Modified Holographic Exposure to Fabricate Varied Bragg Grating in an Identical Chip *

Xie Hongyun, Zhou Fan, Wang Baojun, Yang Hua, Zhu Hongliang, Zhao Lingjuan, and Wang Wei

(Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, China)

Abstract: A new fabricating method is demonstrated to realize two different Bragg gratings in an identical chip using traditional holographic exposure. Polyimide is used to protect one Bragg grating during the first period. The technical process of this method is as simple as that of standard holographic exposure.

Key words: holographic grating; DFB laser; multi-wavelength; CWDM

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1 Introduction

Bragg grating is used in fiber-optic communication systems to complete the wavelength selection. It has been inserted in the structure of InP/InGaAsP laser diodes since 1980's in order to achieve a reliable single-mode operation and narrow line width at room temperature[1]. Traditional holographic exposure is used to define the grating pattern on the photoresist and wet etching or dry etching is used to transfer the pattern to the semiconductor optical confining layer. These technical processes are mature and simple in semiconductor fabrication, so the DFB and DBR laser diodes become the key light sources for fiber-optic communication systems. This technology ensures the development of a wavelength division multiplexer, including the DWDM and CWDM.

Compared with the DWDM, the CWDM has wider channel spacing such as 20nm ruled by ITU-T in G694.2[2]. As a result, it can be used for wide-band communications and especially for metropolitan networks. Low cost and simplicity of light source are the initial requirements for CWDM. Multiple DFB laser modules in parallel or varied Bragg gratings in DFB laser array are fabricated to realize the multiple wavelength light source. However, the DFB laser module in parallel requires a complex fabricating processing[3], e-beam writing, to realize varied Bragg gratings, which is costly. It is highly desirable to vary the lasing wavelength of the light source used in CWDM without using rather complicated and expensive procedures.

In this paper a modified holographic exposure is presented to fabricate two different gratings in an identical chip. The processing of this new method is as simple as that of traditional holographic exposure, so the period of Bragg grating for different wavelengths can be conveniently realized. Thus, two lasing wavelengths corresponding to the standard channel spacing of a CWDM can be achieved by this simple method.

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Xie Hongyun female, was born in 1978, PhD candidate. Her research interests are in DFB laser and optic-electronic integrated devices.

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2 Technical realization

Holographic exposure commonly is used to fabricate the Bragg grating of a DFB or DBR laser diode. This conventional method for grating definition is shown in Fig. 1.

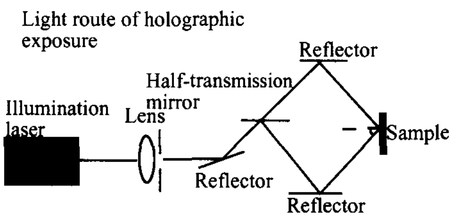

Fig. 1 Holographic exposure setup for grating definition

The period of Bragg grating is given as follows[4,5] :

$$\Lambda = \lambda' / 2\sin\theta \qquad (1)$$

where Λ represents the period of the Bragg grating, λ' is the wavelength of the illumination laser used, and θ is demonstrated in Fig. 1. After exposure, an interference pattern is formed on the surface of the sample, which has been coated by a photoresist. Generally, wet etching or RIE or ECR is used to transfer the pattern to the surface layer of the sample after the developing of the photoresist is coated on it. Compared with the e-beam writing process, this technique is simple, fast, and low-cost, suitable for fabricating the Bragg grating of the DFB laser used in CWDM. But, this technique can only achieve a uniform period of grating in an identical chip, so we develop the modified holographic exposure to realize two different periods in an identical chip. Thus, the double wavelength DFB laser based on an identical chip is realized.

The modified holographic exposure is completed through four steps. The technical flow is shown in Fig. 2. Firstly, a standard contact photolithography combined with chemical etching through patterned photoresist is used for the definition of the area for the first grating, with the period A, while the remaining area for the second grating, with the period B, is protected with InP. Secondly, the period of grating is conformed from Eq. (2)[6] :

$$\lambda_B = 2 n_{eff}' \Lambda \qquad (2)$$

where λ_B is the Bragg wavelength in free space, n_{eff}' represents the real part of the effective refractive index of the waveguide structure without the grating, and Λ gives the period of the grating structure. Combined with Eq. (1), θ_1 corresponding to the first wavelength is confirmed for the holographic exposure. After stripping photoresist and cleaning the surface of the sample, the first grating is fabricated in relevant area by traditional holographic exposure. Then, polyimide is coated homogeneously on the whole surface of the sample; to protect the first grating, contact photolithography and developing the photoresist are again used to define the area for the second grating (with period B). Cleaning the polyimide and etching the InP in those areas complete the definition of the area for the second grating. At last, θ_2 for the second wavelength is confirmed through the combination of Eq. (1) with (2). The second grating is also realized in relevant area by the traditional holographic exposure.

