2x2 Waveguide based Thermooptic Photonic Switch

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ABSTRACT

We demonstrate a waveguide based thermooptic photonic switch with low electric power consumption using polymer material. The buried square core waveguides structure has been adopted for single mode operation at third telecommunication window. The index contrast of the upper cladding and the waveguiding layers is 0.2%, the lateral section of the waveguiding and lower cladding layer is 0.35%. The asymmetrical fabricated switch exhibits very low switching power of 12.26 mW. The crosstalk level of -30 dB for the initial and switching states have been achieved, respectively.

1 INTRODUCTION

Photonic switches are the newest network element being introduced into the communications industry. The photonic switch is the only missing device to realize the all-optical network to exploit the enormous bandwidth of the optical fiber. Photonic switch can switch light pulses without converting them into electrical signal at any point. However, a photonic switch can switch an entire fiber band of wavelengths, or single wavelength in any band, irrespective of the data rate or protocol. Photonic switch promises to relieve bottlenecks, cut costs, saving power, less floor space needed and make it easier for telecom engineers to deploy future developments in transmission technology. The advantages of photonic switching over electronic switching were discussed details in [1].

Due to advantages of photonic switching over electronic switching, the communication industries are pushing the researchers all over the world towards the development of photonic switch. For the realization of photonic switch different technology and technique are proposed and developed from the last decade. Among these technologies, polymer thermooptic (TO) switch is one of the most promising technologies for low cost, easy fabrication process and high scale of integration on large substrate [2-8].

In this paper we demonstrate an asymmetric 2x2 directional coupler based thermooptic photonic switch using all polymer material. The polymer based waveguides with buried square core (BSC) structures have been adopted for polarization independence and single mode operation at 1550 nm wavelength. The temperature dependence of refractive index is achieved by heating one of the electrodes heater placed alongside the branches.

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2 OPERATION PRINCIPLES

Figure 1 shows a schematic view of the proposed 2x2 directional coupler based polymer switch. It consists of two identical waveguides and separated by waveguide spacing of g. The d is center-to-center distance between the core and the electrodes heater. The bend waveguides with curvature radius, R_c are connected to both the input and output ports of two parallel waveguides.

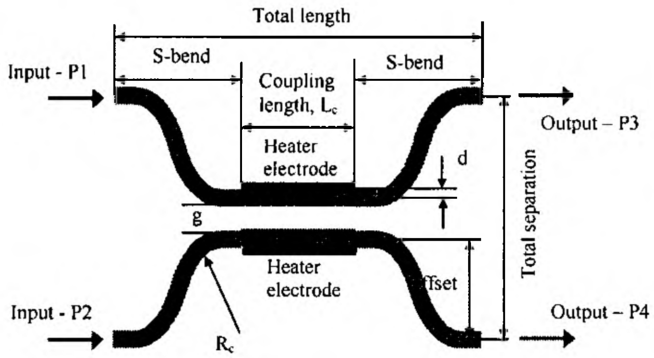


Fig. 1. A schematic view of 2x2 photonic switch

In two well separated waveguide regions, there are two uncoupled waveguide modes with the same propagation constant. In the interaction region, the two waveguide modes are symmetric and asymmetric modes with propagation constant β_{sym} and β_{asym} respectively. While light is propagating through the interaction region, the phase difference of the two eigenmodes increase due to the difference in their propagation constant. Interference of the two modes allows light power to transfer between the two channels. In other words the change in propagation constants leads to a change in the coupling length, L_c which is the minimum length of interacting waveguides required to obtain complete crossover or cross state. But the two waveguides in two distinct transition regions or taper regions start to couple and showing a difference in their propagation constants when they are close enough. This coupling contributes to the power transfer as well. If low loss arc bend waveguides are used in the transition regions this contribution can be significant when the two channels are strongly coupled in the interaction region.

When the voltage is applied along the electrode heater, the refractive index under the electrode heater is lowered due to the TO effect. Owing to the high thermal conductivity of the polymer used the temperature of the right waveguide will be lowered as well even if only the left waveguide is heated. Therefore, the propagation constant of the waveguides will be changed almost synchronously to keep $\Delta\beta \approx 0$ as long as the applied voltage is maintained at a low level. By raising the applied voltage or heating power the resulting temperature difference between the two branches of the waveguides will induce an increasing mismatch $\Delta\beta$ of propagation constant and as a results the switch will behave asymmetrically to reach the bar state.

3 PHOTONIC SWITCH FABRICATION

The device was fabricated on a 4-inch Si wafer, using standard polymer fabrication technology as shown in Figure 2.

