Fabrication of an Electro Optic Polymer Ringresonator

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A ringresonator made of an electro optic (EO) polymer was designed, realized and characterized. The ring was made of a 4-dimethylamino-4-nitrostilbene (DANS) containing polymer and used in a vertical coupling with the waveguides. The waveguides were made of the photo-definable SU8, preventing an additional etching step in the fabrication process. Measurements were done on a ring of 100 μm radius and TE polarization was used. Thermo optic tuning of 170 pm/°C and EO modulation were measured.

Introduction

The application of EO ringresonators is very divers. This type of devices can be used in for instance communication setups as either tunable filters or modulators. When used as a filter it can be used to take signals of a certain wavelength of a main waveguide. Because the resonance peaks of a ringresonator are very narrow, the wavelength selectivity is very high. When used as a modulator the properties of the ring can be changed slightly by an electric signal, causing the ring to go in and off resonance. Because of the narrow resonance peaks this change in the ring can be very small and still have a large modulation. A sensitive modulator can be made with these rings.

Design

This section describes the design of the polymer ringresonator. A topview of the realized device is given in figure 1 and a cross-section (along the dotted line in figure 1) is given in figure 2.

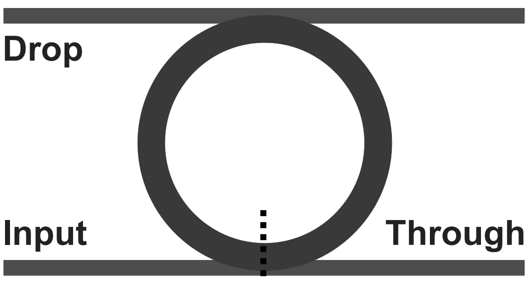

Figure 1: Topview of the realized device

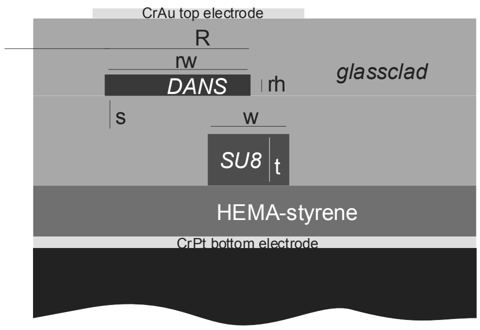

Figure 2: cross section of the ringresonator

By making the waveguide in the photo-definable SU8, a waveguide can be created without an etching step in the fabrication process.

The refractive indices of the used materials are given in table 1. All simulation results in this section are for TM polarization, because the EO effect is larger for TM with the electrode configuration as in figure 2. The two major design parameters are the phase matching between microring and waveguide and the mono-modality of both.

Polymer	Refractive index at 1550 nm
Glassclad	1.407
SU8	1.580
4-dimethylamino-4-nitrostilbene (DANS)	1.590 (for TE polarization poled at 130V/µm)
	1.656 (for TM polarization poled at 130 V/µm)
	1.605 (TE and TM unpoled)
HEMA-styrene	1.550

TABLE 1: Refractive indices of the used polymers

The mono-modality condition determines the maximum dimensions of both ring and waveguide. The waveguide thickness (t) should be smaller than 3.5 µm in order to be singlemode. For the ring this maximum thickness (rh) is 0.9 µm.
For the waveguide a thickness of 2.8 µm is chosen. For the ring the thickness of 800 nm is chosen.
With these thicknesses the effective indices of the propagating modes can be calculated for different ringradii and waveguide width. The waveguide width has to be smaller than 1.5 µm in order to stay singlemode. The results of these simulations are given in figure 3. Figure 4 also gives the calculated bendinglosses of the ring for different ringradii. From figure 3 and 4 it can be seen that phasematching and low loss rings is possible for “larger” rings and “smaller” waveguides.

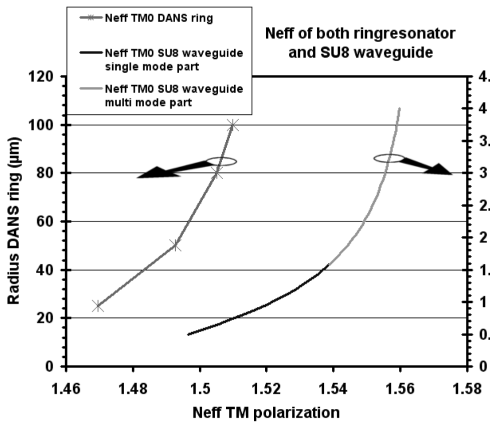

Figure 3: Neff for ring and waveguide for different ringradii and waveguide width

