Ultra-Low Crosstalk Optical Inter Leaver Filter Based on Sin Platform with Cascaded AWGs

Lianxi Jia, Qing Fang, Junfeng Song, Mingbin Yu, and Guoqiang Lo

***Abstract*—We demonstrated a very low crosstalk SiN-based interleaver with cascaded AWGs. The measured results show a crosstalk less than -31dB with good suppression to the adjacent and non-adjacent crosstalk. Compared to single AWG, the noise ratio of the cascaded AWGs is decreased 3%.**

***Index Terms*—AWG, silicon, interleaver filter.**

I. Introduction

Silicon photonics have attracted much attention due to its advantages of low cost, high volume manufacturability and its compatibility with complementary metal oxide semiconductor (CMOS) technology. So it is feasible to monolithically integrate most of the electronic-photonic components on a single chip, which significantly reduces assembly processes and can drastically reduce component sizes.

Recently, silicon photonic devices have made a rapid progress, including arrayed grating waveguide (AWG). AWG can be used as a multiplexer (MUX) or demultiplexer (DEMUX) optical wavelength filter, which is a vital component in wavelength division multiplexing (WDM) system. Silicon photonic AWG has been reported by several research groups [1-3]. This kind of AWG is very compact, due to the high refractive difference between the Si core and the SiO2 cladding. However, the optical crosstalk of reported silicon photonic AWG is high, > -20dB.

Compared to the Silica-based AWG with micron-scale waveguide dimension [4], the silicon AWG needs a higher lithography resolution for good performances [5]. Reducing the index difference can lower the requirement to the lithography resolution and cascaded-AWG is another alternative to efficiently enhance the optical crosstalk under the same process. In this paper, we designed and fabricated an optical interleaver filter with cascaded-AWG on SiN platform. Compared to silicon and silica, SiN has a moderate refractive index to reduce the sensitivity to the lithography resolution but keep the tight dimension of the devices at the same time. In addition, SiN material is compatible with CMOS technology and can be monolithically integrated with other Si photonic devices.

The measured crosstalk of the cascaded SiN AWG is less than -31 dB. Compared to the single AWG, the noise ratio of the cascaded AWGs is decreased 3%.

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L. X. Jia is with the Institute of Microelectronics, A*STAR, Singapore (e-mail: jialx@ime.a-star.edu.sg).

II. Design and Fabrication

The proposed schematic structure of the filter is shown in Fig. 1(a). It is composed of three identical 1×2 AWGs. The two output channels of AWG1 are separately connected to the input of AWG2 and AWG3. Because the three AWGs have the same parameters, they have the same spectral properties. The output spectrum of the AWG1 can be further filtered by the cascaded AWG2 and AWG3.

The sidelobe and background scattering will be suppressed. The optical signals with high crosstalk can be expected from the channels of output1 and output2. The other two outputs of AWG2 and AWG3 are abandoned. Also due to the same parameters of the three AWGs, the fabrication variation (including the waveguide width and the slab thickness) affects all AWGs in the same level. So, the center wavelength shifters of the three AWGs are the same. Normally, 2 μm buried oxide is enough for Si waveguide. But the refractive index difference for SiN waveguide with SiO2 cladding is lower than that for Si waveguide, the optical mode filed of SiN waveguide is bigger. In order to reduce the optical loss caused by the leakage to the substrate Si, 4 μm-thick buried oxide is used. The designed parameters of SiN based AWG are shown in Table.1. The footprint size of each AWG is 500 μm (*H*) × 450 μm (*W*). The total filter size is 1.2 mm (*H*) × 1.0 mm (*W*).

