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NanoWestern

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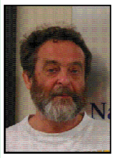
WINS Annual Meeting May 15, 2007, In Review

CAW Symposium Review

Photolithography Mask Design Using ™L-Edit Layout Editor



Dr. Richard Glew
Nanofabrication Laboratory Manager
University of Western Ontario

In order to use the contact photolithography mask aligners in Western's Nanofabrication Laboratory, one requires a photomask. Previously, having a mask made to a particular specification had been expensive and time consuming. In order to make the process more time and cost efficient, we have acquired a computerized layout editing software package which enables photolithographic patterns to be drawn.

We have chosen to use is L-Edit™ version 12.10 (Tanner Research) because it is widely used in the semiconductor industry and by numerous universities. L-Edit™ is a computer-aided design tool which combines simple shapes such as rectangles, circles, arcs and polygons to form complex patterns with dimensions from centimetres down to fractions of a micron. L-Edit™ can be used for one or more photolithographic levels with suitable alignment marks on each level. Large dimensional patterns can be integrated with nanometre sized patterns by combining photolithography with e-beam lithography. When the design is complete, the patterns are compiled into a format ready for mask making.

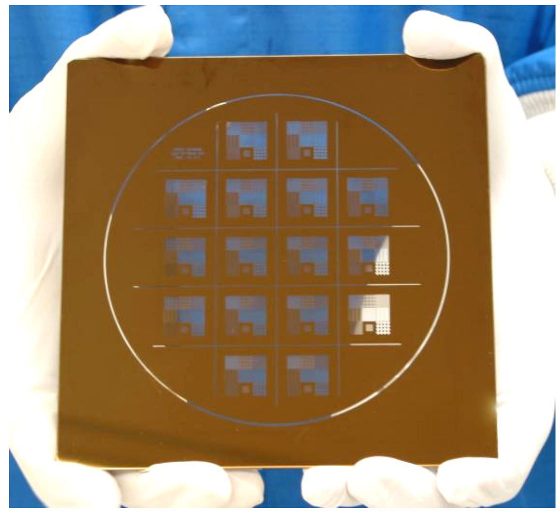


Figure 2. Layout from Figure 1 as a complete mask.

Since the Nanofab does not have a mask making facility, the pattern has to be sent out for processing. There are numerous commercial mask making outfits which offer their services; the cost being dependant on the lithographic dimension required. Over the last few months, our mask designs have been processed by the Nanofab facility at the University of Alberta via their online submission system. They have a Heidelberg 200 Laser lithographic system which can draw features down to 1.0 micron. The approximate cost per mask, for a two hour write time, is $120 plus shipping for a 5 x 5 inch chrome mask. The mask is ideal for exposing photoresist on four inch wafers with the Karl Suss MA6 contact lithographic tool.

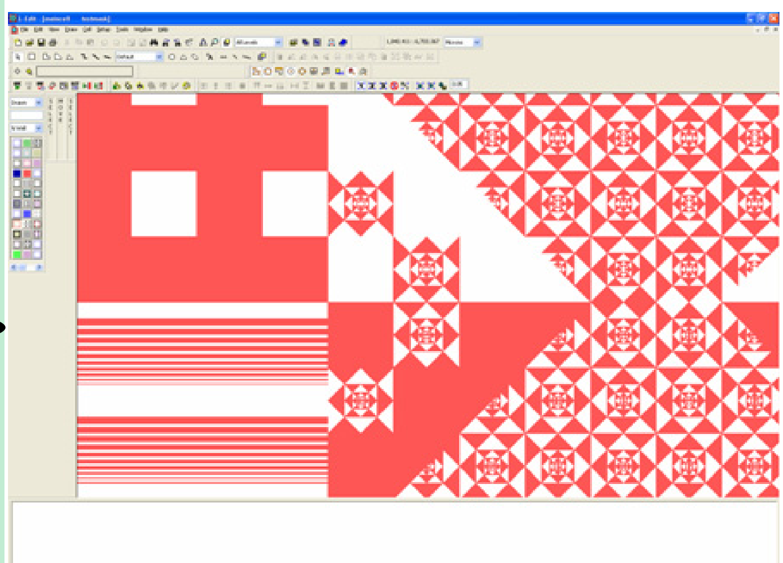


Figure 1. Screen image of L-Edit™ software showing mask design.

Contact Dr. Richard Glew (rglew@uwo.ca) to discuss your photomask requirements or if you require access to the L-Edit™ Layout Editor.

