Fabrication of 17 × 17 polymer/Si arrayed waveguide grating with flat spectral response using steam-redissolution technique*

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Abstract: Arrayed waveguide grating (AWG) is a key device in the wavelength-division multiplexing (WDM) system, and the flat spectral response of the AWG device is required. In this paper, the RIE process has been improved. By using the steam-redissolution technique, the insertion loss and the crosstalk have been reduced. Experimental results show that the central wavelength is 1550.86 nm, the channel spectral response flatness is about 1.5 dB, 3-dB bandwidth is about 0.478 nm, insertion loss is 10.5 dB, and crosstalk is about –22 dB. The insertion loss of an AWG device is reduced by about 3 dB for the central channel and 4.5 dB for the edge channels, and the crosstalk is reduced by 2.5 dB after the steam- redissolution.

Key words: arrayed waveguide grating; flat spectral response; steam-redissolution; 3-dB bandwidth; crosstalk
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1. Introduction

Arrayed waveguide gratings (AWG) can serve some basic functions including multiplexing, demultiplexing, interconnection and so on; the spectral response of AWG plays an important role in the dense wavelength-division multiplexing (DWDM) system[1–5]. The conventional AWG device usually possesses a Gaussian spectral response, which imposes a strong wavelength control in the communication network. In order to reduce the need for accurate wavelength control, some techniques have been proposed to form the flat spectral response of the AWG device. These techniques include using multimode output waveguides[6], a multimode interference (MMI) coupler in the input waveguide[7], triple-Rowland-circle structure[8], varying the widths and positions of the arrayed waveguides[9], and varying the lengths and positions of the arrayed waveguides[10].

In this paper, a polymer arrayed waveguide grating multiplexer with flat spectral response has been fabricated by varying the widths and positions of the arrayed waveguides. That is, by subtracting an increment from the length difference for odd arrayed waveguides and by adding the same increment to that for even arrayed waveguides in the conventional AWG. In the fabrication of the AWG, the reactive ion etching process has been improved. By using the steam-redissolution technique, a smooth surface of the waveguide has been obtained. The insertion loss and crosstalk of the AWG have been reduced, and the device performance is improved.

2. Fabrication and measurement

The FPE-51 is chosen as core material, and its refractive index is 1.5100. The styrene (St) is chosen as cladding material through regulating the mol percent of FPE-51 and FPE-49, and its refractive index is 1.4979. So the refractive index difference between the core and the cladding is about $\Delta = (n_1 - n_2)/n_1 = 0.8\%$. The process of optimizing the structure design was omitted[11], and the optimized values of the parameters are listed in Table 1.

We have fabricated a 17×17 polymer AWG device by using conventional RIE[12]. The measured transmission spectrum is presented in Fig. 1, where we can see that the center wavelength is 1550.83 nm, the channel spectral response flatness is about 2.5 dB, 3-dB bandwidth is about 0.464 nm, insertion loss is about 15 dB, and crosstalk is about –20 dB.

In this paper, we have improved the reactive ion etching process; the guide core is buried in cladding, and the fabrication steps are shown in Fig. 2 as follows: (a) spin-coating the under-cladding and core layer in turn. We spin and coat the under-cladding two times, spin-coat at 1500 rmp, and increase its thickness to about 15 μm. (b) We deposit Al mask and increase its thickness to about 30 nm. (c) The BP-212 is chosen as photolithographic material, spin-coat at 4000 rmp. (d) We dry-etch square waveguide patterns using the RIE process, and

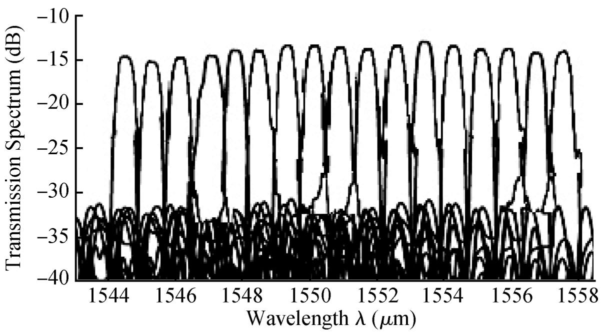

Fig. 1. Measured transmission spectrum of the fabricated AWG.

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Table 1. Optimum values of parameters of a polymer AWG with flat spectral response.

Parameter	Value
Central wavelength	$\lambda_0 = 1550.918$ nm
Wavelength spacing	$\Delta\lambda = 0.8$ nm
Width of guide core	$a = 6\ \mu$m
Thickness of guide core	$b = 4\ \mu$m
Width increment of guide core	$\delta a = 0.24\ \mu$m
Pitch of adjacent waveguides	$d = 15\ \mu$m
Refractive index of polymer guide core	$n_1 = 1.51$
Refractive index of polymer cladding	$n_2 = 1.4979$
Diffraction order	$m = 56$
Length difference of adjacent arrayed waveguides	$\Delta L = 57.786\ \mu$m
Focal length of slab waveguide	$f = 7519.539\ \mu$m
Free spectral range	FSR = 13.77 nm
Number of I/O channels	$2N + 1 = 17$
Number of arrayed waveguides	$2M + 1 = 151$

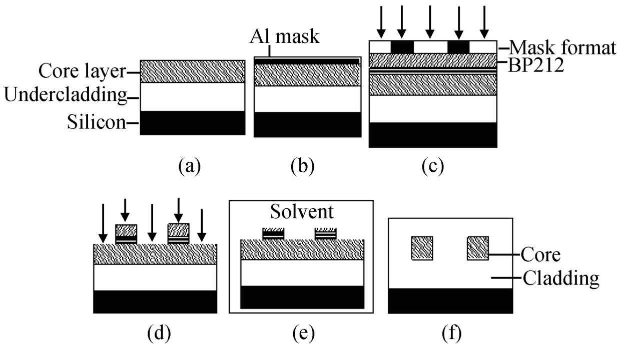

Fig. 2. Process steps of fabrication.

