Fabrication of varied line space grating by elastic Optics

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Abstract: We demonstrate a method to fabricate varied-line-spacing grating by employing elastic medium with variable vertical section. The advantages of this technique include continuous diversity of variation of line-space, high fabrication efficiency and low cost, etc. It is very difficult or unrealizable to produce this variation of line-space by traditional interference lithography. This kind of grating can be used in the optical position sensor and it can improve the precision of the sensor.

Key Words: Lithography; Diffractive optics

1. Introduction

Plane varied-line-spacing grating have applications in monochromator of the third-generation synchrotron radiation and in high-resolution tunable spectrograph for x-ray laser linewidth measurements [1,2,3]. Traditionarily, the plane varied-line-spacing grating is fabricated mainly by holograph lithography and mechanical ruling [1]. For the holograph lithography, its advantage is high efficiency of fabrication, and its disadvantage is that it cannot generate some computer designed pattern or gratings with special line-space variation. Therefore, interference lithography is introduced to generate plane varied-line-spacing grating in MIT Microsystems Technology Laboratories [11]. However, the line space produced by this method varied with segment or the variation is not continues. Mechanical ruling also produces the same segment variation. The low fabrication efficiency and some errors introduced by environment are also its disadvantages comparing with holograph lithography and interference lithography. We also have tried to get varied line space grating on plane surface by laser writer, but the process control is very difficult [4,5,6,7].

Recently, elastic optics or soft lithography present many characteristics in the fabrication of optical elements [8,9,10]. G. M. Whitesides use elastic membrane to generate gratings with variable uniform line-space [9]. Lorne A. Whitehead generates the Variable-spacing diffraction grating employing elastomeic surface waves [10]. In order to get continuous diversity variation, in this letter, we demonstrate a method, which combine interference lithography with soft lithography, to fabricate plane varied-line-spacing grating by employing elastic medium with variable section. The advantages of this technique include continuous diversity of variation of line-space, high fabrication efficiency and low cost, etc.

2. Fabrication and Characterization

Fabrication begins with preparation of the compound of Polydimethylsiloxane(PDMS, which comes in two parts: a base and a curing agent) and montmorillonite(which is mineral, Na-MMT, on the market). To improve the physical characteristic of PDMS, the montmorillonite is introduced in the PDMS, and it will be more appropriate to produce varied line space grating with fine pattern. In our experiment, 8% of montmorillonite is introduced in the PDMS. When the prepolymer of PDMS and montmorillonite is mixed, they should be agitated

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adequately. Then they are put in the vacuum container for about 10 minutes to reduce the gas bubbles in the compound.

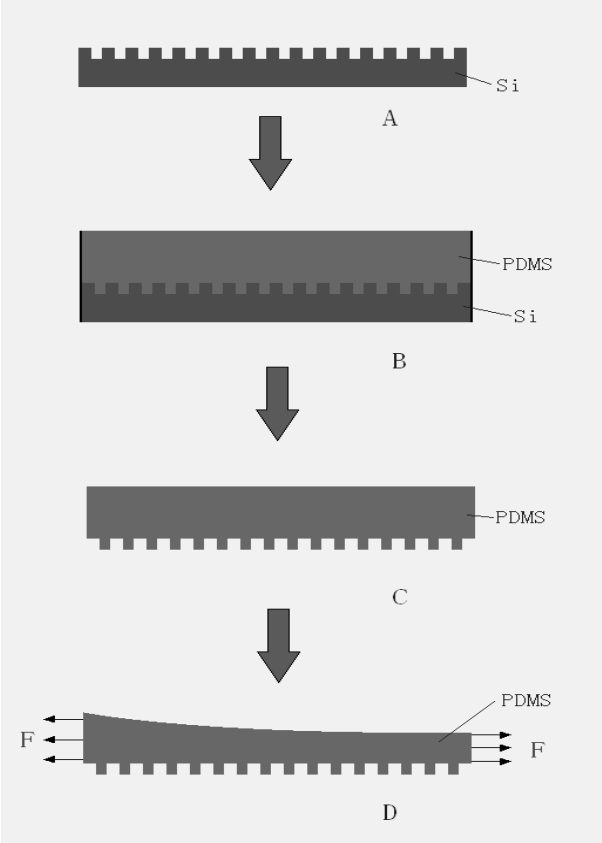

Fig.1 The schematic of the fabrication of variable line space grating.

A grating of silicon can be produced by interference lithography or electron beam direct writing with ion beam etching. After the grating of silicon is steamed by $CF_3(CF_2)_6(CH_2)_2SiCl_3$ for about 20 minutes (Fig.1 (a)), pour the compound of PDMS and montmorillonite on the grating. Then put them in the oven at sixty degrees centigrade for about one hour (Fig.1 (b). Thirdly, cure and peel off PDMS form the grating of silicon and the pattern on the silicon substrate will be transferred on the PDMS (Fig.1(c)). Fourthly, cut the PDMS and let its vertical section varies according to the line space variation of the grating. When there has a balance force on the two ends of the PDMS, the grating with constant line space will form a varied line space grating according to PDMS vertical section variation (Fig.1 (d)).

It can be explained in theory:

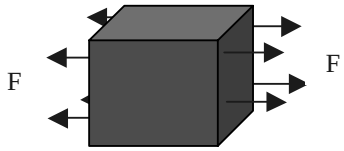

Fig.2 The elastic cubelike substance with force.

According to the theory of the deformation produced by the force on an elastic cubelike substance (fig.2), the strain in force direction will be (on one vertical section):

$$\vec{\sigma} = \frac{\vec{F}}{S}$$

Here, $\vec{F}$ -----the force on the vertical section;

S ------the area of the vertical section;

$\vec{\sigma}$ -----the strain of the vertical section;

Considering the variable area vertical section with a constant force:

$$\vec{\sigma}(x) = \frac{\vec{F}}{S(x)}$$

Here, $\vec{F}$ -----the force of the vertical section;

$S(x)$------the variable area of the vertical section, which is a function of the length coordinate: x ;

$\vec{\sigma}(x)$ -----the variable strain of the vertical section, which is also a function of the length coordinate: x ;

The line space of period of n will be:

$$d_n = \int_{x_1}^{x_2} \frac{\sigma_x}{E} dx$$

Here, d_n -----the line space of period of n ;

x_1 ----- the length coordinate of the start point of the period of n;

x_2 ----- the length coordinate of the end point of the period of n;

E ----- strain coefficient of the substance;

σ_x ----the variable strain of the vertical section in the horizontal direction.

It is obviously that the line space is the function of the area of the vertical section. Therefore the variation of line-space can be obtained by according to the variation of the area of the vertical section of the substance, the same is diversity of variation of line space.

3.Conclusion

Here, we demonstrate a new method to fabricate plane varied-line-spacing grating by employing elastic medium with variable vertical section. The advantages of this technique include continues diversity of variation of line-space, high fabrication efficiency and low cost, etc. The diversity of variation of line-space can be obtained by according to the diversity of variation of area of the vertical section of the substance. The variation of the line space is obviously or significantly and it is very difficult or unrealizable to be produced by traditional interference lithography. For the elastic medium is flectional, the curved variable line space grating can also be produced or transfer the plane variable line space grating pattern to the curved surface. This grating will be used in the optical position sensor in aviation in plan.

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