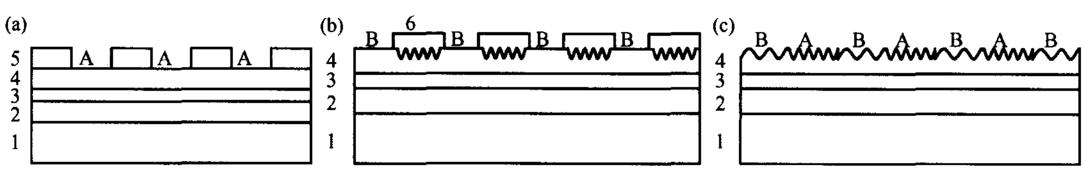

Fig. 2 Technical flow of modified holographic exposure (a) Definition of the area for the first grating; (b) Definition of the area for the second grating; (c) Bragg grating of different periods 1. InP substrate; 2. InGaAsP confining layer; 3. active layer; 4. InGaAsP confining layer; 5. InP; 6. Polyimide

3　Results : double wavelength DFB laser based on an identical chip

The DFB laser is fabricated on InP substrate. The waveguide structure is successfully grown by a low pressure MOVPE at 665 ℃. The thin bulk active layer possesses a certain tensile strain to ensure a larger gain spectrum band (about 108 nm) and the central wavelength is fixed at 1570nm[7]. The varied Bragg gratings are fabricated in the upper waveguide layer by modified holographic exposure. The SEM of the two gratings with different periods is shown in Fig. 3. The periods of these two gratings are 244.5 and 241.4nm, respectively, corresponding to two wavelengths with a spacing of 20nm. After fabricating the two varied grating, the InP cladding layer and the InGaAs contact layer are grown in the second step epitaxy. Then, the ridge

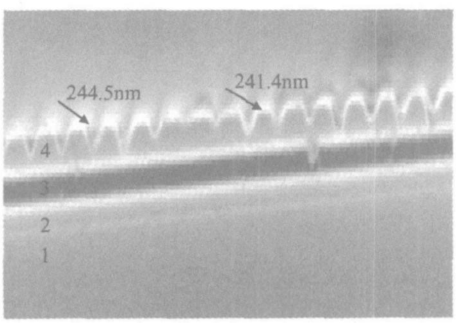

Fig. 3　SEM photo of the Bragg grating in the device
1. Buffer layer; 2. Lower waveguide layer; 3. Active layer; 4. Upper waveguide layer.

etching, ion implantation, sputtering p-electrode (Ti/Pt/Au) and vaporizing n-electrode (Au/Ge/Ni) are successfully completed. Finally, the devices are cleaved and AR-coating is carried out in the front and rear facets. The ridge width of the laser array is about 2μm. The total device length is about 500μm and each laser section is 250μm. The lasing spectrum of this device is given in Fig. 4. Two wavelengths, 1542.4 and 1562.5nm, are achieved in the identical chip under different work conditions. Both have high SMSR. This result benefits from the Bragg grating with different periods. The output light power from one facet of each section is achieved to several milli-watts.

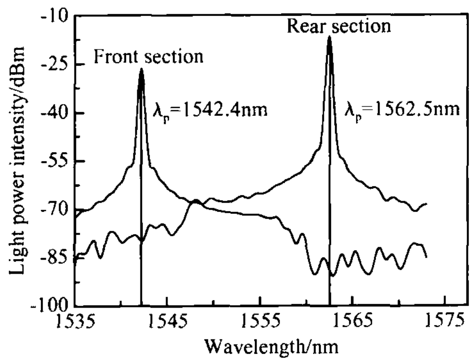

Fig. 4　Lasing spectra of the device with varied Bragg gratings

4　Conclusion

A novel modified holographic exposure is achieved. Polyimide is used as a protector for the first grating in this method of realizing a different grating in an identical chip. This new fabricating method is as simple as the conventional holographic exposure and the technical realization is compatible to the traditional technical processing of semiconductor DFB laser diodes. The cost is low enough to apply potentially in fabricating the multi-wavelength DFB laser used in CWDM. This technique provides a foundation for fabricating more complicated matrix laser array and other optical integrated devices.

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同一芯片上制作变周期布拉格光栅的改进全息曝光法*

谢红云 周 帆 王宝军 杨 华 朱洪亮 赵玲娟 王 圩

(中国科学院半导体研究所, 北京 100083)

摘要: 提出了一种采用传统光学全息曝光技术,在同一芯片上制作不同周期的布拉格光栅的新方法. 在这个简单实用的方法中,聚酰亚胺用来保护第一次做好的某一周期的光栅. 这种新方法制作工艺简单,成本低,且与传统的半导体工艺兼容.

关键词: 布拉格光栅; DFB激光器; 多波长: 疏波分复用

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