TABLE I: Design Parameters of AWG

Parameter	Symbol	Value
Center wavelength	λ_0	1550 nm
Number of arrayed waveguide	N	11
Waveguide width	W	600 nm
Waveguide height	H	450 nm
Slab waveguide height	h	180 nm
Bend radius of arrayed waveguide	r	50 μm
Arrayed waveguide separation	d	4 μm
Output waveguide separation	D	4 μm
Focus length of the slab waveguide	f	40.78 μm
Path length difference	ΔL	72.03 μm
Diffraction order	m	76
Slab waveguide index	n_s	1.891
Arrayed waveguide mode index	n_c	1.65
Arrayed waveguide group index	n_g	2.159
Wavelength spacing	$\Delta\lambda$	8 nm
Free spectral range	FSR	16 nm

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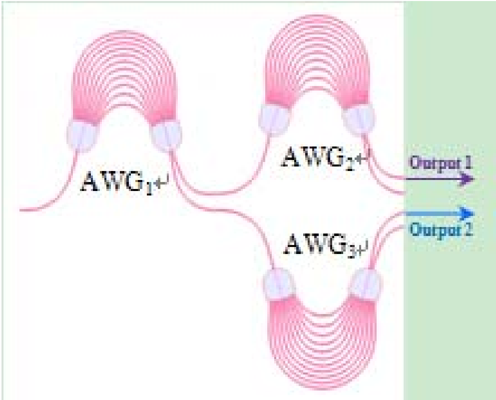
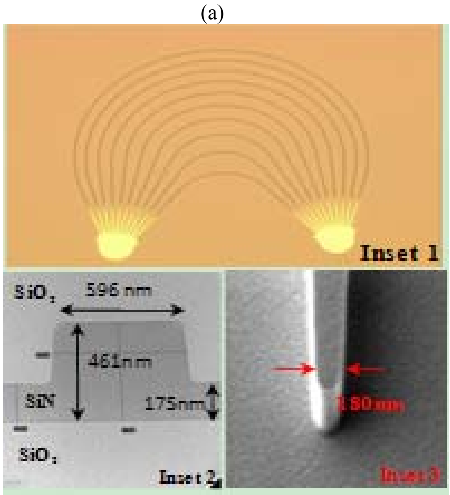


(a)



(b)

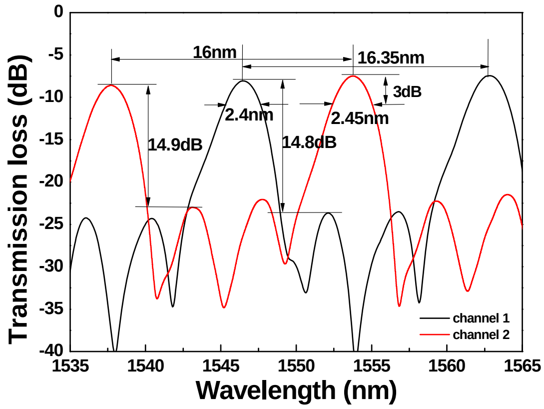
Fig. 1 (a) The schematic of the interleaver filter based on cascaded 1×2 AWG. (b) Image of the processed filter. Inset 1: The microscope image of the AWG;Inset 2: Cross-section of a waveguide showing the ridge structure; Inset 3: Nano-taper of the SiN waveguide.

The interleaver filter was fabricated on an 8-inch bulk Si wafer. A layer of 4-µm low stress SiO2 (nSiO2~1.45) was deposited firstly as the lower cladding layer. To reduce surface roughness of the film, which will make the underside of SiN waveguide rough, chemical mechanical polishing (CMP) was employed (CMP) after the deposition of the film. The roughness root mean square (RMS) was reduced to 0.17 nm from 7.6 nm after CMP. Then, 500nm-thick SiN is deposited with plasma-enhanced chemical vapor deposition (PECVD) and polished to 450nm using CMP. The roughness of SiN surface is also 0.17 nm.

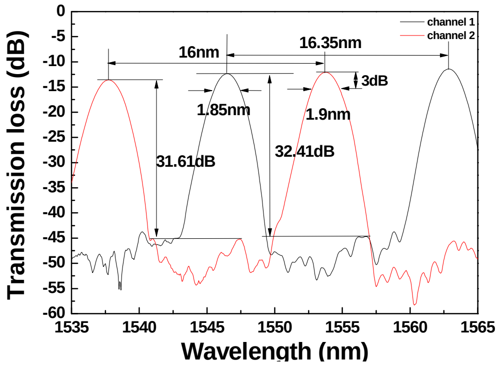
The devices were patterned using 248-nm deep-ultraviolet lithography and partially etched to reduce the scattering loss of the AWG by dry etching process. The transmission electron microscopy (TEM) image of the SiN waveguide is shown in Fig. 1 (b-inset 2). The etching height is ~ 290 nm and the waveguide width is near to the design value. For reducing the mode mismatching loss between the waveguide and optical lensed fiber, a reverse tapered mode converter is adopted in the input and output of the waveguide, which has a tip width 180nm. The SEM image of reverse tapered mode converter is also shown in Fig. 1 (b-inset 3). After waveguide formation, 2-µm high density plasma (HDP) SiO2 was deposited to fill up the small gaps at the fan-out section of AWG and another 2-µm low stress SiO2 was deposited as up-cladding layer to protect the waveguide. A top-view microscope picture of the AWG is given in Fig. 1(b-inset 1).