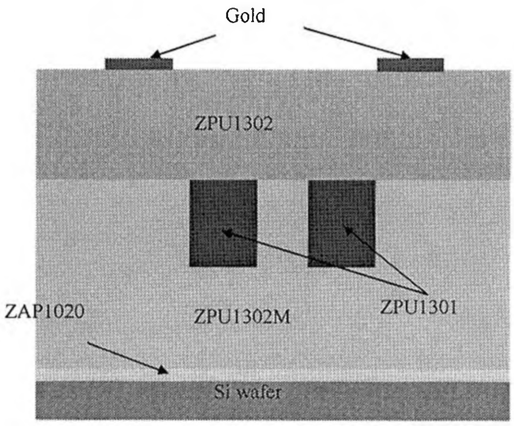


Fig. 2. Cross-section of fabricated 2x2 photonic switch

A new technique of inverted channel structure using inductively coupled plasma (ICP) etching had been introduced for BSC waveguides definition. Before coating ZPU 1302M as under cladding polymer, an adhesion promoter ZAP1020 was spin coated because ZPU series polymer had weak adhesion to the Si wafer. Positive photoresist, ATMR was used for waveguides patterning in the photolithography process. The photoresist was exposed with UV light while the wafer is in contact position with the mask. The developer for ATMR was AZ500MIF and used for 5 seconds, suffices to remove the illuminated photoresist. After having completed the photolithography process, the under cladding polymer was etched down for waveguide core definition using ICP etcher. The O_2 flow rate of 20 lpm was used as the etching gas. Thereafter the polymer, ZPU1301 waveguiding layer was deposited by spin coating. The thickness of the waveguiding layer needs to be controlled accurately to guarantee the designed switching behavior and therefore planarization technique was introduced and it had two folds benefits. First, to get rids of the 'dips', which occurred during the core layer coating due to inverted channel technique used. Second, for the accuracy of channel definition of step etch into the under cladding of ZPU1302M polymer. Subsequently the upper cladding ZPU1302 polymer layer was deposited and heating electrodes and pads were fabricated using e-beam evaporation and Au plating methods, respectively.

Figure 3 shows the micrograph of the heater electrodes and heater pads after the seeds metal were removed. The bend waveguides of parallel BSC waveguides with the side linewidths of

7 μm with a waveguide gap spacing of 5 μm at the end of the coupling length could also be seen. The micrograph indicates that the side linewidths of the BSC waveguides were flat and the narrow gap spacing was completely parallel and well determined on top of under cladding layer. The thickness of the heater electrodes and heater pads were measured to be 0.4 μm and 3.2 μm, respectively. The resistance of the heater electrodes and the heater pads were measured to be 130 Ω and 10 Ω, respectively. This micrograph also indicate that the forming of heater electrodes and heater pads were well defined on top of the BSC waveguides structure.

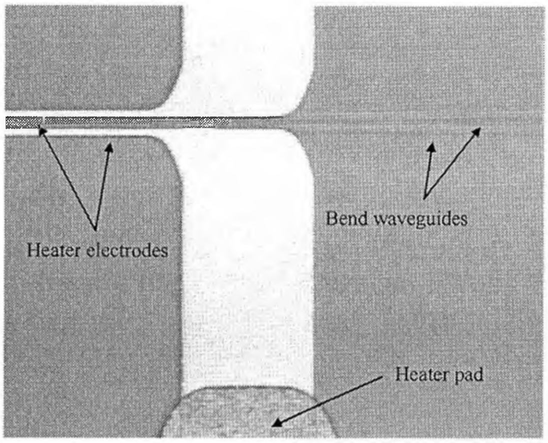
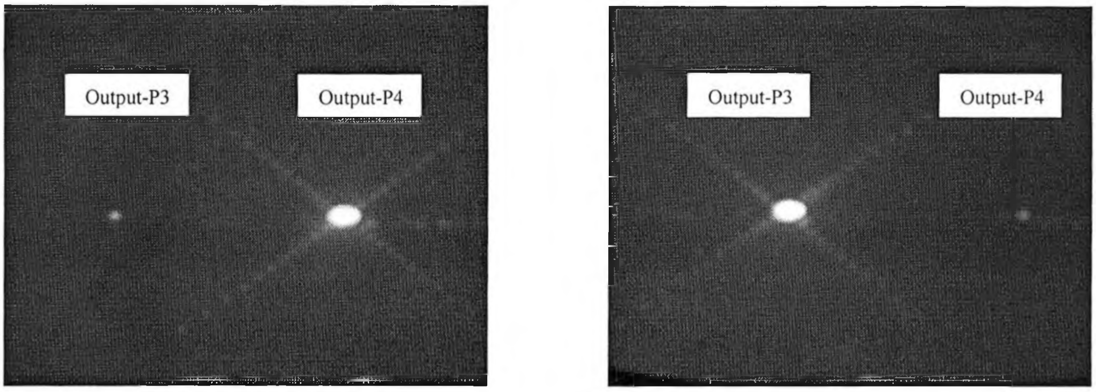


Fig. 3. Electrodes heater and heater pads after the seeds metal is removed (M100X)

4 RESULTS AND DISCUSSIONS

The analysis of the switching characteristics has been performed using laser diode (LD) source at 1550 nm wavelength. Using LD at the input, IR camera and TV monitor at the output, the switching characteristics were analyzed by seeing the near field patterns either at initial state or at switching state. Referring to schematic view of the photonic switch in Figure 1, the initial and switching states mean that the light is launched at the input-P1and the near field patterns were viewed at the output-P3 and output-P4, respectively. The near field patterns of the initial state and the switching state of 2x2 photonics switch were shown in Figures 4(a) and (b), respectively.