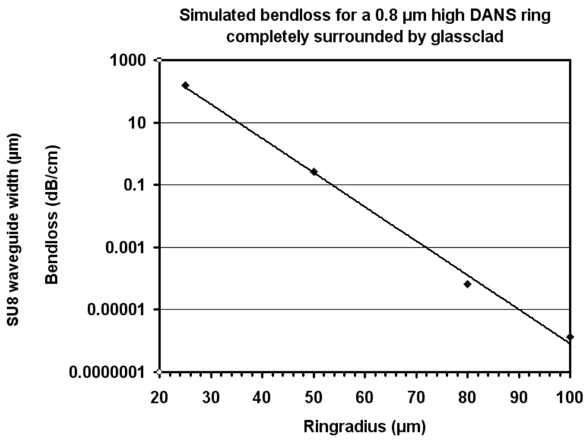

Figure 4: Bendloss of DANS ringresonator for different ringradii

Realization

The device was fabricated in the MESA+ cleanroom. The different steps in the fabrication process are shown in figure 5.
The two largest problems in the fabrication process are the roughness and alignment of the etched DANS ring.
The roughness issue can be solved by reflowing the ring. By etching a bit deeper than the height of the ring, the ring is placed on a ridge. When the sample is than heated the DANS starts to reflow and surface tension will smoothen the edge of the ringresonator. Because the DANS ring stands on a ridge it will not flow over the edges of this ridge and therefore the dimensions of the ring will be preserved. A realized example is given in figure 6.

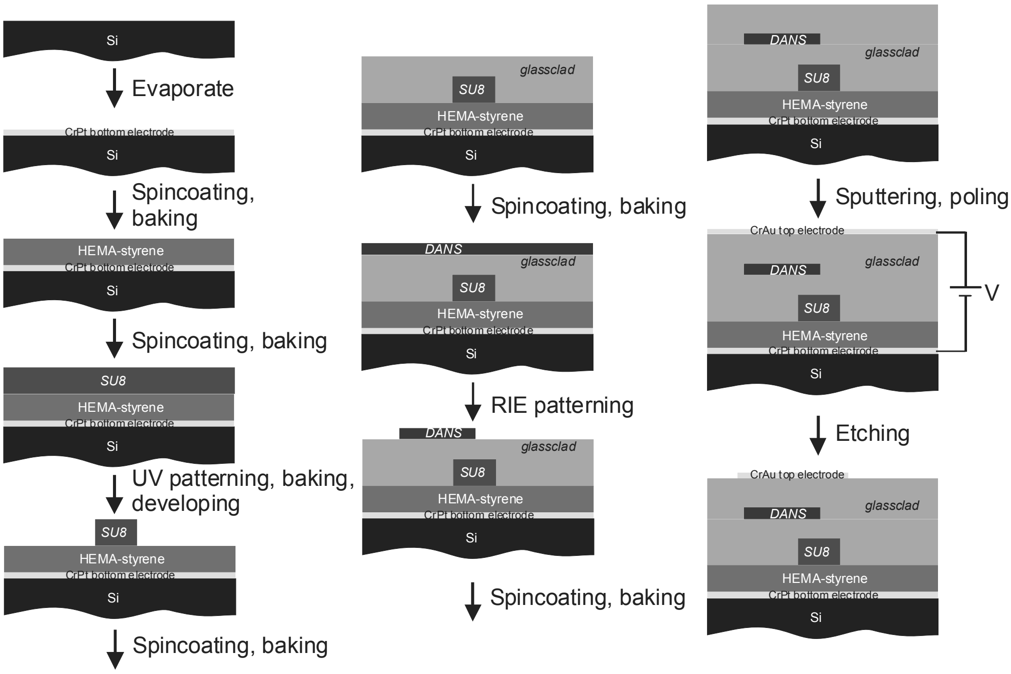

Figure 5: Schematic view of the fabrication process of the polymer microring resonator

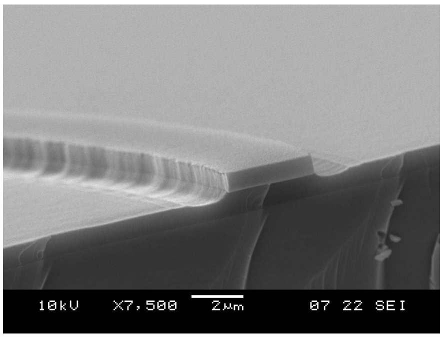

Figure 6a: DANS ringresonator before heating

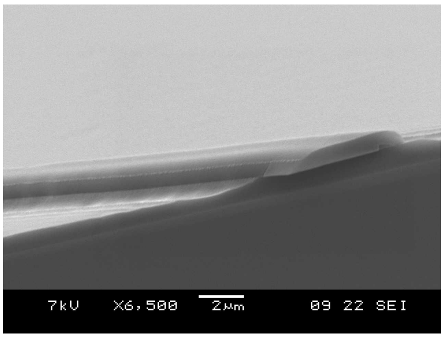

Figure 6b: DANS ringresonator after heating and reflowing

The alignment problem can be solved by making sure that the wafers are as flat as possible. An example of misalignment is shown in figure 7.
This amount of misalignment is also in the sample on which measurements were done.

