The Nanolithography Toolbox: Design Solutions for Nanoscale Devices

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Various lithography patterning technologies can be used to define structures with nanometer-scale lateral dimensions. The first step in any lithographic process consists of device design. There are a number of available design packages that output semiconductor standard graphic database system (GDSII) files, which is a binary format representing planar geometric shapes. These packages are ideal for creating integrated circuits with rectilinear design layout geometries, where shape edges are parallel to the x and y axes. In this scenario, every polygon is a rectangle. However, many of these packages are limited when dealing with curved geometries at the aggressively nanoscaled dimensions needed for nanophotonic and nanoplasmonic devices. In general, imprecise representation of curved objects at the nanoscale results in increased line edge roughness. Scattering from edge asperities along device peripheries leads to undesirable dissipative effects in plasmonic, photonic and other complex networks. To solve this design problem, we have developed a computer-aided design (CAD) software package [1] for streaming complex shapes to GDSII. The platform-independent Nanolithography Toolbox runs on Linux, Windows and MacOS, and is free for users to download from the Center for Nanoscale Science and Technology at the National Institute of Standards and Technology website (http://www.nist.gov/cnst/).

Figure 1a shows the 4 sections of the Nanolithography Toolbox (NT) package. The graphical user interface (GUI) allows direct GDSII export of predefined shapes, limited to a small subset of parametrized shapes. The scripting branch allows full device layouts with structural hierarchy, vertex control for individual shapes and more than 400 parameterized shapes. Figure 1b shows a small subset of available shapes including ones from the nanophotonic and MEMS-NEMS libraries. The programming branch allows for control statements and full access to scripting methods, enabling generation of custom parametrized shapes and interface to simulation software for algorithmic design of topologically optimized, complex nanostructures. The machine resources branch allows users to graphically create complex electron beam lithography (EBL) job and schedule files. The Toolbox allows users to precisely define the number of vertices for each shape or to create vectorized shapes using Bezier curves. Rendering of vectorized curves automatically yields an increased vertex density at higher curvatures. Higher density of points along curved objects allows more accurate EBL pattern fracturing that consequently leads to smoother structures. Figure 2 shows representative devices from several projects that have used the Toolbox. These representative devices demonstrate the applicability of the NT package to a broad range of design tasks in the fabrication of microscale and nanoscale devices.

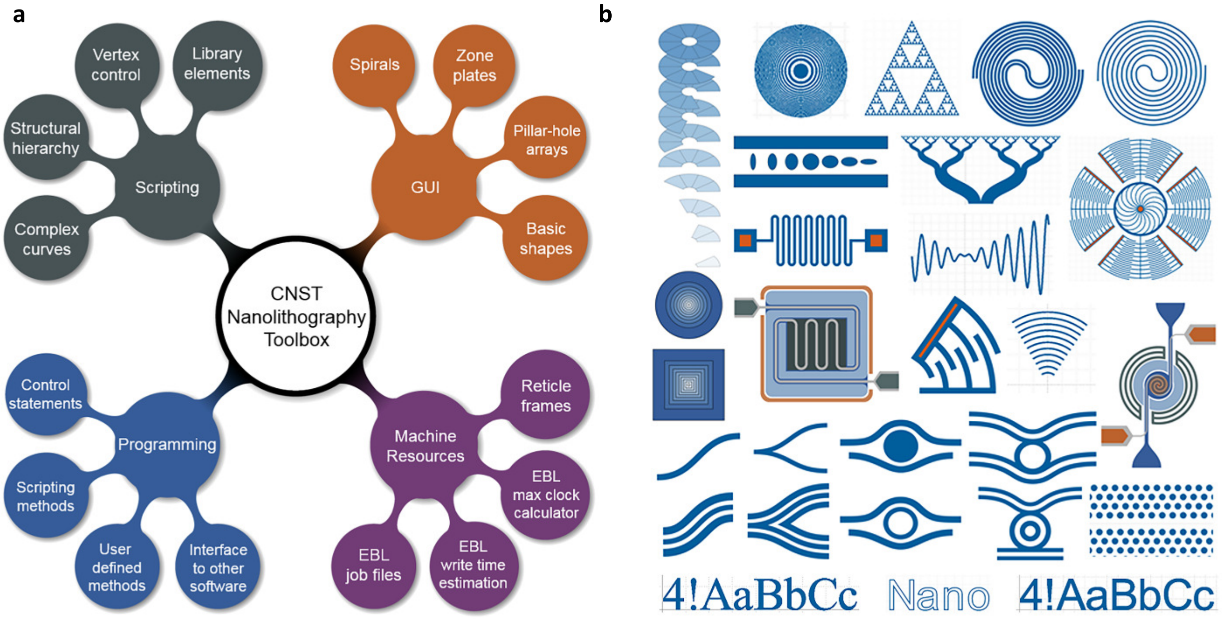

Fig. 1. (a) Nanolithography Toolbox schematic illustrating the graphical user interface (GUI), scripting, programming, and machine resource sections. (b) Illustrative subset of parameterized shapes available for nanoscale photonic, electronic, mechanic, fluidic, and other applications.

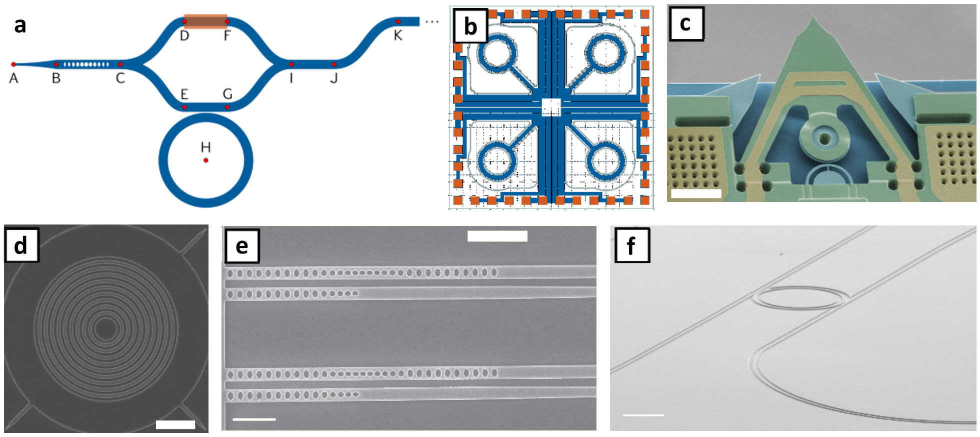

Fig. 2. (a) Pattern layout design schematic highlighting a structure composed of various available nanophotonic elements placed between grid points A through K. (b) Layout design of a real-time Polymerase Chain Reaction system capable of performing 4 simultaneous reactions [2]. Scanning electron micrographs of devices created using NL. (c) an on-chip cavity optomechanical transducer platform [3,4], (d) circular grating geometry used to efficiently extract light emitted from an embedded quantum dot [5], (e) two optomechanical crystal devices [6] and (f) microring resonator add/drop device that operates as an octave-spanning optical frequency comb [7].

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