Reducing optical losses in focused-ion-beam etched silicon

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Silicon-on-insulator is rapidly emerging as the material system of interest for future photonic devices for the consumer market. Optical lithography with 248 nm and 193 nm UV lithography on wafer scale is the ideal tool for volume production of photonic components [1]. However, due to the cost of masks and processing it is expensive and often slow to fabricate prototypes of new device concepts with optical lithography.

Therefore one needs prototyping technologies that enable rapid and flexible fabrication of nanophotonic components. The best example nowadays is electron beam lithography. One of the inconveniences however, is the fact that electrons can not directly etch a semiconductor. Therefore one has to work with resist layers and etch with the conventional tools such as plasma etching. This slows down the optimization process and limits the designs to planar structures. An interesting alternative is focused-ion-beam (FIB), where a beam of ions is used instead of an electron beam. In current commercial systems the particle optics enables local sputtering with a spot smaller than 10 nm, enabling fabrication of devices with a smallest feature size < 50 nm [2].

However, it was reported that FIB etching generates high optical losses in silicon [3]. We propose iodine enhanced etching and annealing at high temperatures as techniques to reduce these optical losses after FIB etching. The best results were obtained for 2 hours annealing at 1000°C: optical losses are reduced from several thousands to less than 100 dB/cm; for a typical device length of 10-100 μm the losses will thus be reduced to 0.1-1 dB, which is a tolerable value for most now device concepts.

1. S. Selvaraja, P. Jaenen, S. Beckx, W. Bogaerts, P. Dumon, D. Van Thourhout, R. Baets, LEOS Annual Meeting 2007, United States (2007)
2. W. C. L. Hopman, F. Ay, W. B. Hu, V. J. Gadgil, L. Kuipers, M. Pollnau, and R. M. de Ridder, Nanotechnology **18**, 195305 (2007).
3. J. Schrauwen, D. Van Thourhout, and R. Baets, "Focused-ion-beam fabricated vertical fiber couplers on silicon-on-insulator waveguides," Applied Physics Letters **89**, 141102 (2006).

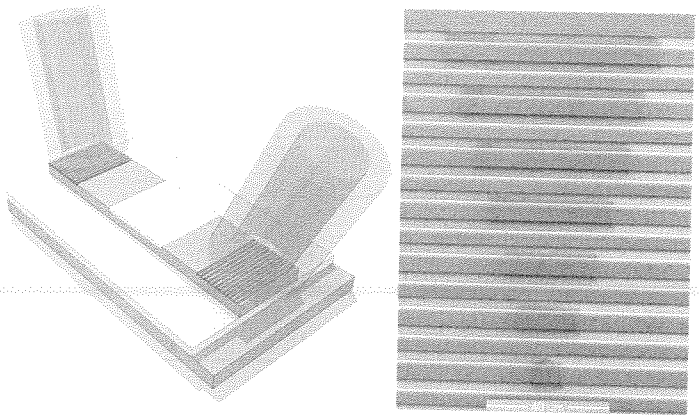

Fig. 1. Left: Principle of the experiment: implantation and etching of prefabricated waveguides; light is coupled from fibers by vertical grating couplers. Right: SEM micrograph of implantations on varying length sections.

