Polymer Arrayed Waveguide Grating with Box-Like Spectral Response*

Qin Zhengkun[1,2,†] and Ma Chunsheng[2]

(1 *College of Information and Technology, Jilin Normal University, Siping* 136000, *China*)
(2 *State Key Laboratory of Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Changchun* 130012, *China*)

Abstract: An efficient technique is used to flatten the spectral response of an arrayed waveguide grating (AWG) multiplexer. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained. A 17×17 polymer AWG multiplexer with box-like spectral response has been made using FPE polymer materials. Measured result for the AWG shows that the box-like spectral response has a 3dB bandwidth of 0.476nm, the crosstalk is about or less than −21dB for every output channel, and the insertion loss is 13～15dB.

Key words: arrayed waveguide grating; box-like spectral response; 3dB bandwidth; crosstalk
EEACC: 1320
CLC number: TN252　　**Document code**: A　　**Article ID**: 0253-4177(2008)12-2307-04

1 Introduction

The spectral response of the arrayed waveguide grating (AWG) multiplexer plays an important role in optical networks[1～5]. Ideally, the AWG should have a so-called box-like spectral response to reduce the need for accurate wavelength control. Some research groups proposed various techniques to flatten the spectral response of the AWG device [6～9].

Manufacturing tolerances are hard to avoid in the fabrication of the arrayed waveguide grating (AWG) multiplexer, which will result in the shift of the transmission spectrum of the AWG device. However, the conventional AWG device usually possesses a Gaussian spectral response, which imposes a strong wavelength control in the communication network. Therefore, the flat spectral response of the AWG device is required.

In this paper, an efficient technique is used to flatten the spectral response of an AWG multiplexer. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained[10]. A 17 × 17 polymer AWG multiplexer with box-like spectral response has been made by using FPE polymer materials.

2 Optimization design of device

The FPE-51 is chosen as core material, and the styrene (St) is used to regulate the mol percent of FPE-51 and FPE-49 to form the cladding material. The cladding refractive index can be easily controlled from 1.49 to 1.51 through regulating the mol percent of FPE-49 and FPE-51. In this paper, we select the refractive index of the polymer guide core to be n_1 = 1.51, and that of the polymer cladding surrounding the guide core to be $n_2 = 1.4979$. So the refractive index difference between the core and the cladding is about $\Delta = (n_1 - n_2)/n_1 = 0.8\%$. Based on these polymer materials, a 17×17 conventional AWG multiplexer with 0.8nm channel spacing is designed[11], and the optimized values of the parameters are listed in Table 1.

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

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
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 = 13.77nm
Number of I/O channels	$2N + 1 = 17$
Number of arrayed waveguides	$2M + 1 = 151$

* Project supported by the National Natural Science Foundation of China (No.60576045)
† Corresponding author. Email: qin_zhengkun@126.com
Received 2 June 2008, revised manuscript received 21 August 2008

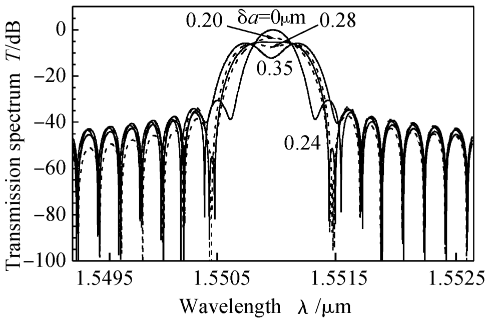

Fig. 1 Effect of the core width increment δa on the spectral response $\delta a = 0$: conventional AWG; $\delta a = 0.20, 0.24, 0.28, 0.35\mu m$: improved AWG

In this section, we improve the structure of the preceding conventional AWG, and flatten the spectral response of the improved AWG. We reduce the core width of the odd arrayed waveguides from a to $a - \delta a$, and increase that of the even arrayed waveguides from a to $a + \delta a$, that is, the AWG is divided into two sub-gratings, the core width of one sub-grating is $a - \delta a$, and that of another is $a + \delta a$, where δa is the core width increment. In this case, using the grating diffraction theory[12], Figure 1 shows the effects of the core width increment δa on the spectral response, where $\delta a = 0$ is corresponding to the conventional AWG, and $\delta a = 0.20, 0.24, 0.28, 0.35\mu m$ are corresponding to the improved AWG. It can be seen from Fig. 1 that when the core width increment $\delta a = 0$, the spectral response of the conventional AWG is sharper and narrower, of which the shape is convex, and the 3dB bandwidth is about 0.23nm. As the core width increment δa increases, the spectral response of the improved AWG becomes flatter and wider. As the core width increment δa increases to a proper value, for instance $\delta a = 0.24\mu m$ (bold solid line), a box-like spectral response is formed, of which the 3dB bandwidth is about 0.5nm. If the core width increment δa further increases, however, the spectral response becomes saddle-backed.

