X-ray Micromachining SU-8 Resist for a Concave Grating Demultiplexer

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We successively fabricate a NIR cylindrical grating demultiplexer based on DXL SU-8 resist technology. Thank to the high sensitivity and contrast behaviors of the SU-8 resist, its corresponding mask absorber can be thinner and the mask membrane can be thicker. As a result, the fabrication processes of the X-ray mask will be much simpler and easier than ever before. Optical measurement results indicate that the resolving resolution of the grating is about 0.4 nm, meeting the design specification of the micro-optic.

Grating demultiplexers have been widely used in many applications such as bio-chemical detection, absorption/emission spectrum analysis and optical communications. Among them, cylindrical concave grating provide both dispersing and focusing functions in single element, the optical system can be effectively miniaturized in consequence. X-ray LIGA technology is always used to fabricate the cylindrical grating since it can provide high aspect ratio, high resolution and excellent lithography quality for optical application. However, the traditional X-ray resist (PMMA) has very low lithographic sensitivity and contrast, the mask membrane must be thin and transparent to X-ray; and the mask absorber must be thick enough to shadow X-ray irradiation. Such a mask structure is very fragile and difficult to fabricate.

In this study, the feasibility of using SU-8 resist as a resist for high-resolution X-ray lithography was investigated. Experimental results indicated that SU-8 resist yields very high lithographic contrast other than its superior sensitivity; therefore, its corresponding X-ray mask absorber can be thinner and the mask membrane can be thicker. An X-ray mask with a thick (5 μm) Si membrane and thin (4 μm) Au absorber was used in this work to pattern a cylindrical grating with a grating constant of 3 um and a thickness of 125 um. The grating is designed as a DWDM (dense wavelength-disperse multiplexer) for optical communication in the spectral range centered at 1550 nm (Fig.1). The details of the optical design work is described elsewhere. Lithographic results show that the DXL SU-8 grating not only has perpendicular sidewall (>89.9^{o}) but also reveal excellent surface quality (Ra<5nm) and resolution (Fig.2). After sputtering a thin gold film as the reflection layer, two channels of C23 (1558.98nm) and C24 (1558.17nm) were then coupled into the grating chip and the dispersed signals are colleted by a SM fiber (Fig.3). As shown in Figure 4, the two channels are successively resolved. The full width at half maximum of the two channels is only about 0.4nm, which is good enough for communication application. Since the cylindrical grating can be mass-produced via polymer molding (i.e. “LIGA” process), its potential in communication and bio-chemical analysis applications is highly expected. The DXL SU-8 technique seems to be a promising way to fabricate the grating demultiplexer after this exploration.

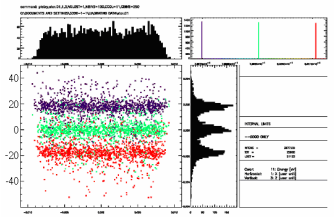

Figure 1. Ray tracing of the designed NIR grating demultiplexer. This simulation work is done by SHADOWS.

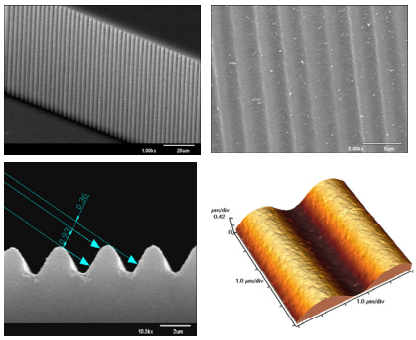

Figure 2. SEM photos of the DXL SU-8 resist microstructure (a, b, c). AFM image of the grating (d)

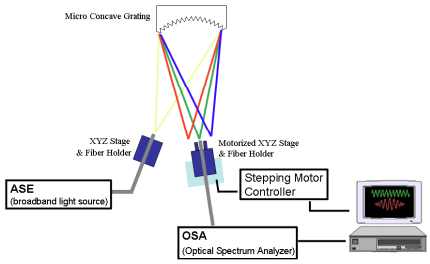

Figure 3. Schematic diagram of the optical measurement bench.

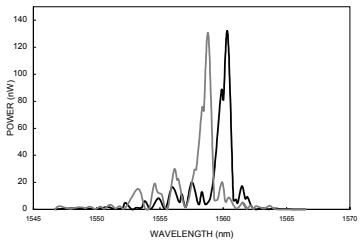

Figure 4. Dispersed spectrum of the C23 and C24 channels diffracted from the concave grating