Add-Drop Filters utilizing Vertically-Coupled Microcavities in Silicon

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ABSTRACT

Add-drop multiplexers based on vertically coupled microresonators resonators in Silicon, using SIMOX 3-D Sculpting is reported. SIMOX 3-D sculpting involves the implantation of Oxygen ions into a Silicon substrate patterned with thermally grown oxide, followed by a high temperature anneal in order to cure the implantation damage. The thickness of the oxide mask is chosen suitably to decelerate the Oxygen ions that penetrate into the area underneath the mask, resulting in the formation of buried rib waveguides. After the annealing, microdisks were defined on the top layer Silicon by standard photolithography. Disks of radii 20, 20.5 and 21 microns were used to obtain resonators with slightly shifted resonance wavelengths. The thickness of these disks is around 260 nm. The fabricated devices have a free spectral range of around 5 nm. The best value of the suppression of adjacent channel cross talk of more than 15 dB is observed around 1545 nm.

Keywords: microresonators, integrated optics, nanophotonics.

1 INTRODUCTION

Micro-resonant optical cavities find with applications ranging from add-drop WDM multiplexers, optical filters to microdisk lasers. Their compactness facilitates dense integration of these devices on a chip. Vertically integration of optical devices offer the inherent advantage of achieving densely integrated 3-D optical structures. Also, they offer more precise control over the critical dimension of the structure, than laterally patterned structures, where the limits are set by the photolithography [1-3]. This paper reports the realization of add-drop multiplexers based on vertically coupled microdisk resonators in Silicon, using the technique of SIMOX 3-D Sculpting.

2 SIMOX 3-D SCULPTING

SIMOX 3-D sculpting has been utilized to fabricate low loss nanophotonic waveguides, and vertically coupled microdisk resonators on the SOI platform [4, 5]. The process involves the implantation of Oxygen ions into a Silicon substrate, followed by a high temperature (around 1300ºC) anneal of the substrate in order to cure the implantation damage. Figure 1 depicts the process flow of the fabrication of vertically integrated structures using the SIMOX process. Implantation of oxygen ions is performed on an SOI substrate that has been patterned with thermally grown oxide. The thickness of the oxide mask is chosen suitably to decelerate the Oxygen ions that penetrate into the area underneath the mask. The angled side wall of the buried rib waveguide formed after the high temperature anneal arises due to the lateral straggle of the implanted oxygen ions. After the anneal, the microdisk structure may be defined on the top layer using conventional lithography and etching process, as shown in figure 1.

![Fig.1 SIMOX 3-D sculpting process flow.](image1)

Figure 2 shows an SEM photograph of the microdisk resonator on the top layer Silicon, straddling the buried bus waveguide on the bottom layer Silicon. The disks were defined on the top layer Silicon by patterning a Silicon Nitride layer and oxidizing the sample to remove Silicon everywhere on the top layer, except underneath the circular Silicon Nitride disks. It may be noted here that the buried oxide layer formed during the implantation was removed to obtain SEM photographs that clearly illustrate the structure of the device. Figure 3 shows the top view of a 1×3 drop filter fabricated using this process. Disks of radii 20 μm, 20.5 μm and 21 μm were used to obtain resonators with slightly shifted resonance wavelengths. The thickness of these disks is around 260 nm.

![Fig.2 SEM of vertically coupled microresonators.](image2)
3 EXPERIMENTAL RESULTS

The drop port responses of the filter were characterized using an Amplified Spontaneous Emission (ASE) source, by launching optical power at port A and observing the drop port optical spectra at port B, C and D, using a spectrum analyzer, the results of which are shown in figure 4. Fabricated disks show a free spectral range of around 5 nm. The adjacent channel wavelength separation between port B and port C is approximately 1.0 nm whereas that of port B and port D is around 1.5 nm. At the 3 dB bandwidth of the channel dropped at port D, suppression of adjacent channel cross talk of more than 15 dB is observed around 1545 nm. The average value of adjacent channel cross talk suppression, over the wavelength band of 1534 nm -1560 nm, was found to be 12.1 dB for channels dropped at port D. At ports B and C this value was found to be 8.3 dB and 6.2 dB respectively. The device characteristics may further be improved by optimizing the processing conditions, and also using multistage microdisk resonators.

REFERENCES