Large-Area Linear and Nonlinear Nanophotonics

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Optical lithography has long been the mainstay of the integrated circuit industry, and, despite many and frequent predictions to the contrary, is now widely accepted as the dominant volume manufacturing technology for the next several generations, accessing scales to less than 20 nm ($\lambda/10$ with a 193-nm wavelength). A major reason for the continued ascendency of optical lithography in manufacturing is its parallel writing capability that scales to large volumes at low cost. The issue with optical lithography for research applications is the extreme cost of modern lithography tools and masks which limits research accessibility. In contrast, much of the work in nanophotonics has been carried out with e-beam and related serial lithography techniques that inherently have low throughput. Interferometric lithography (IL) provides the bridge between these two trends. IL uses the interference between a small number (usually two) of coherent beams to produce a maskless periodic pattern. Scales as small as 22-nm half-pitch have been demonstrated. The restriction to periodic pattern arrays is not of major concern for many nanophotonic applications, mix-and-match with conventional, lower resolution, optical lithography techniques provides the additional customization needed for many device applications. Processing can provide more complex structures such as split ring resonators as shown in Fig. 1(a). We have used IL for a wide variety of nanophotonic structures including: 2D and 3D photonic crystals, metamaterials (Fig. 1(a) shows negative permeability split-rings with ~ 5 μm resonance wavelength), negative index materials (Fig. 1(b)), and plasmonic structures (Fig. 1(c)). Current efforts focus on active metamaterials for high speed modulators where we have just demonstrated a > 1 Tb/s modulation capability, higher-order nonlinearities in second harmonic generation in plasmonic structures and various approaches to 3D photonic crystals. Coupling plasmonics to IR detectors provides a route to high quantum efficiency multiwavelength IR focal plane arrays. Progress in these areas will be reviewed.

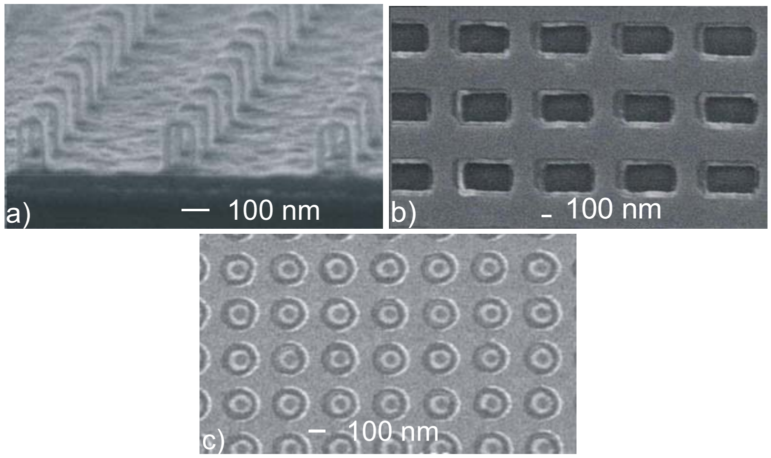

Fig. 1: Large area (> several cm^2) nanophotonic arrays fabricated with interferometric lithography. A) Vertical split ring resonators (Au:MgO:Au) providing a negative permeability at ~ 5μm; b) Au:Al_2O_3:Au negative index metamaterial at ~ 2 μm; and c) GaAs-filled Au plasmonic structure for second harmonic generation. Note that all three structures exhibit complexity at the individual nanostructure level as a result of the integration of lithography and processing.