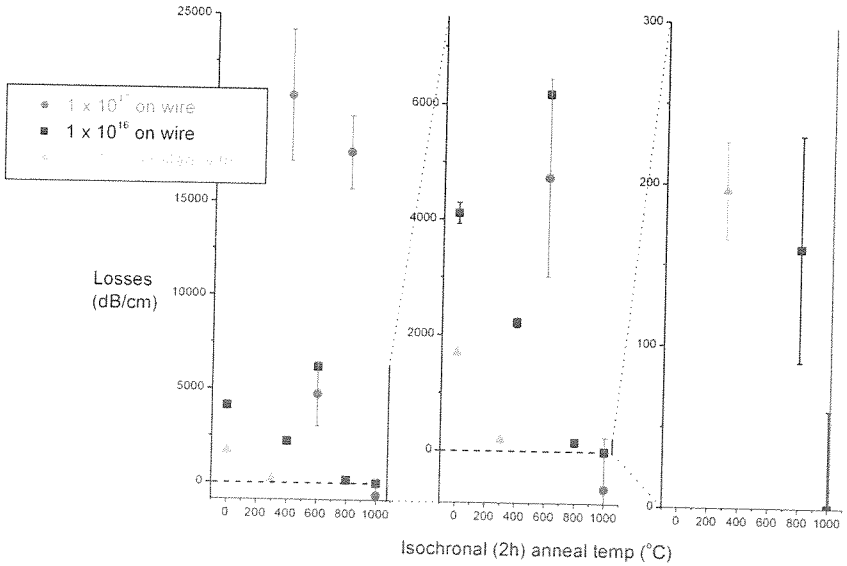

Fig. 2. Optical losses extracted from transmission measurements on wire and slab waveguides. The losses can be reduced to practicable values by both annealing at high temperatures and/or using iodine etch.

2:00 PM 2C-2 **(Invited) Interfacial Mesoscopic Structuring As A Highly Probable Origin Of The Mysterious "LER Fundamental 5nm Limit",** *Yehiel Gotkis, KLA Tencor*

LER is one of the stumbling blocks in SC technology. Leveling at 5 nm it refuses to show "improving" responses, provoking the term "LER fundamental limit" to appear. Highly interfacial (no bulk) ultra-thin films become dynamically very non-uniform. Phenomena, inducing long-range LER and complicating progress in LER improvement are discussed.

2:30 PM 2C-3 **Contributions Of Resist Polymers To Innate Material Roughness,** *Theodore Fedynyshyn, David Astolfi, Russell Goodman, Susan Cann and Jeanette Roberts*, Lincoln Laboratories, MIT, *Intel Corporation*

We have applied an AFM-based technique to measure intrinsic material roughness (IMR) of different resist polymers to IMR, including polyhydroxystyrene, polymethacrylate and fluorinated polymers. The IMR of these polymers with both EUV and DUV exposure was determined and similarities and differences between exposures at the two wavelengths will be described.

2:50 PM 2C-4 **An Alternative Electron Beam Exposure Mechanism For Hydrogen Silsesquioxane – A Raman And FTIR Study,** *Deirdre Olynick, Andreas Schipotinin, Stefano Cabrini and Jim Schuck, Lawrence Berkeley National Laboratory*

FTIR and Raman spectra of HSQ in baked and exposed samples show the presence of the SiH2 bond indicating cross-linking during exposure can occur via a redistribution reaction and which does not require hydroxyl groups. Field enhancing plasmonic devices for high resolution Raman studies will also be addressed.

3:10 PM 2C-5 **Improvement In Line Width Roughness (LWR) By Post-Processing,** *Manish Chandhok, Kent Frasure, Steve Putna, Todd Younkin, Willy Rachmady, Uday Shah, Wang Yueh and Melissa Shell, Intel Corporation*

Transistor performance can be impacted when the 3σ LWR is greater than 10% of the gate CD. So, for 22 nm node devices LWR < 2.2 nm is required. We will present post-processing techniques to reduce LWR and show ~2 nm LWR for 40 nm hp features using EUV lithography.

3:30 PM Break

Poster Session

Plaza Foyer and Broadway Rooms
3:45 pm – 6:30 pm

Nano-Optic Devices I Session Posters

P-2B-1 **Fabrication Of 200 Nm Period Blazed Transmission Gratings On Silicon-On-Insulator Wafers,** *Minseung Ahn, Ralf Heilmann and Mark Schattenburg, Massachusetts Institute of Technology*

We present progress in the fabrication of 200 nm-period blazed transmission gratings with a 25 μm-pitch support mesh on 3-5 μm thick SOI wafers. We achieved very high etch anisotropy of about 500-1000 on a <110> silicon wafer using a room temperature etching process in a high concentration KOH solution.

P-2B-2 **Reducing Optical Losses In Focused-Ion-Beam Etched Silicon,** *Jonathan Schrauwen, Roel Baets, Dries Van Thourhout, Edwin J. Klein*, Feridun Ay*, Wico C.L. Hopman* and Rene. M. De Ridder*, Ghent University, University of Twente*

Focused-ion-beam (FIB) is an interesting alternative for prototyping of photonic components because it can directly etch a semiconductor and reach feature sizes < 50 nm. However, silicon exhibits high optical losses after FIB etching. We propose two techniques to reduce these losses: high temperature annealing and iodine enhanced FIB etching.

