, the ratio of the power confined in the SU8 region must be taken into account. If this ratio is very low, it will lead to a low effective thermo-optic coefficient, which causes large device dimension and high power consumption. Thus,

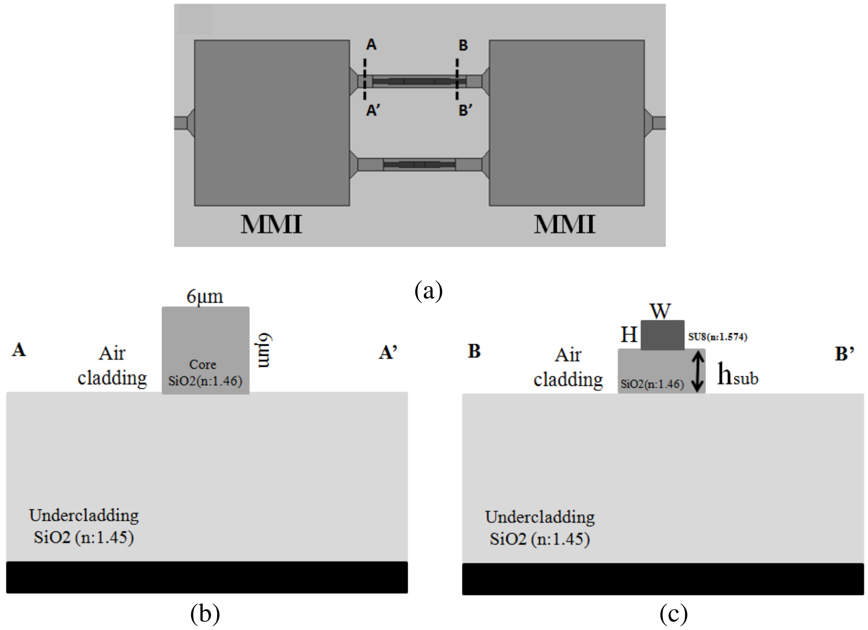


Figure 1: (a) The shematic of the SU8-silica hybrid thermo-optic switch; (b) the cross section of the silica waveguide region (AA'); (c) the cross section of the SU8-silica hybrid region (BB').

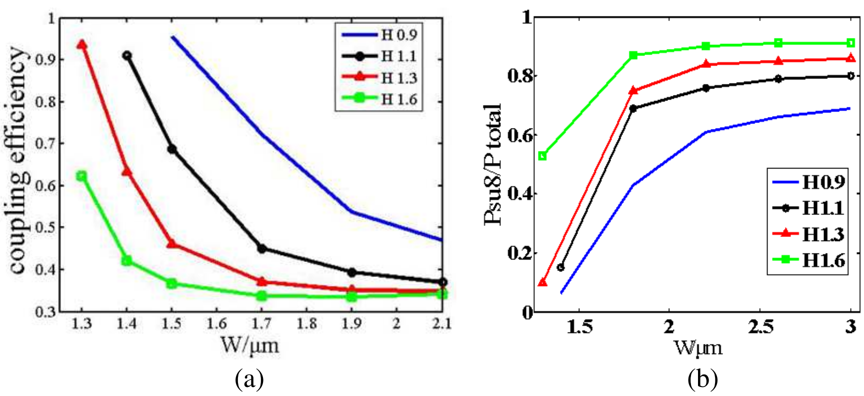
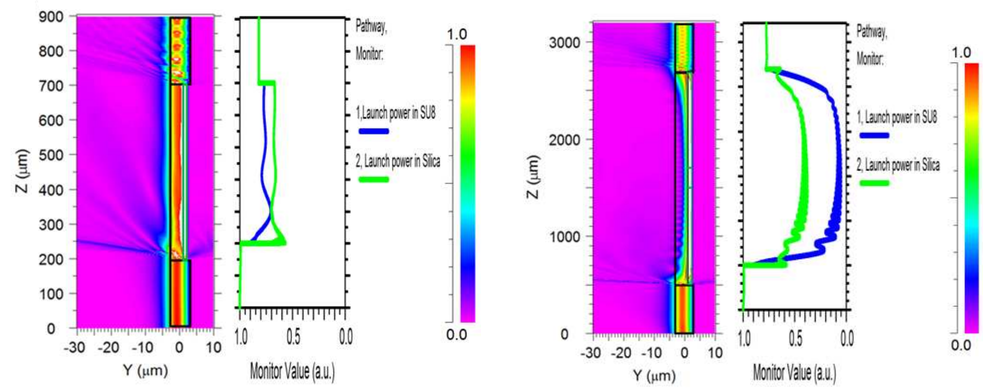


