Focused-ion-beam lithography for prototyping of silicon photonic components

J. Schrauwen, G. Roelkens, D. Van Thourhout and R. Baets
Photonics Research Group, Department of Information technology, Ghent University – IMEC, Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium

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 devices [1,2]. 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. Furthermore feature sizes are limited to more than 100 nm, which is not sufficient for various new concepts.

These problems can be circumvented by a hybrid approach: UV lithography followed by a serial lithography technique with higher resolution. For mass fabrication one could use electron beam lithography. On dedicated tools a minimum feature size and overlay accuracy below 20 nm are feasible.

We propose an alternative technique, Focused-ion-beam (FIB) lithography, where a ceramic/metallic layer is directly patterned by sputtering. This process can be performed in a machine without high energy column (> 50 keV) and without interferometric translation stage. The pre-patterned sample is first covered with a 50 nm layer of sapphire (Al₂O₃) and a 50 nm layer of titanium by evaporation. These layers follow the topography of the sample; and the titanium layer is conductive, which guarantees easy visual overlay alignment to existing structures.

In the second process step the Ti layer is etched by Focused-ion-beam lithography, where the sapphire layers acts as a protective mask for the underlying silicon structures. In a subsequent step the sapphire layer is opened by chemical etching. Then the silicon is etched in an Inductively Coupled Plasma (ICP) where the sapphire layer acts as hard mask. This is depicted in Figure 1. Finally the sacrificial layers are removed chemically.

We have optimized the process for etching both broad (~400 nm) and narrow (~100 nm) trenches in the 220 nm top silicon layer of a silicon-on-insulator substrate. The silicon was etched in an SF₆/O₂ inductively coupled plasma. The resulting slits have nearly vertical sidewalls, as shown in Figures 2 and 3. We believe that this technique can be further optimized to etch 50 – 100 nm wide slits.

Figure 1. Schematic overview of the three-step process flow. In the first step Al₂O₃ acts as etch stop layer and protects the silicon, in the final step Al₂O₃ is again etched slowly and acts as hard mask.

Figure 2. Cross-section micrograph of fabricated 100nm wide slits in the top 220 nm silicon layer of a silicon-on-insulator substrate. Pt was deposited in the slits to keep them intact while making the cross-section with FIB.

Figure 3. Cross-section micrograph of fabricated 400 nm wide and 150 nm deep trenches in the top 220 nm silicon layer of a silicon-on-insulator. Some Ti is still visible on top of the Al₂O₃.
P-2B-3 Thermal Infrared Detection Using Antenna-Coupled Metal-Oxide-Metal Diode Detectors, Jeffrey Bean, Badri Tiwari, Gary Bernstein, Patrick Fay and Wolfgang Porod, University of Notre Dame

Antenna-coupled metal-oxide-metal diodes (ACMODs) can be used as detectors of thermal infrared radiation. ACMODs are fabricated using a single electron beam lithography (EBL) step, followed by a shadow metal evaporation. Detection characteristics such as specific detectivity, noise equivalent power, and signal-to-noise ratio will be presented.

P-2B-4 (Invited) DNA Directed Assembly Of Nanoparticles Linear Structure For Nanophotonics, Baoquan Ding, Stefano Cabrini, Ronald Zuckermann and Jeff Bokor, Lawrence Berkeley National Laboratory

Stiff DNA motifs were used here to organize Au nanoparticles to generate linear array of nanoparticles with decreasing sizes and precise control of distance under 10 nm. This linear chain structure has the potential to work as an efficient nanolens.


A model based on isotropic local etching is suggested and a fast algorithm is developed for calculation of optimum ion doses for 3D patterning with ion multi-beam sputtering. Comparison with rigorous (but much slower) Isoslicer(R) simulator and with experimental 3D patterning by CHARPAN tool confirms usefulness of the approach.

P-2B-6 Fabrication Of Fresnel Zone Plates By Holography In The Extreme Ultraviolet Region, Sankha Subhra Sarkar, Pratap Kumar Sahoo, Harun H. Solak, Christian David and Johannes Friso van der Veen, Paul Scherrer Institut

We demonstrate the fabrication of a Fresnel zone plate by recording the interference pattern between a spherical and a plane wave in the EUV region. The holographic technique offers a path for obtaining FZPs with nanometer scale resolution free from pattern placement errors that influence serial writing methods.