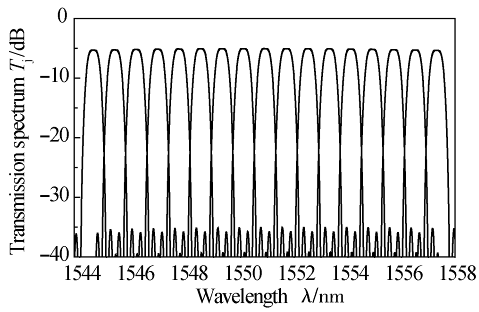

Fig. 2 Simulated transmission spectrum of the designed AWG

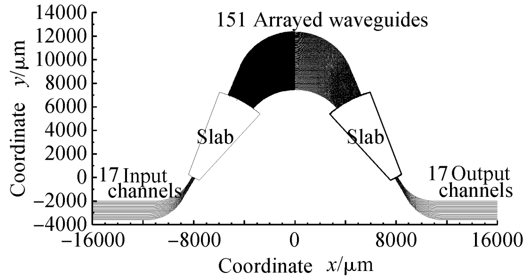

Fig. 3 Schematic layout of the designed AWG

We select the core width increment to be $\delta a = 0.24\mu m$. Figure 2 shows the calculated demultiplexing spectrum of 17 output channels of the designed AWG. It can be seen from Fig. 2 that a box-like spectral response is formed, of which the 3dB bandwidth is about 0.49nm. The AWG multiplexer is shown schematically in Fig. 3.

3 Fabrication and measured results

The guide core is buried in the cladding, and the schematic diagram of the fabrication procedures is drawn in Fig. 4, which includes (a) spin-coating the lower cladding and core layer in turn, (b) depositing metal mask, (c) photolithography, (d) reactive ion etching, and (e) spin-coating the upper cladding. Figure 5 shows the scanning electron microscope micrograph of waveguides after the reactive core etching.

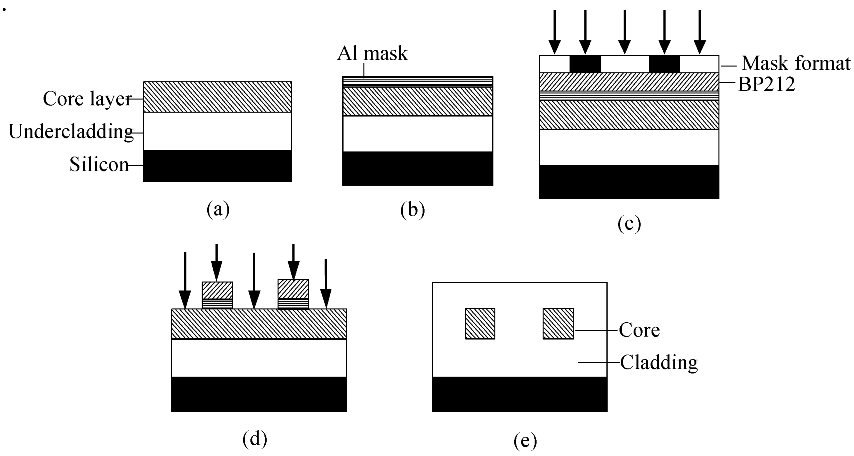

Fig. 4 Process steps of fabrication of guide core

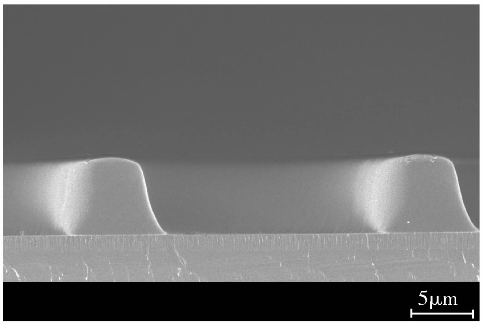

Fig.5 SEM micrograph of waveguides after reactive core etching

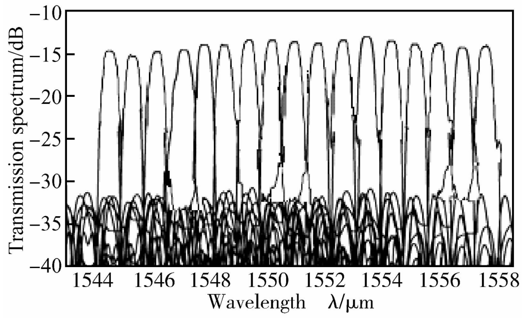

Fig.6 Measured transmission spectrum of the fabricated AWG

The measured transmission spectrum is presented in Fig.6, where a box-like spectral response is formed, of which the 3dB bandwidth is about 0.476nm. This proved that the method to design AWG device with box-like spectral response is feasible and that we stated theoretically, it has certain practical value. We have fabricated a 17×17 polymer AWG device, 0.49nm, which is more than two times of that of the conventional AWG. When some factors result in the shift of the transmission spectrum of the AWG device, it relaxes a wavelength control in the communication network. For the designed AWG device, the central wavelength of the AWG is about 1550.97nm, the shift of the transmission spectrum is about 0.05nm, which is much less than the wavelength spacing of 0.8nm, so the AWG may realize normal demultiplexing. The insertion loss and the crosstalk are 13～15dB and about －21dB respectively. For the designed AWG device, however, the increments are 5 and 4dB, respectively, mainly because the additional insertion loss and crosstalk have be produced in the flat transmission spectrum. So how to reduce the insertion loss and the crosstalk of AWG device is a problem that needs further to be solved.