(a) (b)

Fig. 4. Switching characteristics (a) Initial state (b) Switching state

The crosstalk of the initial state and the switching state was calculated in dB for the power ratio of undesired output port to the total power of desired output port. When light is launched into port P1, the switching curve was plotted for insertion loss (IL) in dB as a function of switching power in mW. The switching curve is shown in Figure 5. At initial state; P1=>P3, the IL was –30.4 dB and P1=>P4, the IL was –2.01 dB, respectively. This corresponds to a crosstalk of –28.39 dB. At switching state; P1=>P4, the IL was –36 dB and P1=>P3, the IL was –1.7 dB, respectively. This corresponds to a crosstalk of –34.3 dB. The switching power required was 12.26 mW.

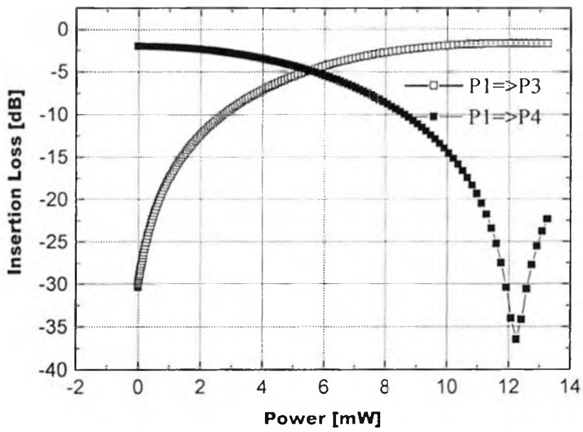


Fig. 5. Switching characteristics for 2x2 photonic switch

5 CONCLUSIONS

We have demonstrated 2x2 asymmetrical waveguide based photonic switch using all polymers. The index contrast of the upper cladding and the waveguiding layers is 0.2%, the lateral section of the waveguiding and lower cladding layer is 0.35%. The photonic switch exhibits very low switching power of 12.26 mW. The photonic switch shows very good performances in terms of reducing the heating power. The crosstalk level of -30 dB for the initial and switching states have been achieved, respectively.

ACKNOWLEDGMENT

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REFERENCES

[1] E. Ionnone and R. Sabella, "Optical Path Technologies: A Comparison Among Different Cross-Connects Architectures," Journal of Lightwave Technology. 14, 2184-2196 (1996).

[2] A.S Mohd Supa'at, M.H. Ibrahim, A.B. Mohammad, N.M. Kassim and N.E. Ghazali, "A Novel Thermo-optic Polymer Switch Based on Directional Coupler Structure," American Journal of Applied Sciences 5(11), 1552-1557 (2008).

[3] Abdulaziz M. Al-hetar, I. Yulianti, Abu Sahmah M. Supa'at, A.B. Mohammad, "Thermo-optic multimode interference switches with air and silicon trenches," Optics Communications 281 (18), pp. 4653-465, 2008.

[4] Abdulaziz M. Al-hetar, Abu Sahmah M. Supa'at, A.B. Mohammad, I. Yulianti, "Crosstalk improvement of a thermo-optic polymer waveguide MZI–MMI switch," Optics Communications 281 (23), pp. 5764-5767, 2008

[5] N. Keil, H. H. Yao, C. Zawadzki and B. Strebel, "Rearrangeable nonblocking polymer waveguide thermo-optic 4x4 switching matrix with low power consumption at 1.55 μm," Electron Letters 3, 403-404 (1995).

[6] N. Keil, H. H. Yao and C. Zawadzki, "A novel type of 2x2 digital optical switch realized by polymer waveguide technology," 22nd European Conf. on Optical Comm. 2, 71-74 (1996).

[7] J. Kobayashi, T. Matsuura, Y. Hida, S. Sasaki and T. Maruno, "Flourinated polymide waveguides with low polarization dependent loss and their application to thermooptic switches," Journal of Lightwave Technology 16, 1024-1029 (1998).

[8] X. Wang, B. Howley, M.Y. Chen and, R. T. Chen, "Polarization- Independent All-Wave Polymer-Based TIR Thermooptic Switch," Journal of Ligthwave Technology 24, 1558-1565 (2003).