Figure 2: (a) The coupling efficiency between the buried silica waveguide and SU8-silica hybrid waveguide; (b) the ratio of the power confied in the SU8 region for the SU8-hybrid waveguides.

we also calculate the ratio of the power confined in the SU8 region for different waveguide structures. Fig. 2(b) shows the power ratios vary as the waveguide width for hybrid waveguides with different H.

From Fig. 2(b), it is obviously that the ratio of the power confined in SU8 region increases with the height of SU8. By comparing Fig. 2(a) and Fig. 2(b), we can find that it is difficult to find a waveguide structure which can provide high coupling efficiency and large power ratio simultaneously. Thus, a taper structure can be introduced. Taking into account the fabrication feasibility, width taper is preferred. According to Fig. 2(a), the height and width are determined to be $H = 1.1\,\mu\text{m}$ and $W = 1.4\,\mu\text{m}$. The SU8-silica hybrid waveguides are tapered from 1.4 μm to 2.3 μm to achieve a high switching efficiency. At the other side, the 2.3 μm wide waveguide is tapered linearly to 1.4 μm.Three dimensional beam propagation method (3D-BPM) is utilized to verify the design. Fig. 3(a) shows the simulation light propagation from of a 1.4 μm wide and 1.1 μm high SU8-silica hybrid waveguide (h_{sub} is 4.2 μm) connected with buried silica waveguide on both sides. As Fig. 3(a) indicated, the coupling efficiency is approximately 0.81 which is quite agree with the one obtained by using the overlap integral (~ 0.828). However, the ratio of the power confined in such a SU8-silica waveguide is quite low. Fig. 3(b) shows light propagation in the waveguides with tapered structures as described above. We can see that large ratio of the propagation light couples into SU8 waveguide through taper while a high coupling efficiency can be maintained.



(a) (b)

Figure 3: 3D BPM simulation shows the light propagates in (a) a 1.4 μm wide and 1.1 μm high SU8-silica hybrid waveguide (h_{sub} is 4.2 μm) with buried silica waveguide on both sides; (b) 1.4 μm wide SU8-silica hybrid waveguide tapared to 2.3 μm wide.

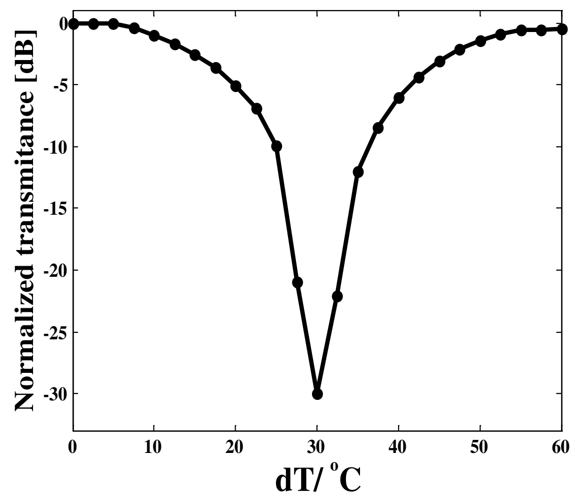


Figure 4: Simulated switching characteristics of the proposed SU8-silica hybrid waveguide switch.

Figure 4 shows the simulated switching characteristics of the proposed SU8-silica hybrid thermo-optic switch. Only 30 degree temperature change is required for a switching function.

3. CONCLUTIONS

In this paper, we propose a novel Mach–Zehnder interferometer (MZI) type thermo-optic switch based on SU8-silica hybrid waveguide structures. It combines the advantages of the low propagation loss of the silica waveguides and the large thermo-optic coefficient of the SU8. Although the design is based on the TO effect of SU8, the concept can be applied to the other type of polymers (e.g., EO polymers) to achieve high performance switches based on silica platform.

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