Silicon-Photonic Circuit Fabrication at Western's Nanofabrication Laboratory

Dr.Andy Knights
Department of Engineering Physics
McMaster University

For five decades silicon has been the material of choice for microelectronic fabrication. However, this dominance has not been transferred to the semiconductor based photonics industry mainly as a result of the lack of an efficient silicon light emission mechanism. There is significant interest in the development of silicon-based systems which can use photons as opposed to electrons as carriers of information. For instance, it has been recognized for some time that if photonic components are to be reduced in unit cost, silicon must play a significant role [1]. This is a direct result of the mature processing strategies, established high volume manufacturing procedures and numerous industrial fabrication facilities that are in place throughout the world.

In addition to providing low-cost, reliable and application specific components, silicon-based photonics has the potential to make a critical impact in the microelectronics industry allowing interconnect technology to overcome the predicted bottleneck in the next decade [2]. Also, silicon optical systems will play an important role in the development of sensors for use in the biological, mechanical and chemical industries, particularly when incorporated with the concept of lab-on-a-chip [3].

The research performed by the silicon photonics group at McMaster University [4] in collaboration with the Western's Nanofab Lab and Interface Science Western (ISW) is aimed at addressing various technological hurdles which need to be negotiated before silicon can achieve its full potential as a truly optoelectronic material. The collaboration operates as part of the highly successful Ontario Photonics Consortium [5]. The objective of this research is the fabrication of novel, silicon-based devices |incorporating high levels of optical and electrical functionality, integrated on a single silicon chip. These functions include emission, detection and modulation of light signals confined in a planar waveguide structure. Despite a growing research community and an increasing profile, integrated optical chips containing all of the desired functionality have yet to be fabricated in silicon.

Silicon is transparent to wavelengths above ~1100nm, and it is at this range that most silicon photonic circuits are designed to operate (of note, this makes silicon waveguides compatible with the important communications wavelengths around 1300nm and 1550nm). The vast majority of silicon photonic circuits have been fabricated in the silicon-on-insulator (SOI) platform (more specifically silicon-on-oxide). It is well-established that optical confinement in both the vertical and horizontal directions and subsequent single mode propagation of an optical signal can be achieved by the fabrication of a rib structure in the silicon over-layer of SOI [1]. Optical mode solving can be performed using high-level simulation tools such as the BPM package provided by RSOFT [6], providing details of the distribution of optical power (figure 1). This thus allows the design of an array of devices, such as the rib waveguide optical power coupler shown in cross-section in figure 2.

Fabrication of silicon photonic devices may be performed using standard processing technologies. In the case of the current

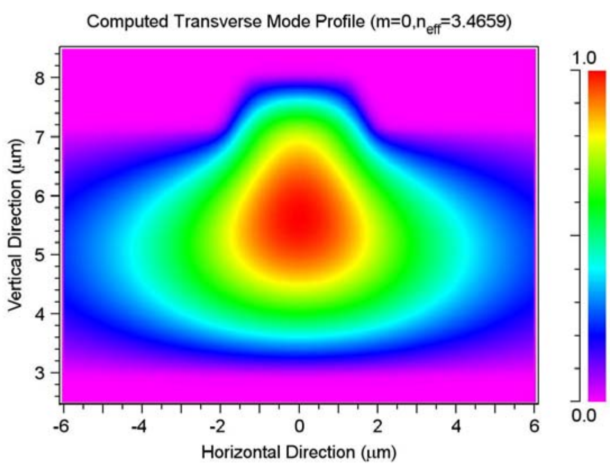


Figure 1. Simulation of fundamental mode propagating in a silicon waveguide.

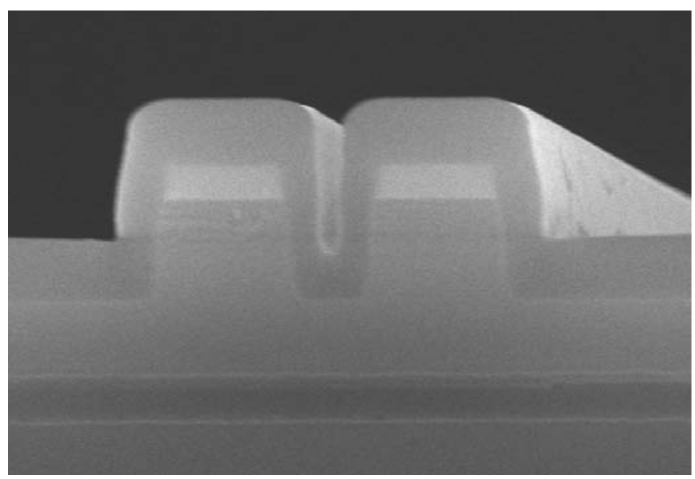


Figure 2. Cross section of an SOI rib waveguide coupler.