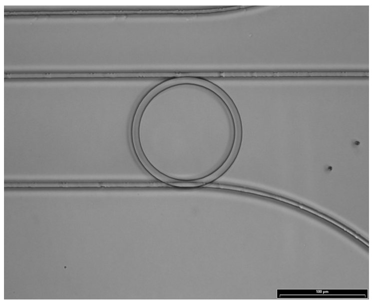
Figure 7: Misalignment of ringresonator

Characterization

A device with a 100 μm radius ring was diced and light is coupled in with fibers. A polarizer with a polarization maintaining fiber (PMF) is used to couple light in the fiber. An ultra high numerical aperture (UHNA) fiber is used at the output of the device. At the input port TE or TM light is coupled in and both through and drop are measured. No measurable signal was present in the drop-port. This can be explained by the mis-alignment from figure 7. The signal in the through-port was measured while the wavelength was varied. Results of these measurements are given in figure 8. From figure 8 it is obvious that the finesse of this device is low. This is probably caused by some high losses in the ring. It clearly shows that the dips of the ring are smaller for TM than for TE. This can be explained by the fact that the loss in the ring for TM is larger. Because the dips for TE are easier to measure the rest of the measurements are done for TE polarization.

The ringresonator was heated to see the thermo optic tunability of the ringresonator. Again the trough-port was measured. This measurement is shown in figure 9. It can be seen that tunability of approximately 170 pm/°C is achieved.

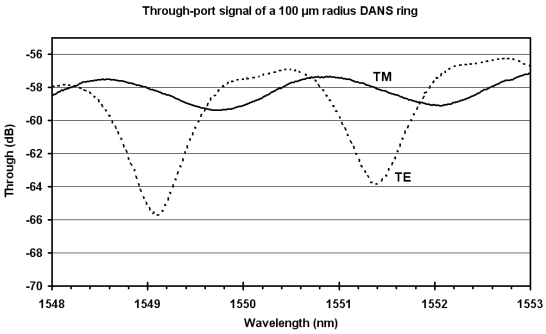

Figure 8: Measurement on through-port of the ringresonator

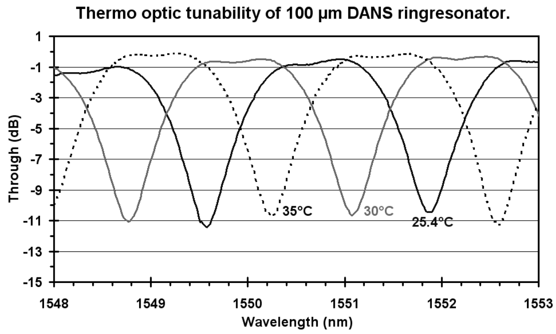

Figure 9: Thermo optic tuning of the ringresonator

EO activity of the device was also measured. The bottom electrode was connected to earth and the top electrode was modulated with a sinus voltage of 20 Vpp. The modulation frequency was low (730 Hz) because the electrodes weren't designed for high frequency. The signal from the trough-port was measured with a DC powermeter and an AC diode combined with a lock-in amplifier.

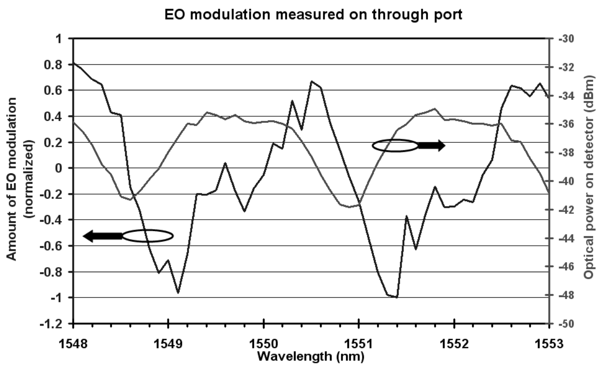

Figure 10: Measurement of EO modulation on single ringresonator

Conclusion

A smooth sidewall DANS ringresonator was realized, with only an etchingstep in the ringdefinition. The waveguides were defined (without etching) in the photo-definable SU8 polymer. The complete device was characterized after fabrication. Thermo optic tunability of 170 pm/°C was measured and EO modulation was measured. The EO effect was still relatively low. Optimizing the alignment, poling and loss in the ring should increase this effect.

References

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