4 Conclusion

In summary, we have designed and fabricated a 17×17 AWG device with flat spectral response by using FPE polymer materials. By subtracting an increment from the core width of odd arrayed waveguides and by adding the same increment to that of even arrayed waveguides, a box-like spectral response can be obtained. In our experiment, we select the core width increment to be $\delta a = 0.24\mu m$, the measured transmission spectrum is presented in Fig.6, where a box-like spectral response is formed, of which the 3dB bandwidth is about 0.476nm, the center wavelength is 1550.87nm, insertion loss is 13～15dB, and crosstalk is about －21dB. Currently, we are devoting ourselves to further reducing the loss and crosstalk of the AWG device in order to fabricate this device with better features.

References

[1] Maru K, Okawa M, Abe Y, et al. Silica-based 2.5%-Delta arrayed waveguide grating using simple polarisation compensation method with core width adjustment. Electron Lett, 2007, 43(1): 26

[2] Yasumoto M, Suzuki T, Tsuda H, et al. Fabrication of (Pb, La)(Zr, Ti)O_3 thin-film arrayed waveguide grating. Electron Lett, 2007, 43(1): 24

[3] Lim J G, Lee S S, Lee K D. Polymeric arrayed waveguide grating using imprint method incorporating a flexible PDMS stamp. Opt Commun, 2007, 272(1): 97

[4] Lang Tingting, He Jianjun, He Sailing. A novel triplexer design based on arrayed waveguide grating. Chinese Journal of Semiconductors, 2006, 27(2): 368

[5] Long Wenhua, Li Guangbo, Jia Kemiao, et al. Design and fabrication of 1×32 silica-based arrayed waveguide grating. Chinese Journal of Semiconductors, 2005, 26(9): 1798

[6] Amersfoort M R, de Boer C R, van Ham F P G, et al. Phased-array wavelength demultiplexer with flattened wavelength response. Electron Lett, 1994, 30: 300

[7] Amersfoort M R, Soole J B D, LeBlance H P, et al. Passband broadening of integrated arrayed waveguide filters using multimode interference couplers. Electron Lett, 1996, 32: 449

[8] Ho Y P, Li H, Chen Y. Flat channel-passband-wavelength multiplexing and demultiplexing devices by multiple-Rowland-circle design. IEEE Photon Technol Lett, 1997, 9(3): 342

[9] Kamalakis T, Sphicopoulos T. An efficient technique for the design of an arrayed-waveguide grating with flat spectral response. J Lightwave Technol, 2001, 19(11): 1716

[10] Ma C S, Zhang H M, Zhang D M, et al. Box-like spectral response of arrayed waveguide grating multiplexers. Opt Commun, 2005, 249(1～3): 209

[11] Guo W B, Ma C S, Zhang D M, et al. Parameter optimization and structural design of polymer arrayed waveguide grating multiplexer. Opt Commun, 2002, 201(1～3): 45

[12] Ma C S, Wang X Y, Zhang H M, et al. An efficient technique for analyzing transmission characteristics of arrayed waveguide grating multiplexers. Opt Quantum Electron, 2004, 36(8): 759

箱型光谱响应聚合物阵列波导光栅的研制*

秦政坤[1,2,†] 马春生[2]

（1 吉林师范大学信息技术学院，四平 136000）
（2 集成光电子学国家重点联合实验室吉林大学实验区，长春 130012）

摘要： 通过减少奇数阵列波导的芯宽度，同时增加偶数阵列波导的芯宽度的技术，构造了箱型光谱．选用氟化聚芳醚 FPE 聚合物材料，设计并制备了 17×17 信道箱型光谱响应阵列波导光栅（AWG）波分复用器．测试结果表明，器件的中心波长为 1550.87nm，波长间隔为 0.8nm，3dB 带宽约为 0.476nm，串扰低于－21dB，插入损耗为 13～15dB．

关键词： 阵列波导光栅；箱形光谱响应；3dB 带宽；串扰
EEACC： 1320
中图分类号： TN252 **文献标识码：** A **文章编号：** 0253-4177(2008)12-2307-04

* 国家自然科学基金资助项目（批准号：60576045）
† 通信作者．Email：qin_zhengkun@126.com
2008-06-02 收到，2008-08-21 定稿