A Tunable Optofluidic Nano-Bragg Microcavity Filter

Abstract: An optofluidic Nano-Bragg microcavity filter is designed using 3-D FDTD technique and fabricated using Electron-Beam Lithography and Reactive Ion Etching techniques. Continuous filter tuning is possible via small refractive index changes by mixing different fluids. An index change of 0.05 corresponds to a wavelength shift of approximately 2 nm.

Keywords: Optofluidic, Nano-Bragg, Optical filters, Nanophotonics, Reconfigurable optics, Microfluidic

Introduction

Optical microcavity filters play vital roles both in telecommunication and sensing applications. The emerging field of optofluidic technologies [1] has triggered important developments in lab-on-a-chip devices for point-of-care health systems [2] and also, in reconfigurable and adaptive optical devices [3]. By the same token, optofluidic tunable microcavity filters could find their applications in microscopy as spectral filters and telecommunication for de-multiplexing applications. Moreover, due to fabrication errors, the spectral bandwidths of optical microcavity filters [4] are not always at their designed spectral position. The fluidic control of these types of filters using a mixture to fluids can be used to fine tune the filter resonance to the desired spectral position. This flexibility is essentially provided by the characteristics of fluids that are scalable at the micron-scale such as fluid mobility and large ranges of index modulation.

3-D FDTD Modeling

A Nano-Bragg microcavity filter is created by the periodic modulation of a photonic wire waveguide core laterally by the insertion of recesses into the wire (Fig 1). The chosen material is Silicon-on-Insulator (SOI) with a core thickness of 340 nm as the light guiding layer and a 1000 nm thick lower silica cladding layer. The photonic wire width is fixed at 300 nm since this size supports a quasi-TE single transverse mode and low propagation losses.

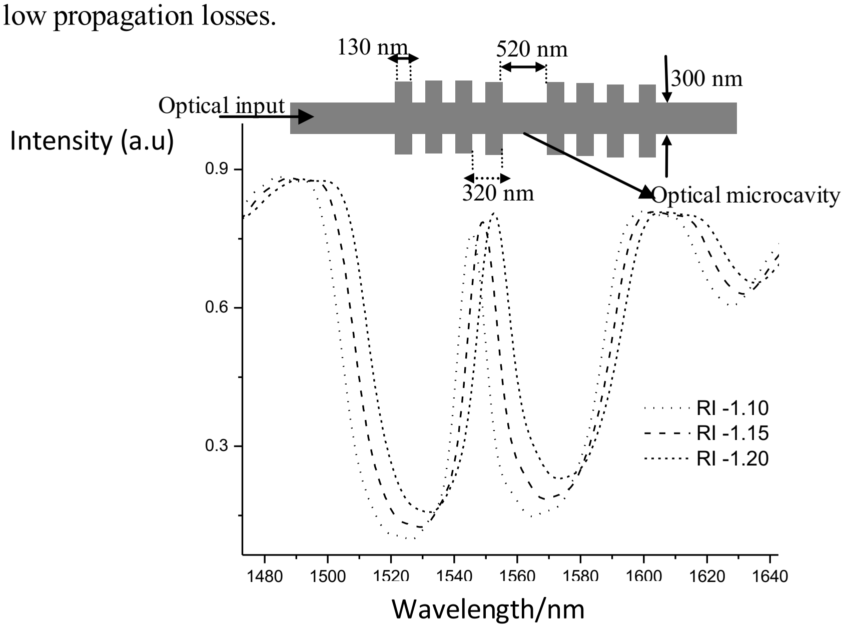

Fig. 1: Wavelength spectrum (3-D FDTD) of the Nano-Bragg microcavity filter at different fluid refractive indices, with a schematic of the device in the inset.

Fig. 1 shows the stop-band spectra with the filter resonance spectrally positioned at 1550 nm. The device parameters such as the period, recess depth and cavity length are optimized to produce a stop band and filter resonance located within the wavelength span of the tunable laser. This particular configuration of the device ensures that the fluid interacts with the evanescent optical fields at the edges of the Bragg microcavity filter, thereby, making this particular filter highly sensitive to varying fluid indices. The number of grating periods is 15 on either side of the microcavity.

Fabrication

The SOI material was coated with a 350 nm thick ZEP520A resist which was exposed using a 100 kV electron beam (Vistec EBPG5000plus) with a dose of 240 μC/cm^2. The ZEP layer was used as hard mask to transfer the patterns onto the silicon core layer. The device was then etched by Reactive ion etching using SF_6 gas. The fabricated device is shown in Fig. 2.

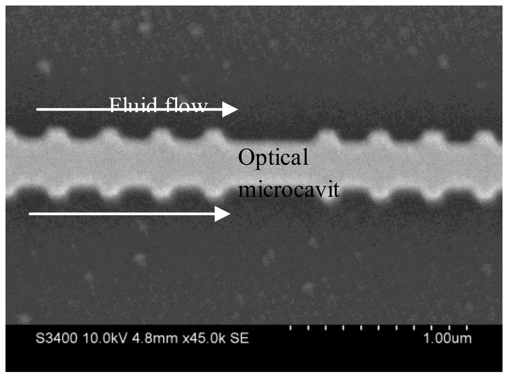

Fig. 2: An SEM image of the fabricated Nano-Bragg optical filter using Electron Beam Lithography and Reactive Ion Etching.

Laser characterization of the device with the fluid flow on the sides is currently underway. This device will then be bonded with a microfluidic chip for fluid delivery as described by the same authors in [2].

Conclusion

An Optofluidic Nano-Bragg grating microcavity filter has been designed using 3-D FDTD and fabricated using Electron Beam Lithography and Reactive ion etching. The spectral position of the resonance peak can be fine tuned using fluid of varying indices. Fully developed versions of this device could be useful as tunable optofluidic microcavity filters for telecommunication applications and also, as spectral filters in microscopy. Optofluidic technologies offer new opportunities for realizing highly responsive and ultra-compact filters.

[1] Erickson, D., Yang, C.H., Psaltis, D, *Photonic Spectra*, Vol. 42, Issue 2, p. 42 2008
[2] Jugessur A. S., Dou. J., Gnan M., Aitchison J. S., De La Rue R., *Microelectronic Engineering*, Vol. 86, Issue 4-6, p. 1488-1490 2009
[3] Monat C., *et al*. *Microfluids and Nanofluids*, Vol. 4, p. 81–95 2008
[4] Jugessur A. S., Pottier P., De La Rue R., *Optics Express*, Vol. 12, Issue 7, p. 1304-1312 2004