(1) Title of letter

**Loss-less multilevel crossing of busline waveguide
in vertically coupled microring resonator filter**

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(4) Running head

**HATAKEYAMA, HANAI, SUZUKI AND KOKUBUN : Loss-less multi-
level crossing**

(5) Abstract

To eliminate the sattering loss at the crossing points of cross grid busline waveguides, a multilevel crossing structure of busline waveguide was introduced into the vertically coupled microring resonator filter. The top surface of each buried waveguide was perfectly planarized by a new fabrication process and clear filter responses were observed for a single ring and a series coupled double ring resonator with multilevel crossing busline waveguides.

I. Introduction

We proposed and demonstrated a vertically coupled microring resonator (VCMRR) filter [1]-[3]. This stacked configuration [1],[4] has many features, such as the independent optimum design of lower busline and upper ring waveguides, and the possibility of dense integration [5] resulting from the compactness of the microring and the cross-grid topology of the busline waveguide [2]. However, the scattering loss at the crossing point is as large as 0.2dB/crossing according to the FDTD analysis as shown in Fig.1, although the cross talk to the crossed port is as small as -31dB [2]. This large scattering is attributed to the small spot size of the busline waveguide ($0.55\mu\text{m}\times 0.95\mu\text{m}$) resulting from the small core size (thickness= $0.5\mu\text{m}$, width= $2.0\mu\text{m}$). This scattering loss limits the integration scale to be less than several tens to hundred. In this study, we have introduced a multilevel crossing structure of busline waveguide to eliminate the scattering loss.

II. Perfect planarization technique

Fig.2 shows the structure of VCMRR with multilevel crossing busline waveguide. To realize this structure, the top surfaces of the buried busline and microring waveguides must be perfectly planarized. However, the top surface fabricated by the conventional lift-off process has involved a step height of about $0.2\mu\text{m}$. Thus we developed a new perfect planarization process by incorporating a spin-on-glass (SOG) into the conventional lift-off process.

In this fabrication process, the lower busline waveguide and the microring resonator are made of $\text{Ta}_2\text{O}_5\text{-SiO}_2$ compound glass ($n=1.783$ @ $\lambda=1.55\mu\text{m}$). All the core and cladding layers were deposited by an RF sputtering technique and the waveguide pattern was formed by an ordinary photolithography technique and a reactive ion etching (RIE) with C_2F_6 gas. First the lower busline waveguide core is formed by RIE using the Cr mask, and the ridge-shaped core is buried by SiO_2 ($n=1.451$ @ $\lambda=1.55\mu\text{m}$) using a bias-sputtering deposition technique. The SiO_2 layer on the core is eliminated by the lift-off process using the wet chemical etching of Cr mask. After this process, the residual grooves on both sides of the waveguide pattern are buried by the spin coating of SOG, and a perfectly flat surface is obtained. Thus the ring core can be formed on a perfectly flat top surface of the lower busline waveguide. The ring core is also buried by the same process. The cross sectional SEM photos of busline waveguides fabricated by the conventional and new lift-off processes are shown in Figs. 3(a) and (b).

III. Fabrication and measurement

Using this technique, a single ring resonator with $20\mu\text{m}$ ring radius as shown

in Fig. 2 was fabricated and the filter response was measured using a tunable laser and an optical spectrum analyzer. The results for the through port and the drop port are shown in Fig. 4. Clear filter responses with the FSR of 10nm and the FWHM bandwidth of 0.23nm were observed.

A series coupled double microring resonator with multilevel crossing busline waveguides as shown in Fig. 5 was also fabricated by the same fabrication process. In contrast to the single ring device shown in Fig. 3, this structure consists of two core layers, i.e., both layers involve the busline waveguide and the microring resonator and those waveguides are coupled to each other in the vertical direction. Therefore, all the coupling between the busline and microring and between the microrings can be precisely controlled by the control of vertical distance, i.e. the thickness of buffer layer. In addition, the busline waveguides are also crossed in different layers and so the scattering at the crossing point will not occur. Due to the double series coupled configuration, a box like filter response [6],[7] is expected. The measured filter response of the series coupled double microring resonator with the ring radius of $30\mu\text{m}$ is shown in Fig. 6. A Clear box-like filter response with the FWHM bandwidth of 0.6nm and the FSR of 6.8 nm was successfully observed. A small dip of about 2.5dB was observed in the pass band. This seems to be caused by the strong coupling between microrings and also by the small difference of resonant wavelengths between two microrings, which results from the fabrication error, and will be reduced by improving the fabrication accuracy.

IV. Conclusion

A multilevel busline topology in the vertically coupled microring resonator filter was proposed and demonstrated. A new fabrication technique was de-

veloped to achieve the perfectly flat surface of buried waveguide in each layer by using the lift-off process and the spin coating of SOG. Clear filter responses were observed by a single and series coupled double microring resonators.

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Figure captions

- Fig. 1 FDTD simulation of light scattering at the crossing point of busline waveguides.(core index = 1.65, cladding index = 1.45)
- Fig. 2 Vertically coupled microring resonator with multilevel crossing busline waveguide.
- Fig. 3 Fabrication process of microring resonator filter with multilevel crossing busline waveguide.
- Fig. 4 Measured filter response of single microring resonator filter with multilevel crossing busline waveguide.(ring radius = $20\mu\text{m}$, width of ring core = $1.5\mu\text{m}$, thickness of ring core = $1.0\mu\text{m}$, width of busline waveguides = $1.2\mu\text{m}$, thickness of busline waveguide = $0.8\mu\text{m}$).
- Fig. 5 Double series coupled microring resonator filter with multilevel crossing busline.
- Fig. 6 Measured filter response of series coupled double microring resonator.(ring radius = $40\mu\text{m}$, width of ring core = μm , thickness of ring core = $1.0\mu\text{m}$, width of busline waveguides = $1.0\mu\text{m}$, thickness of busline waveguide = $1.0\mu\text{m}$).

Fig.1 2D-FDTD simulation of light scattering at the crossing point of busline waveguides.(core index = 1.65, cladding index = 1.45)

Fig.2 Vertically coupled microring resonator with multilevel crossing busline waveguide.

(a)

(b)

Comparison of cross sectional SEM photos of busline waveguides fabricated by conventional lift-off process and new planarization process using SOG.

Fig.4 Measured filter response of single microring resonator filter with multilevel crossing busline waveguide.

Fig.5 Double series coupled microring resonator filter with multilevel crossing busline.

Fig.6 Measured filter response of series coupled double microring resonator.