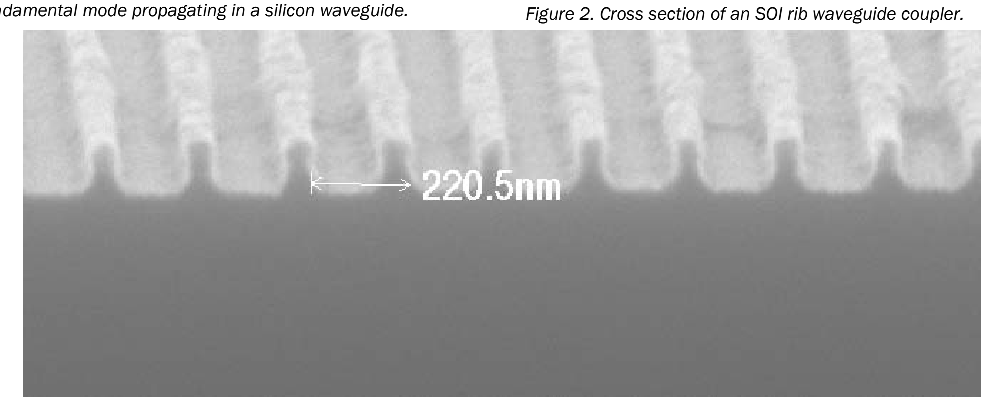


Figure 3. Integrated Bragg grating in SOI waveguide.

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program much of this fabrication is provided by the Western's Nanofab. In particular, the Alcatel 601E silicon etcher has the versatility to produce rather large, deep structures (such as that shown in figure 2) or structures with dimensions of only a few hundred nanometres such as the Bragg grating device shown in figure 3.

Silicon's ability to be doped allows the development of a great deal of interesting and useful photonic functionality. The integration of carrier injection devices, such as *p-i-n* diodes, around the guiding rib provides a means by which charge carriers can be made to interact with optical signals [1]. Thus, dynamic control of both the real and imaginary components of the silicon refractive index can be achieved permitting optical switching and variable attenuation. Additionally, monolithic silicon waveguide detectors suitable for IR wavelengths have been fabricated using the *p-i-n* diode in reverse bias [7]. It is this novel form of detector which forms one of the prime motivations for the three-way collaboration between McMaster, the Nanofab and the ISW. The detectors require the controlled introduction of defects via ion implantation (so-called defect engineering) to provide enhanced sensitivity to sub-bandgap radiation. Fabrication thus proceeds via design and simulation at McMaster, waveguide definition at the Nanofab and doping and defect engineering at ISW. Detectors formed in this way produce photocurrents on the order of 10's of µA's for optical power of 1mW at a wavelength of 1550nm. Typical results are shown in figure 4.

This article provides a brief description and overview of the research currently underway at Western's Nanofab lab in the area of silicon photonics. The collaboration is rapidly establishing its position in the global research arena particularly with regard to functional integration and materials development. We continue to build on our device portfolio and processing expertise which allow us to further our strategic alliances with groups both in Ontario and elsewhere.

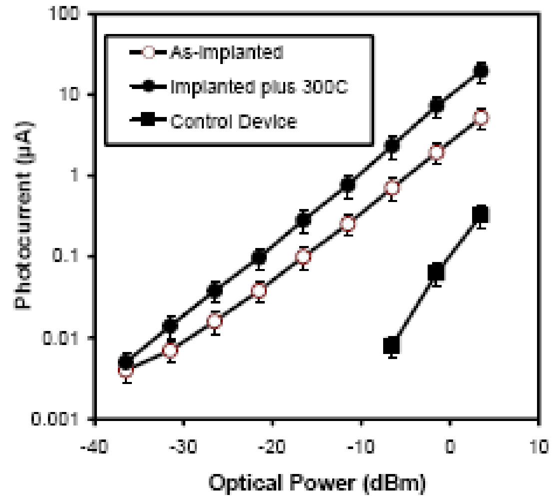

Figure 4. Unbiased photo-current versus on-chip optical power for defect engineered waveguide detectors.

