Burkhardt, Matthias; Fechner, Renate; Frost, Frank; Mitzschke, Martin; Sinzinger, Stefan:

Ion beam etching process simulation for the pattern transfer of photoresist diffraction gratings generated by holography
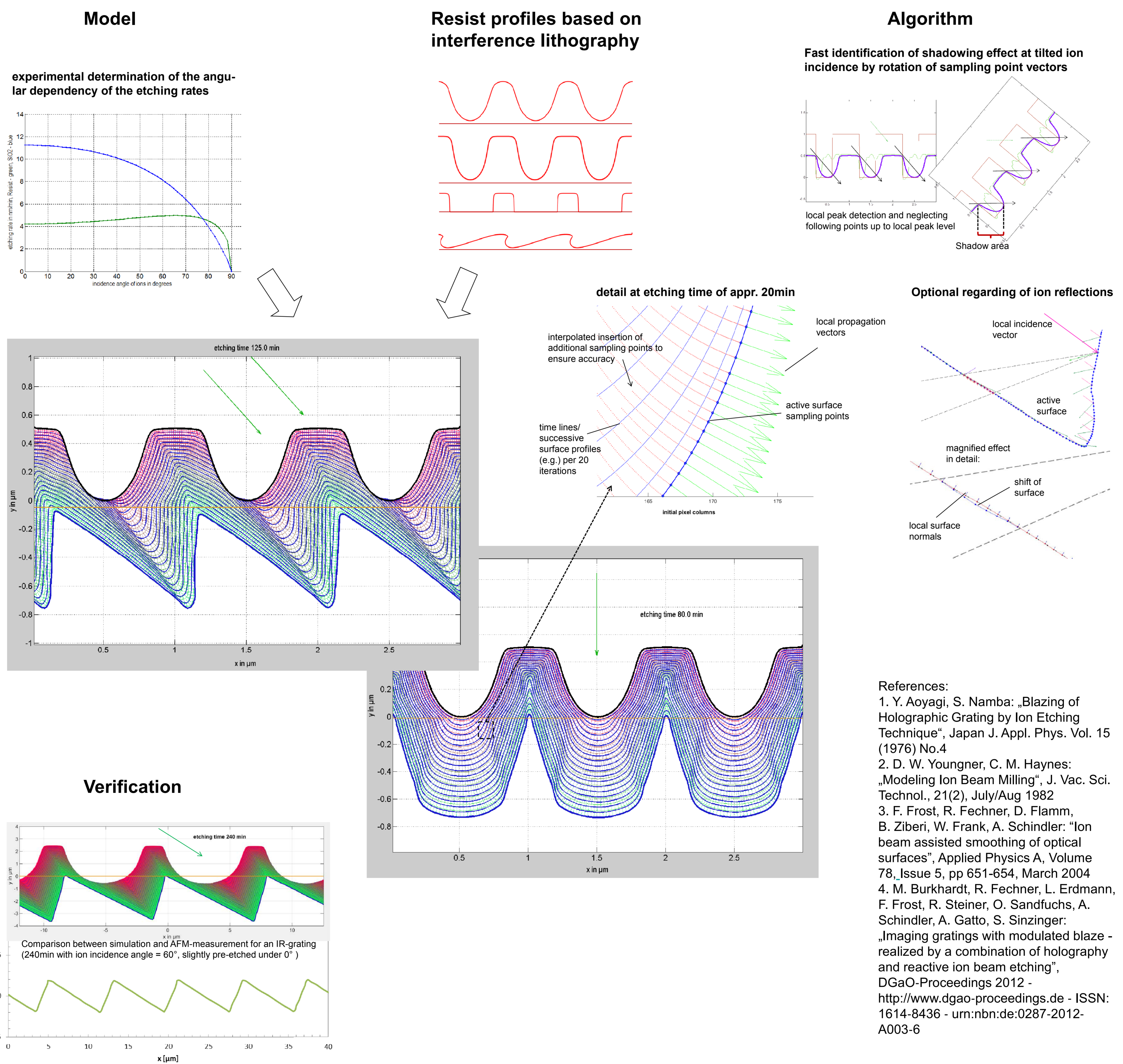
Ion beam etching process simulation for the pattern transfer of photoresist diffraction gratings generated by holography

M. Burkhardt*, R. Fechner**, F. Frost**, M. Mitzschke**, S. Sinzinger***,
*Carl Zeiss Jena GmbH; ** Leibniz IOM Leipzig; ***Technische Universität Ilmenau,
mailto: matthias.burkhardt@zeiss.com

The manufacturing process for diffraction gratings based on interference lithography results at first in a resist surface relief pattern. However, the majority of applications demand grating structures in the inorganic substrate material itself. Commonly, a modification of the grating profile with regard to an optimized diffraction efficiency is necessary. Therefore a number of different etching methods may be employed. For the very often applied dry etching processes an intuitively accessible forecast of the resulting etched profile is virtually impossible. This is caused by the distinct angular dependence of the etching rate. Beside the option to predict etching results the adapted simulation tool based on MATLAB offers a deeper insight into the mechanics of the pattern transfer via ion etching.

Model

experimental determination of the angular dependency of the etching rates

etching time 125.0 min

Resist profiles based on interference lithography

detail at etching time of appr. 20min

interpolated insertion of additional sampling points to ensure accuracy

local propagation vectors

active surface sampling points

time lines/ successive surface profiles (e.g.) per 20 iterations

etching time 80.0 min

Algorithm

Fast identification of shadowing effect at tilted ion incidence by rotation of sampling point vectors

local peak detection and neglecting following points up to local peak level

Shadow area

Optional regarding of ion reflections

local incidence vector

active surface

magnified effect in detail:

shift of surface

local surface normals

Verification

etching time 240 min

Comparison between simulation and AFM-measurement for an IR-grating (240min with ion incidence angle = 60°, slightly pre-etched under 0°)

References:
1. Y. Aoyagi, S. Namba: „Blazing of Holographic Grating by Ion Etching Technique", Japan J. Appl. Phys. Vol. 15 (1976) No.4
2. D. W. Youngner, C. M. Haynes: „Modeling Ion Beam Milling", J. Vac. Sci. Technol., 21(2), July/Aug 1982
3. F. Frost, R. Fechner, D. Flamm, B. Ziberi, W. Frank, A. Schindler: "Ion beam assisted smoothing of optical surfaces", Applied Physics A, Volume 78, Issue 5, pp 651-654, March 2004
4. M. Burkhardt, R. Fechner, L. Erdmann, F. Frost, R. Steiner, O. Sandfuchs, A. Schindler, A. Gatto, S. Sinzinger: „Imaging gratings with modulated blaze - realized by a combination of holography and reactive ion beam etching", DGaO-Proceedings 2012 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2012-A003-6

Summary

We developed a simulation tool that regards basically the angle dependent etching rate. The local angles between ion incidence and surface normal are determined and an iterative algorithm represents the continuous evolution of the surface topography under the etching conditions. Therefore a prior experimentally investigated characteristic of the angular dependence of the etching rate for resist as well as for the substrate material is employed. The model is easily to adapt for special conditions like shadowing due to incidence angles greater than local slope angles or reflected ions at higher local incidence angles. Numerical instabilities are successful reduced by several adjusted fitting and smoothing techniques.