



Chemical Sensors Based on Optical Ring Resonators

Resonance wavelengths are shifted by absorption of chemicals into polymer cladding layers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Chemical sensors based on optical ring resonators are undergoing development. A ring resonator according to this concept is a closed-circuit dielectric optical waveguide. The outermost layer of this waveguide, analogous to the optical cladding layer on an optical fiber, is a made of a polymer that (1) has an index of refraction lower than that of the waveguide core and (2) absorbs chemicals from the surrounding air. The index of refraction of the polymer changes with the concentration of absorbed chemical(s). The resonator is designed to operate with relatively strong evanescent-wave coupling between the outer polymer layer and the electromagnetic field propagating along the waveguide core. By virtue of this coupling, the chemically induced change in index of refraction of the polymer causes a measurable shift in the resonance peaks of the ring.

In a prototype that has been used to demonstrate the feasibility of this sensor concept, the ring resonator is a dielectric optical waveguide laid out along a closed path resembling a racetrack (see Figure 1). The prototype was fabricated on a silicon substrate by use of standard techniques of thermal oxidation, chemical vapor deposition, photolithography, etching, and spin coating. The prototype resonator waveguide features an inner cladding of SiO₂, a core of Si_xN_y, and a chemical-sensing outer cladding of ethyl cellulose. In addition to the ring resonator, there are input and output waveguides separated from the straight segments of the ring resonator by an evanescent-wave-coupling gap of 2 mm.

Figure 2 presents results of a test of the prototype in an open room. During the test, the temperature of the sensor was stabilized to ±0.1 K. The sensor was left undisturbed by chemicals, except during a short interval when a cotton swab wetted with isopropyl was placed 4 in. (≈10 cm) away from the sensor and another short interval when a cotton swab wetted with acetone was similarly placed near the sensor. The chemical exposures resulted in easily detectable signals that exceeded background variations by at least an order of magnitude. The jagged nature of the portions of the plot corresponding to the chemical exposures has been attributed to "mode hops," in which the specific ring-resonator mode that was being followed moved out of the tuning range of a

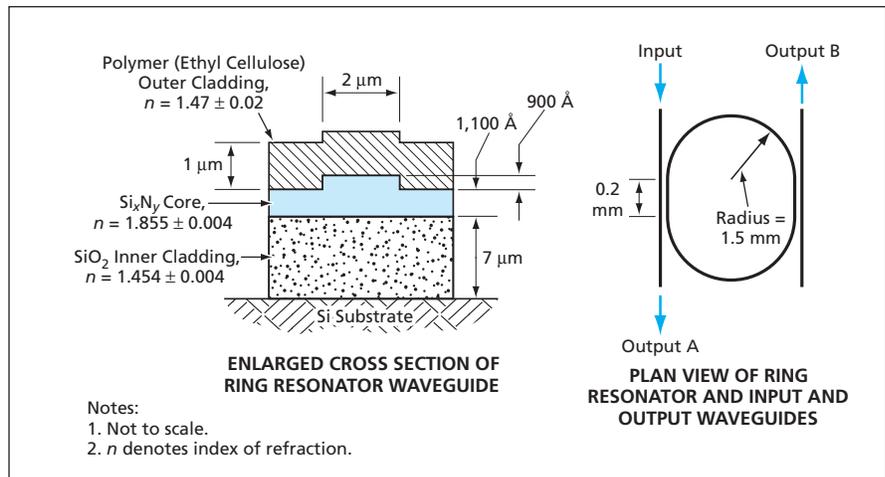


Figure 1. A Polymer-Clad Optical Ring Resonator acts as a chemical sensor in that the resonance spectrum becomes shifted in wavelength when the polymer absorbs chemicals from the air.

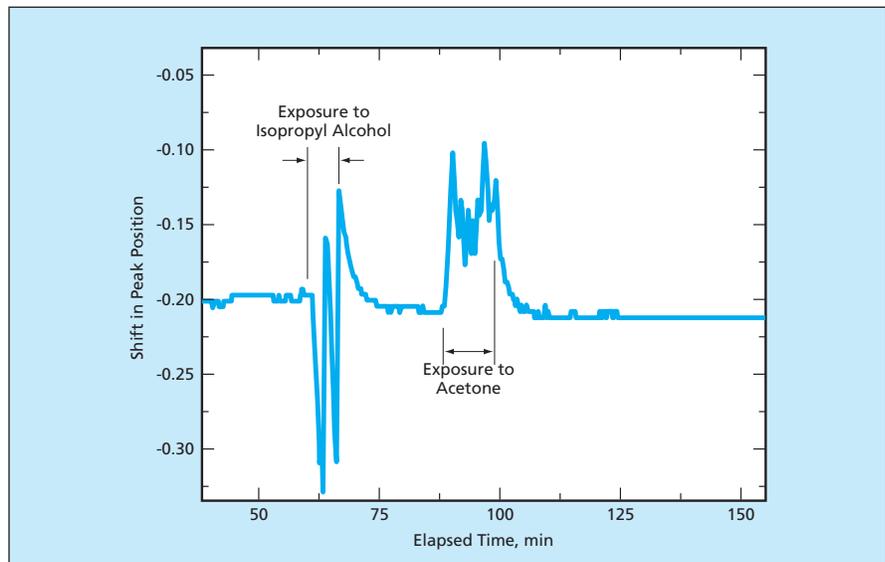


Figure 2. Shifts in the Wavelength of a peak in the resonance spectrum of the device of Figure 1 occurred during exposure to chemicals deliberately introduced into the air.

laser used as the input light source, causing the laser to lock onto a new mode.

The results have been interpreted as demonstrating the feasibility of optical polymer-based sensors. Inasmuch as the index of refraction of ethyl cellulose is known to respond to wide variety of volatiles, sensors like this one could be useful as non-specific indicators of spills of volatile compounds.

This work was done by Margie Homer, Allison Manfreda, Kamjou Mansour, Ying Lin, and Alexander Ksendzov of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-40601, volume and number of this NASA Tech Briefs issue, and the page number.