Development of a nanoscale linewidth-standard for high-resolution optical microscopy

Uwe Huebner**[a], W. Morgenroth[a], R. Boucher[a], W. Mirandé[b], E. Buhr[b], Th. Fries[c], N. Schwarz[c], G. Kunath-Fandrei[d] and R. Hild[e]

[a] Institute for Physical High Technology Jena (IPHT), PO. Box 100239, D-07702 Jena, Germany.
[b] Physikalisch-Technische Bundesanstalt, Bundesallee 100, PF 3345, D-38023 Braunschweig, Germany.
[c] FRT GmbH, Friedrich-Ebert-Str., D-51429 Bergisch-Gladbach, Germany.
[d] Carl Zeiss Jena GmbH, AIM, Carl-Zeiss-Promenade 10, D-07745 Jena, Germany.
[e] HTWK Leipzig, Naturwissenschaften, Trufanowstrasse 6, D-04105 Leipzig, Germany.

Goal

Development of a traceable linewidth/pitch-standard on the nanometre scale for use in new kinds of high resolution light-microscopy:

- DUV and UV microscopy (UVM, DUVM),
- Confocal laser-scanning microscopy (CLSM)

Realisation

Ion-beam sputtering

- Deposition of amorphous silicon film onto a quartz wafer

Electron beam lithography (LION LV1)

- Resist : 120 nm ARP671 (PMMA)

Dry etch of the silicon pattern

- Electron cyclotron resonance (ECR) high-density plasma with CHF_3

Testing

Different user specific measurement and microscopy tools:

- IPHT: SEM JEOL JSM 6700F
- PTB: CD-SEM LEO Supra 35 VP
- PTB: UV-microscope Leica INM 200 (λ = 365 nm, NA = 0.9)
- Leica: UV-microscope Leica INM 300 DUV (λ = 248 nm, NA = 0.8 *dry* and NA=1.2 *immersion*)
- Zeiss: LSM 5 PASCAL (λ = 405 nm, NA = 0.95)
- FRT: FRT MicroGlider® with CWL optical sensor and AFM

Calibration

- PTB Braunschweig
- Leica DKD-Calibration Laboratory Jena

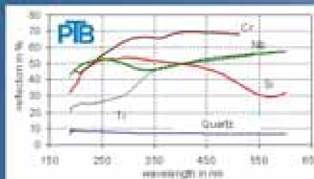
Results

Si gratings on quartz substrates as prototype of a nanoscale CD-standard with pitch structures down to 160 nm, have been fabricated and initially evaluated using state-of-the-art UVM, CLSM, SEM and AFM equipment.

- Quick every day tests of the optical tool:
  - Lateral x-y-resolution and CD (critical dimension),
  - State of the optical system (e.g. astigmatism),
- Upgrade of the microscope to a measurement tool,
- Additional potential for calibration of AFM-tools and scanning electron microscopes (SEM)

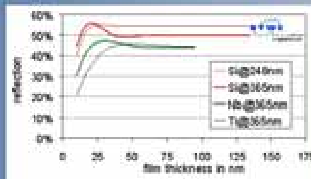
Choice of material → amorphous Si on quartz

Investigations of different materials



Measured spectral reflectance of different thin film materials, with quartz as reference.

Thickness dependence



Dependence of reflection vs. film thickness (simulation)

Contrast "Si on quartz" vs. wavelength

Obtained ratio of reflectance of a 45 nm thick amorphous Si thin film on quartz vs. wavelength.

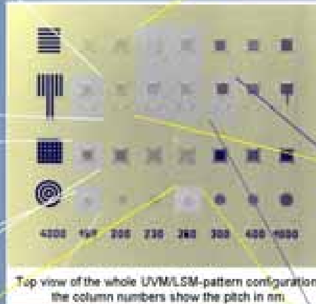
Description and characterisation of the high resolution patterns

Calibration structure

Gratings	1-dim (for both x and y), 2-dim (cross grating) and circular. An isolated single structure for CD-determination is added to one side of the 1-dim grating.
Line width:	**80 nm to 2000 nm**
Pitch:	160 nm to 4000 nm
Material:	**Si (amorphous)** on quartz
Thickness:	30 to 50 nm

1-dim line-grating, pitch 160 nm, etched in 50 nm thick Si on quartz. An isolated single structure for CD determination is added (80 nm).

2-dim (cross grating) with a period of 160 nm



Top view of the whole UVM/LSM-pattern configuration, the column numbers show the pitch in nm

UVM-images of x- and y-gratings Left: pitch 230 nm, CD 115 nm, Right: pitch 260 nm, CD 130 nm, (50 nm Si on quartz, λ = 365 nm, NA = 0.9)

Period: 130 nm (resist mask) — Period: 160 nm (etched into Si on quartz)

SEM-pictures show centre part of circular gratings

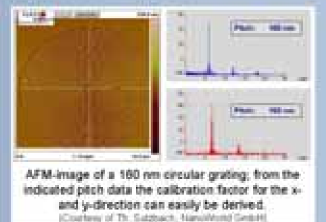
SEM-picture of the centre part (left) and UVM-image (right) of the 260 nm circular grating etched in 50 nm thick Si on quartz. (UVM: λ = 365 nm, NA = 0.9)

CLSM-image shows the surface plot of the 300 nm-Line-Space structure (1dim-grating, Mag. 100x/NA = 0.95)

APPLICABILITY in SEM, DUVM and AFM

SEM-Picture of the centre part of the 160 nm circular grating etched into Si on quartz

DUVM-images of the 160 nm circular grating (Si on quartz) made by dry-objective (left, NA=0.8) and immersion-objective (right, NA=1.2)
(Courtesy of W. Vollrath, Leica Microsystems AG)



AFM-image of a 160 nm circular grating; from the indicated pitch data the calibration factor for the x- and y-direction can easily be derived.
(Courtesy of Th. Sulzbach, NanoWorld GmbH)

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Contact
Institute for Physical High Technology Jena
P.O. Box 100239
D-07702 Jena
Germany
Tel : +49 3641 206 126
Fax : +49 3641 206 199
e-mail : huebner@ipht-jena.de
web : www.cryo-jena.de