P-2B-7 Focused-Ion-Beam Lithography For Prototyping Of Silicon Photonic Components, Jonathan Schrauwen, Gunther Roelkens, Dries Van Thourhout and Roel Baets, Ghent University

We propose a technique for rapid prototyping of novel silicon photonic device concepts with feature sizes as small as 100 nm. It is based on focused-ion-beam lithography on a metallic/ceramic layer stack and pattern transformation into the silicon by Inductively Coupled Plasma etching.

P-2B-8 Efficient Nanoscale Pattern Transfer Process For Porous Silicon, Edmond Chow, Ik-Su Chun and Xiuling Li, University of Illinois at Urbana-Champaign

A simple and effective processing technique for 3D nanoscale pattern formation in light emitting porous silicon is reported. The technique is based on metal assisted chemical etching and defined by the 2D nanoscale metal pattern. Structures obtained and their optical properties are characterized and discussed.


FIB fabrication of fiber optic sensors based on plasmonics-active nanostructures formed on cleaved tips of optical fibers. The metallic nanostructures fabricated include nanoparticles, nanorods, and nanoholes in optically thick metallic films. The sensing mechanism is based on detecting shifts in localized plasmon resonances (LSPRs) and surface plasmon resonances (SPR).
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<td>May 9 - 13, 2008</td>
<td>TMS Annual Meeting: Symposium on Charged Particle Beam-Induced Radiation Effects in Materials (Information: G.S. Was University of Michigan e-mail: <a href="mailto:gsw@umich.edu">gsw@umich.edu</a> <a href="http://cmsplus.tms.org/CMSCMSPlusInf?OpenDatabase">http://cmsplus.tms.org/CMSCMSPlusInf?OpenDatabase</a>)</td>
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<td>May 11 - 15, 2008</td>
<td>American Conference on Neutron Scattering (ACNS2008) (Information: Simon Billinge e-mail: <a href="mailto:billinge@pa.msu.edu">billinge@pa.msu.edu</a> Thomas Proffen e-mail: <a href="mailto:tproffen@lanl.gov">tproffen@lanl.gov</a> <a href="http://www.lansce.lanl.gov/acns2008/index.html">http://www.lansce.lanl.gov/acns2008/index.html</a>)</td>
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<td>May 19 - 25, 2008</td>
<td>XLII Zakopane School of Physics – “Breaking Frontiers: Submicron Structures in Physics and Biology” (Information: Dr. Maria Marszalek e-mail: <a href="mailto:zakopaneschool2008@ifj.edu.pl">zakopaneschool2008@ifj.edu.pl</a> <a href="http://www.ifj.edu.pl/zakopaneschool2008">http://www.ifj.edu.pl/zakopaneschool2008</a>)</td>
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<td>May 26 - 30, 2008</td>
<td>EMRS Spring Meeting. Symposium I. Front-end Junction and Contact Formation in Future Silicon/Germanium Based Devices (Information: Flavio Christiano, LAAS/ CNRS, 7 av du Col Roche, F-31077 Toulouse, France e-mail: <a href="mailto:flavio@laas.fr">flavio@laas.fr</a> or Peter Pichler, Fraunhofer HSB. Schottkystrasse 10, D-91058 Erlangen, Germany e-mail: <a href="mailto:pichler@irish.fraunhofer.de">pichler@irish.fraunhofer.de</a> <a href="http://www.emrs-strasbourg.com">http://www.emrs-strasbourg.com</a>)</td>
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<td>CERN Accelerator School on Beam Diagnostics (Information: S. von Wartburg, CERN Accelerator School DSU Division, CERN, CH-1211 Geneva 23 Fax: +41 2276 75460 e-mail: <a href="mailto:Suzanne.von.Wartburg@CERN.ch">Suzanne.von.Wartburg@CERN.ch</a>)</td>
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<td>June 2 - 5, 2008</td>
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