Investigation of Low Damage Mask Repair by Combination of Electron Beam and Scanning Force Technology

Claus Burkhardt, Sven Bauerdick, Ralf Rudorf, Wilfried Nisch
Volker Bucher [a], Wolfang Barth [b], Albrecht Ehrmann [c], Tarek Lutz [c], Jenspeter Rau [c]

Natural and Medical Science Institute, Reutlingen, Germany
[a]Kleindiek Nanotechnik, Reutlingen, Germany
[b]Nascatec GmbH, Kassel, Germany
[c]Infineon AG, München, Germany

NMI
Applied R&D

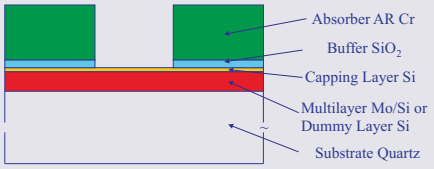
Markwiesenstrasse 55
72770 Reutlingen, Germany
Tel. +49 (0) 7121 5 15 30-55
FAX +49 (0) 7121 5 15 30-62
burkhardt@nmi.de
www.nmi.de

Introduction

To investigate low damage mask repair, we have built a system, which combines electron beam induced deposition (EBID), electron beam induced etching and scratching by an atomic force microscope (AFM). Therefore a three channel gas injection system was built and adapted to a FESEM. The guidance of the precursor gas inside the SEM is done by compact micro manipulators which allow a precise and stable positioning in three dimensions with a resolution below one micrometer. For a first test of the performance of the system we used a mask with defined clear and dark defects with dimensions down to 40 nm nominal size.
Using electrons instead of ions (which are usually used in repair tools) for deposition of material on the mask, clear defects could be completely repaired and show no damage. Defect sizes down to 20 nm can be repaired with a position accuracy below 15 nm. A compact AFM was integrated on the stage of the SEM, thus allowing AFM imaging of the defects under SEM control. Repair of dark defects by e-beam induced etching or by

Design of the test mask

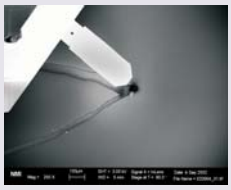
The mask has a chromium absorber layer, a silicon oxide buffer layer on a Mo/Si multilayer stack terminated by a Si capping layer, all deposited on a fused silica substrate. The mask has been patterned with an AMAT-ETEC ALTA laser writer, chrome has been etched with Cl/O plasma, silicon oxide in a two-step process with a fluorine plasma and HF solution [6].



In-situ AFM

Integration of an AFM on the specimen stage of the SEM:

Tube-Scanner mounted on the stage
3 Axes Micromanipulator for Manipulating the AFM tip
Piezo resistiv Cantilever

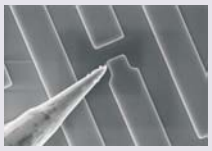


AFM image of several deposited tungsten carbide structures taken under direct SEM observation (left).
SEM micrograph of the AFM-cantilever (right).

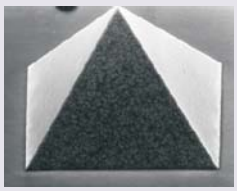
Setup

Our base system is a field emission SEM LEO Gemini 1550 VP. For digital scan control a pattern generator (Raith Elphy Quantum) and beam blanker was adapted to the SEM.
For investigation of e-beam induced deposition and etching with different chemistries, a gas injection system with several channels was built. The system consists of temperature controlled reservoirs outside the vacuum, needle valves to define the gas flow and vacuum feedthroughs. The whole system is mounted on a side flange of the SEM. Inside the vacuum, the gas is guided by a small capillary, which is mounted on a micro manipulator. In our experiments we used tungsten hexacarbonyle as precursor for deposition and xenon difluorid for etching. The third channel of the gas injection is used for O/Cl and further gases.

Nano Scratching



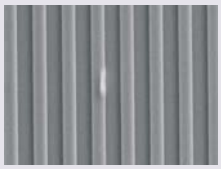
SEM micrograph of a scratch test which has been done on a bond pad (left),
Tungsten needle at position of a dark defect at the end the chromium absorber layer (right)
The hard chromium layer could not be scratched.



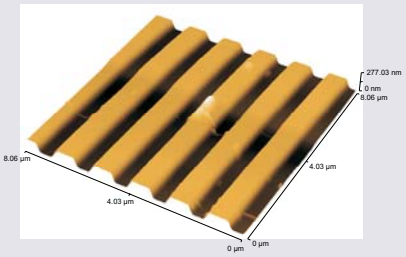
Diamonttip on an AFM cantilever.
This material allows scratching of hard materials.

Electron Beam Induced

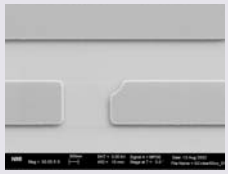
Main parameters of electron beam induced chemistry are the flow of precursor gas to the sample surface, the sticking coefficient of the gas molecules on the surface, surface diffusion of the adsorbed molecules, current density and energy of the electron beam [2].

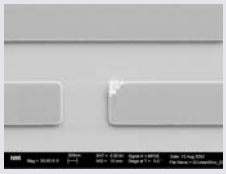


SEM micrograph of a mask with defined 150 nm clear defect. Chromium stripes have a width of 500 nm (left)) micrograph of the mask after repair by deposition of tungsten carbide (right).



AFM micrograph of the repaired defect
Chromium stripes have a width of 500 nm.





SEM micrograph of a mask with defined 50 nm clear corner defect before and after repair.
Chromium stripes have a width of 500 nm.

Conclusions

A system was built, which combines electron beam and scanning force technology.
Repair of clear defects of the chromium absorber layer of an EUV mask was done by electron beam induced deposition. Therefore we have built a novel gas injection system with high precision guidance of the gas flow to optimize the deposition process.
By adapting a AFM inside a SEM, defects can be imaged by the AFM and thus provide additional information about the topography of the mask. In a next step, we plan to use a cantilever with high force constant and a hard tip to demonstrate the repair of dark chromium defects by scratching. Electron beam induced etching with different precursors like XeF_2, and also O_2 and Cl_2 is now possible, but further work is necessary to develop the right process parameters for etching metals (e.g. chromium) and insulators.

Acknowledgement

Part of this work has been suportet by the German federal ministry of science and education, BMBF under No. 13N8004

References

[1] T. Liang and A. Stivers, J. Vac. Sci. Technol. B 18 (6) (2000) 3216
[2] H.W.P. Koops, R. Weiel, D.P. Kern, T.H. Baum, J. Vac. Sci. Technol. B 6 (1) (1988) 477
[3] T. Liang and A. Stivers, SPIE Microlithography 2002, Santa Clara
[4] S. Bauerdick, C. Burkhardt, R. Rudorf, W. Barth[b], V. Bucher[a] and W. Nisch, this proceedings
[5] www.nanotechnik.com
[6] J. Rau, H. Wendt, J. Mathuni, C. Stepper, A. Ehrmann, F. Kamm, Proceedings of EMC 2002, Unterhaching

Links

http://www.uni-tuebingen.de
Http://www.leo.de
Http://www.nanotechnik.com
http://www.nascatec.com
http://www.raith.de

Information

NMI
www.nmi.de
Claus Burkhardt
burkhardt@nmi.de
+49 (0) 7121 - 51530 55

MNE, Lugano 2002