USC University of Southern California

USC Viterbi School of Engineering

Ming Hsieh Department of Electrical Engineering

Doped Microlaser with High-Index Coatings

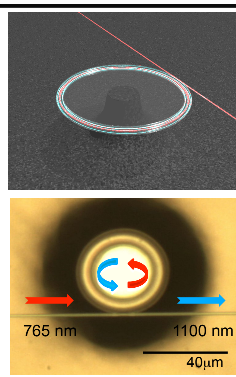
Nishita Deka, Ashley J. Maker, Andrea M. Armani
Mork Family Department of Chemical Engineering and Materials Science, Armani Lab

Abstract

Ultra-low threshold microlasers have applications in satellite communications, biodetection and optical computing. One microlaser being studied in the Armani Lab is based on a microcavity fabricated from doped silica coatings on silicon. However, current fabrication methods are inefficient and low-yield. Here, we investigate a novel method for microlaser fabrication that uses high-refractive index coatings on microtoroids. Such an approach would not only increase the efficiency of production, but also reduce the amount of rare-earth metals used, which is important given recent concerns over the availability of rare-earth metals in the future.

Background

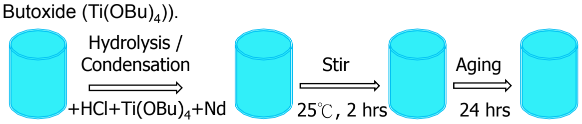
Optical resonators confine light waves through an arrangement of mirrors. A microtoroid is a type of optical resonator that traps light through total internal reflection, allowing the light to propagate throughout the resonator (top). The sol-gel process is a technique for adding doped coatings to the toroid. The high-refractive index film confines light in the coating, enabling more of the circulating light to interact with the dopant. By coupling the pump wavelength into the device, the dopants are excited and emit lasing (bottom).



Device Fabrication

Synthesis of High-Index Coatings

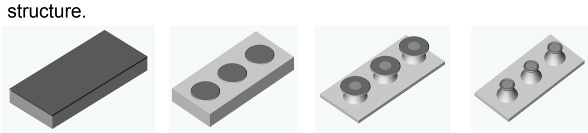
The first step is synthesis of Neodymium(Nd)-doped liquid silica sol-gels with high-refractive index through the addition of Titanium Butoxide ($Ti(OBu)_4$)).



Silica precursor: Methyltriethoxysilane (MTES)+Ethanol(EtOH)

Device Fabrication

Through a series of photolithography, BOE etching, and XeF_2 etching steps, microdisks are fabricated from thermally grown oxide on silicon. CO_2 laser heating reflows the microdisks into the final toroid structure.



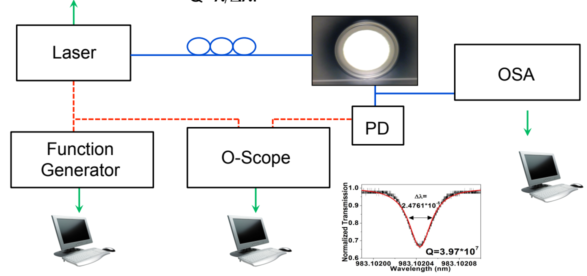
1. Thermally grown oxide on Si substrate.
2. Circular pads etched onto substrate.
3. XeF_2 etching to form microdisks.
4. CO_2 laser reflow to form microtoroids.

Spin-Coating + Thermal Annealing

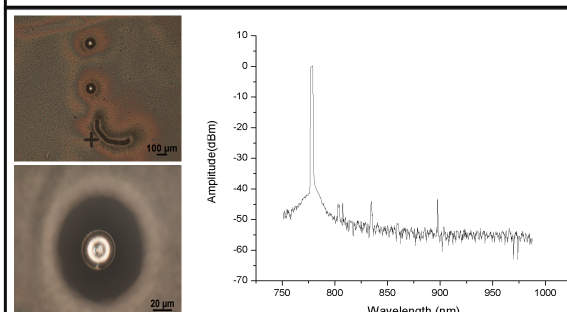
A single layer of the high-index coatings is spin-coated onto the devices and subsequently annealed in a tube furnace to densify the sol-gel and remove hydroxyl nests. The coating is roughly 350 nm thick, for a spin rate of 7000 rpm for 30 sec.

Optics Testing

Using a tapered optical fiber connected to a laser source, light is coupled into the device through the evanescent field. By attaching an optical spectrum analyzer to the other end of the fiber, lasing can be detected. The quality factor is determined by measuring the linewidth ($\Delta\lambda$) of the resonator from the signal on the oscilloscope, and using the simple expression: $Q=\lambda/\Delta\lambda$.



Results



The devices pictured above have been coated with liquid silica containing a $Ti(OBu)_4$ to MTES molar ratio of 0.05 and 5 wt% Nd. Lasing spectra demonstrates Cascaded Raman lasing, but no Nd lasing. Raman lasing was observed at input powers above 1 mW, suggesting two major implications:

1) Coated toroids may be a new method for obtaining Raman lasing with a lower threshold.
2) The Nd concentration in the coatings must be increased, as Nd lasing will occur in the pesence of Raman lasing unless the dopant concentration is too low.

Future Work

The next step is to measure both Raman lasing and Nd lasing. This includes determining the lasing threshold by measuring lasing intensity for various input powers, investigating the effect of Nd and $Ti(OBu)_4$ concentration on the lasing threshold and modeling the distribution of the optical field using FEM simulations.

Acknowledgements

USC wise Women in Science and Engineering
The Rose Hills Foundation
USC Viterbi Merit Research Program