References

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[2] P Kapur and K C Saraswat, *Optical Interconnects for High Performance Integrated Circuits*, Physica E, **16** (2003) 620-627.

[3] A Janshoff et al., *Macroporous p-type silicon Fabry-Perot layers- fabrication, characterization, and applications in biosensing*, J. Am. Chem. Soc. **120** (1998) 12108-12116.

[4] http://engphys.mcmaster.ca/siliconphotonics

[5] http://opc.mcmaster.ca

[6] http://www.rsoftdesign.com

[7] J D B Bradley, P E Jessop, and A P Knights, Silicon-waveguide-integrated optical power monitor with enhanced sensitivity at 1550nm, *Appl. Phys. Lett.*, **86** (2005) 241103.

Growth of Conformal Gold Shells over Silica Nanospheres by Colloidal Chemistry

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The objective of this project is to test the current optical scattering theory by examining light scattering properties from 2-D lattices which are formed by metallodielectric nanoparticles arranged into a lithographically defined array. The light scattering particles will consist of spherical silica cores of submicron diameter (nanospheres) coated with a gold shell to a selected thickness ranging from tens through hundreds of nanometers. We further wish to test the sensitivity of scattering to alteration of the shape of the array by driving the nanosphere into an ellipsoidal shape.

This project has three phases. The first goal of this project is the synthesis of the gold-coated nanoparticles such that the shell is grown uniformly over the core. The nanoparticles of interest for this project are composed of a silica core covered by a conformal shell of gold. The core is grown by the hydrolysis of tetraethoxysilane followed by condensation which forms a silica framework. At the point where the framework has reached the desired size, the silica is terminated with 3-aminopropyltrimeth-oxysilane (APS) in order to

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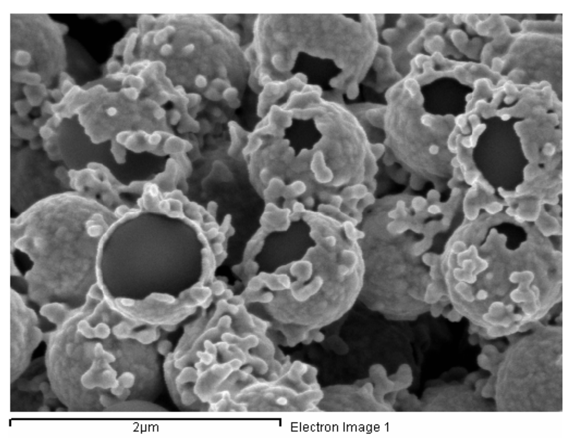
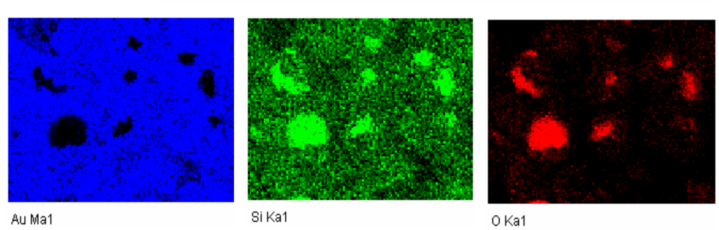
Figure 1.
a) SEM image of successfully coated silica nanospheres with areas of the silica core exposed.

b) EDX elemental maps corresponding to the image for gold, silicon and oxygen.





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discontinue condensation as well as to provide the nanoparticle with amine functional sites on its surface. Particles such as the ones described are commercially available. The shell is produced by preparing small gold clusters by reducing a gold salt and adding the functionalized nanospheres to this solution. The terminal amine is capable of reducing the gold thereby attaching the small clusters to the surface of the nanosphere, a process called nucleation. The gold shell and the silica core are grown to varying thicknesses providing the gold-coated silica spheres with different sizes and different core to shell ratios.

When the nanoparticles have been prepared as in figure 3, they are arranged into a 2-D sphere array to study the optical scattering from individual spheres as well as sphere arrays. The spheres are patterned into arrays by capturing the spheres into a lithographically patterned substrate.

Templates for the array were created in a PMMA resist film (thickness =1.0 μm) which had been spun onto a silicon substrate. The resist was patterned using e-beam lithography. The individual holes prepared were of the right cylindrical type. An aqueous suspension of the spheres was drawn by capillary action along the surface. Trapped spheres bond to the silicon and the remaining PMMA resist is removed by exposure to oxygen plasma (20 min). The array of spheres was then observed by SEM, figure 4.

