Direct Write Laser (DWL) lithography manufacturing of masks for high aspect-ratio grating structures

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Mask manufacturing is the keystone for the obtaining of high quality microstructures from X-ray lithography. Generally E-beam lithography is used to satisfy quality requirements for gratings applied in differential phase contrast imaging (DPCI). An alternative method of patterning is explored, investigating the use of DWL lithography for the manufacturing of both low and high contrast X-ray masks.

**Direct Write Lithography:**
- Heidelberg Instruments DWL660s laser system @355nm wavelength
- Integration in the LIGA process established for phase gratings and metal microstructures
- Substrates: up to 9"x9", different types, seed layers for conformity with electroplating

**Requirements on X-ray masks:**
- Mask membrane with high transmission at low (3-8keV) photon energies
- Gold absorbers: 1-3µm for low contrast, more than 20µm for high contrast
- Low contrast mask for patterning of structures up to 100µm thickness, high contrast for thicknesses up to 1mm (240µm for gratings)

**Low contrast masks**
- Pattern gratings with small periods in high quality on large areas
- Optimize exposure for homogeneous structures
- Find mask membrane which is suitable for large masks and transparent @3keV photon energy

**Process:**
- Periods >4µm directly patterned, 3µm resist thickness → 2µm gold absorbers
- Mask membrane made of kapton foil, 100mm diameter tested

**Results:**
- Large area low contrast mask. Mask diameter: 100mm; grating period: 4.8µm; membrane: polyimide
- Large area grating obtained from low contrast mask. Grating period: 4.86µm; gold absorber height: 85µm
- Visibility mapping of the large area grating. Very good homogeneity at approx. 18% visibility

**High contrast masks**
- Pattern gratings with periods down to 10µm in more than 20µm gold height
- Optimize structures for high verticality
- Enable masks with 100mm diameter

**Process:**
- Direct patterning of 25µm resist on thin silicon wafer (120µm thickness) in 4" and 6" sizes
- Adjustment of writing parameters (dose, focal setting, spotsize)

**Results:**
- Resist pattern for determination of exposure parameters. 14µm period @ DC 0.72 → resist linewidth 3.5µm. Resist height 24µm, aspect ratio 6.4
- High contrast mask for patterning of HAR-gratings. Period 14µm, three DC's implemented on mask: 0.5, 0.6 and 0.72
- Grating obtained from 100mm diameter high contrast mask. Gold thickness 150µm, grating period 10µm, grating diameter 100mm

**Conclusions:**
- Both low and high contrast masks for gratings can be manufactured via DWL lithography
- State-of-the-art limits for masks: 4µm period low contrast, 10µm high contrast (direct patterning)
- Potential of PI and silicon masks has been demonstrated, reliability in comparison to “classic” titanium masks needs to be shown

**Outlook / open tasks**
- 2.4µm period has been patterned on low-contrast mask in small areas → increase area
- Direct patterning of high contrast masks shows smallest features <4µm → investigate & overcome 10µm period limitation (8µm appears feasible)
- Increase mask area to 100x100mm²

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