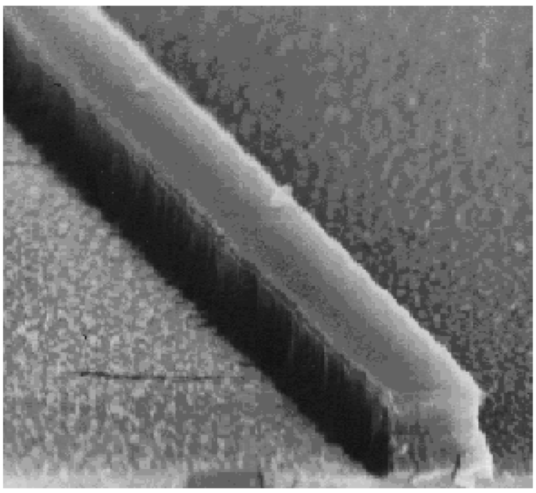

Fig. 3. SEM micrograph of waveguides after reactive core etching.

select the optimized velocity of oxygen flow and etching power as 40 sccm and 40 W, respectively. (e) Steam-redissolution tetrahydrofuran (THF) was used as a solvent vapor back to melting experiments, steam-redissolution temperature at 68 ℃, steam-redissolution time at 27 min. (f) The process of spin-coating the over-cladding is the same as that of spin-coating the under-cladding.

After reactive core etching, we get the channel SEM photographs of the AWG shown in Fig. 3. As can be seen from the figure, the surface of the waveguide is very rough, filled

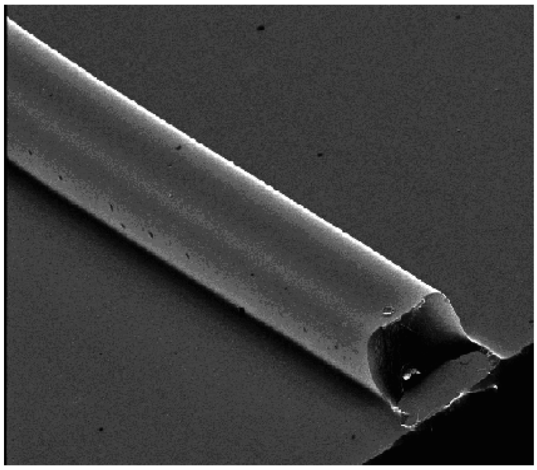

Fig. 4. SEM micrograph of waveguides after steam-redissolution.

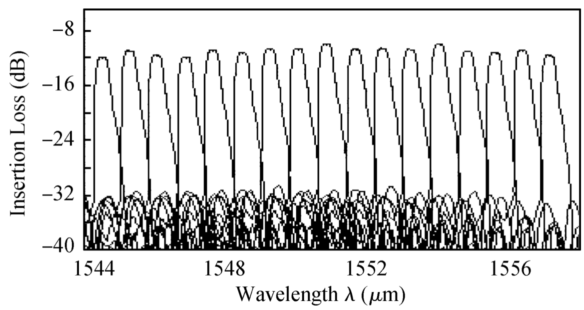

Fig. 5. Measured transmission spectrum of the fabricated AWG.

with a lot of glitches and fold. Figure 4 shows an SEM micrograph of waveguides after steam-redissolution; the surface of the waveguide sidewall becomes very smooth[13].

A 17 × 17 polymer arrayed waveguide grating multiplexer with flat spectral response has been fabricated by varying the widths and positions of the arrayed waveguides. The spectral transmission characteristic of the fabricated AWG device is measured using a tunable and optical power meter. The measured transmission spectrum is presented in Fig. 5, where we can see that the 3-dB bandwidth is about 0.478 nm.

The measured result shows that the central wavelength is 1550.86 nm, the channel spectral response flatness is about

1.5 dB, the 3-dB bandwidth is about 0.478 nm, the insertion loss is 10.5 dB, and the crosstalk is about –22 dB. Compared Fig. 5 with Fig. 1, we can see that the insertion loss of the device is reduced by about 3 dB for the central channel and 4.5 dB for the edge channels, and the crosstalk is reduced by 2.5 dB after the steam-redissolution. Therefore, we can conclude that the presented AWG device exhibits good characteristics.

3. Conclusion

In summary, we have improved the reactive ion etching process. A 17 × 17 polymer arrayed waveguide grating multiplexer with flat spectral response has been fabricated by varying the widths and positions of the arrayed waveguides. By using the steam-redissolution technique, the insertion loss and the crosstalk have been reduced. The measured results show that the center wavelength is 1550.86 nm, 3-dB bandwidth is about 0.478 nm, insertion loss is about 10.5 dB, and crosstalk is about –22 dB. Excellent AWG devices are dependent on accurate structural design and fine technology processing. Next, our research work will focus on the characteristic of RIE, improvement of the design method and the steam-redissolution technique, and further reduce in the loss and crosstalk of the ploymer AWG device in order to fabricate this device with better features.

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