Advanced Silicon Processing for Active Integrated Photonic Devices

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We present a set of processing technologies that in concert enable the monolithic integration of light generation, guiding, and output on a silicon chip. In particular, the combination of highly anisotropic etching of an Si-on-insulator (SOI) wafer[1] followed by wafer bonding allows for the creation of low threshold, active hybrid silicon/III-V structures. Our approach is based on low temperature bonding of InGaAsP material on top of a pre-patterned SOI wafer. The geometry of the bonded structure is designed to support a joint optical mode, whose profile overlaps both Si and III-V.[2] Using precise control of the silicon waveguide dimensions, the relative overlap of the optical mode between the materials can be controlled.[3]

We have demonstrated CW operation of a hybrid Fabry-Perot laser with single facet power as high as 12.5mW. Using an SF_6/C_4F_8 reactive ion etch (RIE), followed by H_2SO_4/HF surface treatment[4] and thermal oxidation or PECVD oxide deposition, the optical losses due to the silicon waveguide are minimized. In passive devices, quality factors of nearly 10^6 were achieved in ring resonators. By using the same etch process, gratings and other optical elements can be fabricated and etched into the structure with high fidelity; features as small as 30 nm have been etched into Si with 80nm thick PMMA resist to depths of over 200nm. Continuing work in on-chip feedback using a Bragg reflector or other dielectric patterning will be presented at the conference.

[1] G. DeRose, M. Shearn, M. D. Henry, Y. Chen, and A. Scherer, "Deep RIE and Cryo-Etching of Nanostructures in Silicon and Polymers," *Microscopy and microanalysis,* vol. 14, 2008.

[2] A. W. Fang, H. Park, O. Cohen, R. Jones, M. J. Paniccia, and J. E. Bowers, "Electrically pumped hybrid AlGaInAs-silicon evanescent laser," *Opt. Express,* vol. 14, pp. 9203-9210, 2006.

[3] X. Sun and A. Yariv, "Engineering supermode silicon/III-V hybrid waveguides for laser oscillation," *Journal of the Optical Society of America. B, Optical physics,* vol. 25, p. 923, 2008.

[4] M. Borselli, T. J. Johnson, and O. Painter, "Measuring the role of surface chemistry in silicon microphotonics," *Applied physics letters,* vol. 88, p. 131114, 2006.

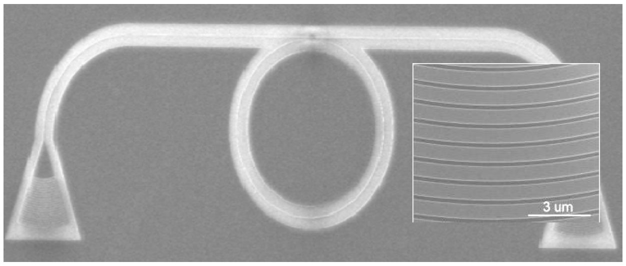

Fig. 1 - Typical passive planar Si device incorporating a bus waveguide, ring resonator, and grating couplers for vertical input and output of light. The ring diameter is 75 microns. (Inset) Detail of grating coupler section.

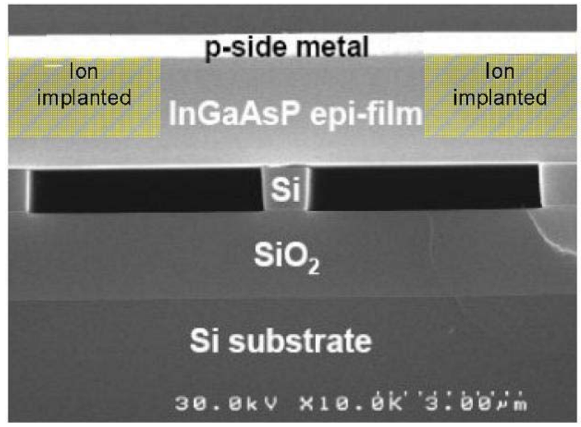

Fig. 2 - SEM image of the hybrid Si/III-V device cross section. Approximate ion implanted regions are superimposed on the image for illustration purposes.

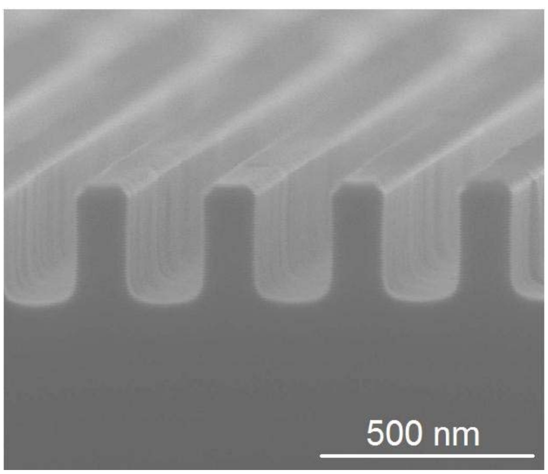

Fig. 3 - High aspect ratio silicon structure using ICP-RIE etching of SF_6/C_4F_8.

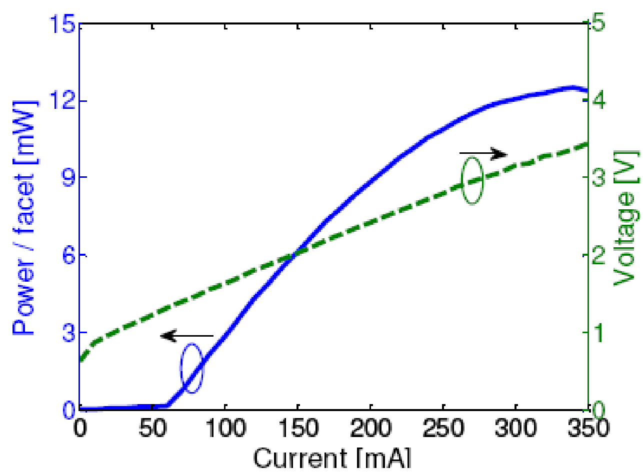

Fig. 4 - L-I-V curve of 960 μm long laser under CW operation at 15°C. The device has a turn-on voltage of 0.8 V, has a lasing threshold voltage of 1.3 V, and has a threshold current of 60 mA.