Fabrication of X-ray reflection sinusoidal grating using fast electron beam direct writing

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X-ray reflection sinusoidal grating is a novel dispersing element which is able to suppress high-order diffraction in various applications. Its grating bars consist of circular holes which randomly shift along grating axis to form sinusoidal transmission function. To reduce the noise of scattered X-rays, groove profile was designed as 500 nm /100 nm silicon/Au stack on bulk substrate with thickness of 10 mm. The aspect of nanoscale gaps between randomly distributed holes and pattern area of 7.5 cm^2 inevitably causes troubles in fabrication. In process (Fig. 1), the first step was started by patterning ZEP520A resist structures of sinusoidal grating with thickness of 500 nm on 4 inches standard silicon substrates using JBX 9500 FSZ electron beam writer at 100kV accelerating voltage and ultra high current of 30 nA. Second, induced coupling plasma etching was used to transfer resist patterns to silicon structures with thickness of 540 nm. The smallest gap is 12 nm (Fig. 2). Thirdly, 4 inches standard substrate with sinusoidal grating structures was cut into rectangle shape and bonded with offstandard bulk silicon substrate using Au-Au diffusion bonding technique. Finally, gold layer of 100 nm was sputtered for reflecting X-rays (Fig. 3). In experiment, several critical techniques have been investigated. In electron beam lithography, circles were replaced by polygons to reduce both data size of layout and reading time in exposure. Ultra large current was applied for fast writing process for costly fabricating structures with nanoscale critical dimension and large area. Moreover, the writing time was significantly reduced. In bonding process, titanium layer of 50 nm was deposited to prevent gold atoms from diffusing into silicon substrates. Furthermore, low bonding pressure was applied to decrease nonuniform stress at corners of substrates.

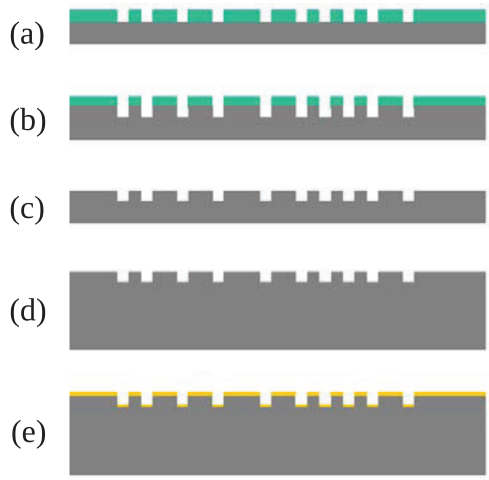

Fig. 1 Integration process of X-ray reflection sinusoidal grating. (a) Fast electron beam direct writing. (b) Induced coupling plasma etching. (c) Removal of the resist. (d) Au-Au bonding. (e) Sputtering Au layer.

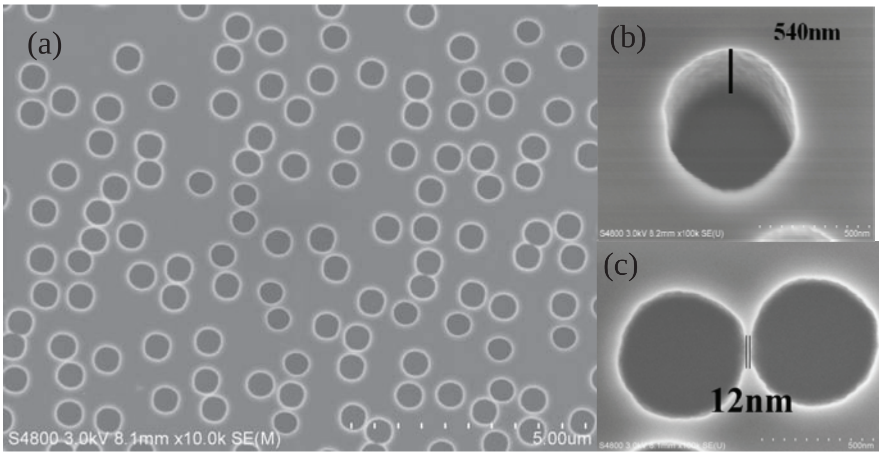

Fig. 2 Images of sinusoidal grating patterns. Ultra fine structures was patterned using electron beam writer at 30 nm current and followed by induced coupling etching.(a) Low magnified image. (b) The thickness is 540 nm with tilting angle of 30 degrees. (c) Critical dimension is 12 nm.

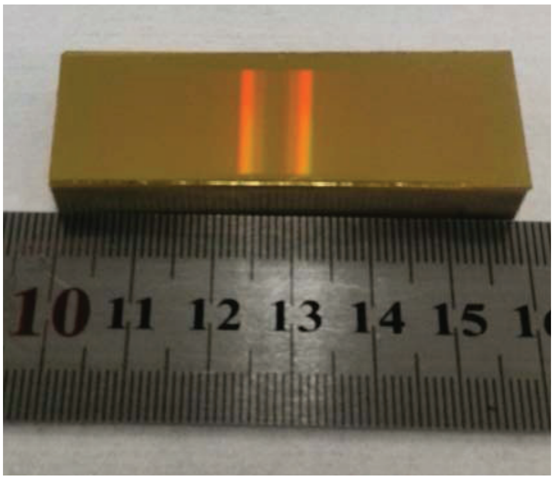

Fig. 3 Images of finished X-ray sinusoidal grating. The dimension of substrate is 60mm×20mm×10mm and pattern area is 50mm×15mm.