Finally, the optical scattering properties of the metallodielectric core-shell nanoparticles will be studied for single particles as well as for an array to determine the effects of the array. If it is possible to deform the nanoparticles into an ellipsoidal shape, the optical properties will be compared to the parent spheres. Changes in the optical properties of the particles would suggest sensitivity of plasmon frequencies to the shape of the particle.

Michelle Watroba recently completed her Chemistry 490 Honours Research Project under the supervision of Dr. Kim Baines, Dr. Todd Simpson and Dr. Ian Mitchell.

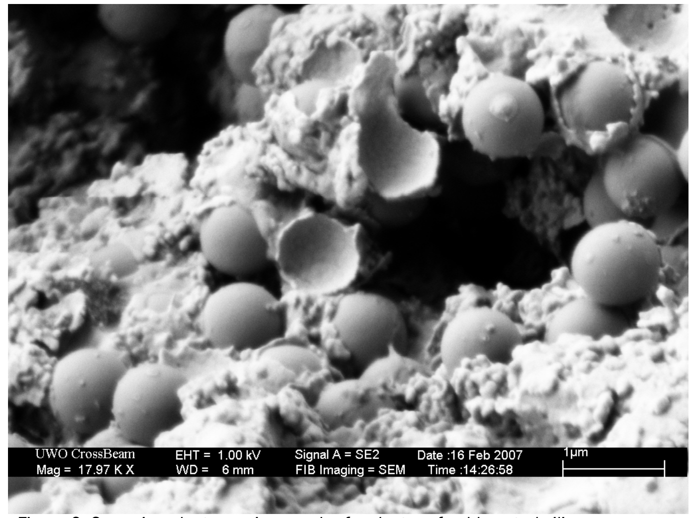

Figure 2. Scanning electron micrograph of a cluster of gold coated silica nanoparticles showing the continuity of the gold shell.

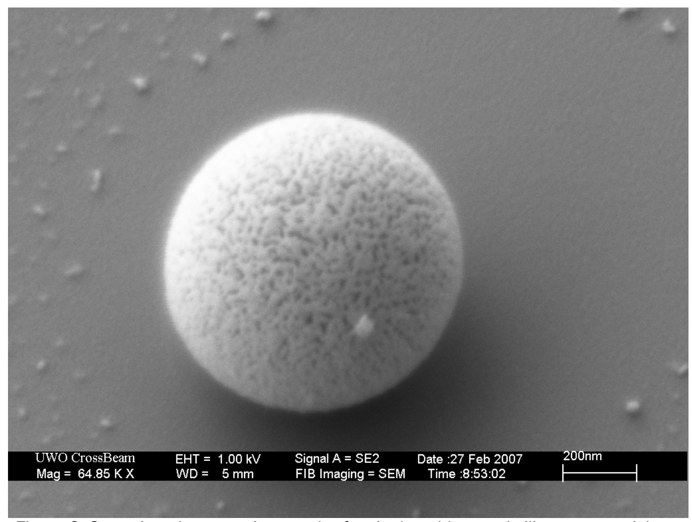

Figure 3. Scanning electron micrograph of a single gold-coated silica nanoparticle used in the preparation of the 2-D array.

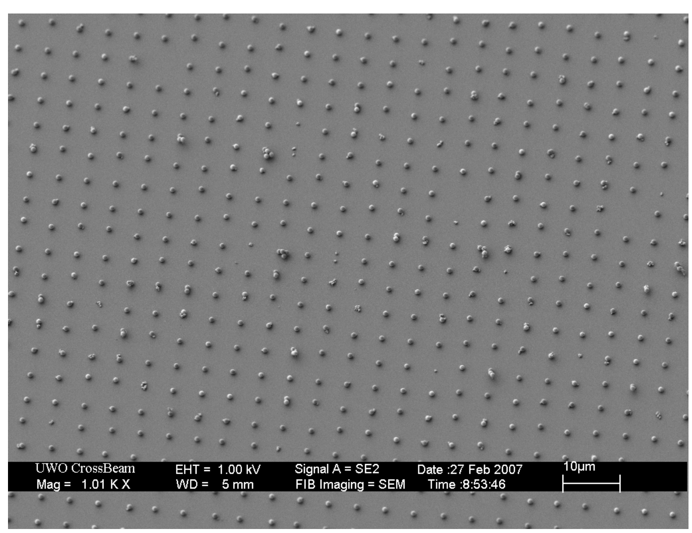

Figure 4. Scanning electron micrograph of a 2-D array of gold-coated silica nanoparticles.