THE 52nd INTERNATIONAL CONFERENCE on ELECTRON, ION, and PHOTON BEAM TECHNOLOGY & NANOFABRICATION

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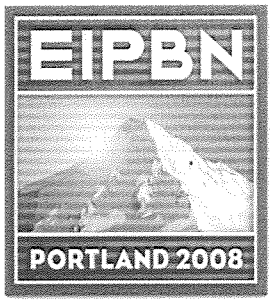

Affiliates Program

Commercial session

Tuesday, May 27: 2 pm – 9 pm
Wednesday, May 28: 8 am – 1 pm (optional)

Conference attendees have the opportunity to become acquainted with your company and products, meet your representatives, and view company information of all kinds. The setting is informal, with refreshments served. This year we will also have the Welcome Reception in the Commercial Exhibit area from 7:00 to 9:30 pm on Tuesday. It is a terrific opportunity to make new contacts, renew existing ones, and gain valuable exposure in a very active community. Many students attend EIPBN, and welcome the opportunity to connect with possible future employers! Two booth sizes are available:

Standard (10 x 10 feet, one 4 x 8 feet poster, mountings provided)	**Cost: $ 800**
Large (10 x 20 feet, two 4 x 8 feet posters, mountings provided)	**Cost: $ 1,100**

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NIM B
Beam Interactions with Materials & Atoms

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Calendar

A list of conferences and schools scheduled within the coming two years and covering topics related to energetic beam interactions with materials and atoms. * Indicates new or changed information.

March 9–13, 2008
New Orleans, USA

TMS Annual Meeting: Symposium on **Charged Particle Beam-Induced Radiation Effects in Materials**
Information: G.S. Was
University of Michigan
e-mail: gsw@umich.edu
http://cmsplus.tms.org/CMS/CMSPlus.nsf?OpenDatabase

May 11–15, 2008
Santa Fe, New Mexico, USA

American Conference on Neutron Scattering (ACNS2008)
Information: Simon Billinge
e-mail: billinge@pa.msu.edu
Thomas Proffen
e-mail: tproffen@lanl.gov
http://www.lansce.lanl.gov/acns2008/index.html

May 12–16, 2008
Siena, Italy

37th Int. Symp. of **Archaeometry**
Information: http://www.inisi.it/eventi/isa2008

May 19–25, 2008
Zakopane, Poland

XLII Zakopane School of Physics – **"Breaking Frontiers: Submicron Structures in Physics and Biology"**
Information: Dr. Marta Marszałek
e-mail: zakopaneschool2008@ifj.edu.pl
http://www.ifj.edu.pl/zakopaneschool2008

May 26–30, 2008
Strasbourg, France

EMRS Spring Meeting. Symposium I. **Front-end Junction and Contact Formation in Future Silicon/ Germanium Based Devices**
Information: Fucio Christiano, LAAS/ CNRS, 7 av du Col Roche, F-31077 Toulouse, France
e-mail: Fucio@laas.fr
or Peter Pichler, Fraunhofer IISB, Schottkystrasse 10, D-91058 Erlangen, Germany
e-mail: pichler@iisb.fraunhofer.de
http://www.emrs-strasbourg.com

May 27–30, 2008
Portland, Oregon, USA

The 52nd International Conference on **Electron, Ion, and Photon Beam Technology, and Nanofabrication (EIPBN 2008)**
Information: Prof. Steven Brueck
Center for High Technology Materials, University of New Mexico
1313 Goddard SE, Albuquerque, NM 87106
Tel.: 505 272 7800
e-mail: eipbn08@comcast.net
http://www.eipbn.org

May 28–June 6, 2008
Dourdan, France

CERN Accelerator School on **Beam Dignostics**
Information: S. von Wartburg, CERN Accelerator School
DSU Division, CERN, CH-1211 Geneva 23
Fax: +41 2276 75460
e-mail: Suzanne.von.Wartburg@CERN.ch

June 2–5, 2008
Lyon, France

Int. Conf. on **Swift Heavy Ions in Matter, SHIM 2008**
Information: Denis Dauvergne, IPN Lyon, 4 rue E. Fermi, F-69622 Villeurbanne Cedex, France
Tel./fax: +33 4724 46257/31452
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