III. Measured Results

Firstly, the performance of the stand-alone single 1×2 AWG was evaluated. We fabricated a reference AWG with identical parameters as the cascaded AWGs on the same chip. After wafer dicing, a polarization-maintaining lensed fiber with 2.5 µm spot diameter was used to couple the light into the SiN waveguide from the exposed facet and a SMF lensed fiber with same spot diameter was used to couple the light out of the waveguide.



(a)



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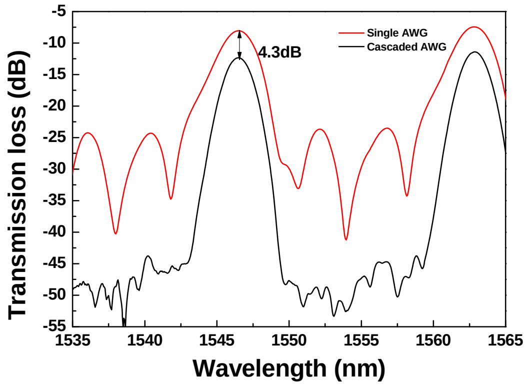

(c)

Fig. 2. (a) Optical transmission spectra of the single AWG. (b) Optical transmission spectra of the interleaver filter composed of cascaded AWGs. (c) Comparison of the optical transmission spectra in the output 1 of single AWG with cascaded AWGs.

The transmission loss of the transverse-electric (TE) polarization state for the two output ports is shown in Fig. 2(a), which is normalized by the direct transmission power of the two lensed fiber. The FSR is about 16nm and the 3dB bandwidth of the transmission spectra of the two outputs are all 2.4nm. The adjacent and non-adjacent crosstalk are all about -14.8dB, which isn't prominent compared to similar Si waveguide. We obtained the spectral property of the interleaver filter composed of cascaded-AWG as shown in Fig. 2(b) with the same measurement setup.

The adjacent crosstalk was significantly improved to less than -31dB, which fulfils the requirement of the communication system [6], and the non-adjacent crosstalk is about -32 dB. The sidelobe and the background scattering are both suppressed effectively. The 3dB bandwidth is reduced to smaller than 1.9 nm approximating the evaluated value 1.7 nm according to ref. [6].

However, the FSR is not affected because all the AWGs have identical parameters, which will not generate Wiener effect. Besides, we compared the maximum transmission power of the single AWG and cascaded AWGs at the same lobe peak wavelength. The two cascaded AWGs suffered a extra loss about 4.3 dB as shown in Fig. (c), which can be considered the on-chip transmission loss of a single AWG. This large loss is mainly caused by the scattering of light in the fan-out and fan-in splitter.

We can further extract the coupling loss of the lensed fiber with the reverse taper mode converter from the transmission spectra of the single AWG, which is about 2.5dB/facet.

IV. Conclusion

In conclusion, a SiN interleaver filter composed of cascaded AWGs has been presented using CMOS technology with a low crosstalk less than -31 dB. Compared to the conventional single AWG with the same parameters, the noise ratio of this interleaver filter is reduced 3%. This result is better than the current reported silicon photonics AWG.

Acknowledgment

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Jia Lianxi received the Ph. D. degree from Institute of Semiconductor, Chinese Academy of Sciences, China, in 2010. Currently, he is a scientist at the Institute of Microelectronics, A*STAR, Singapore. His research interests include silicon photonics components and nonlinear effect in silicon waveguide.