Technology Focus: Sensors

Protein Sensors Based on Optical Ring Resonators

Progress has been achieved in the continuing development of optical chemical sensors.

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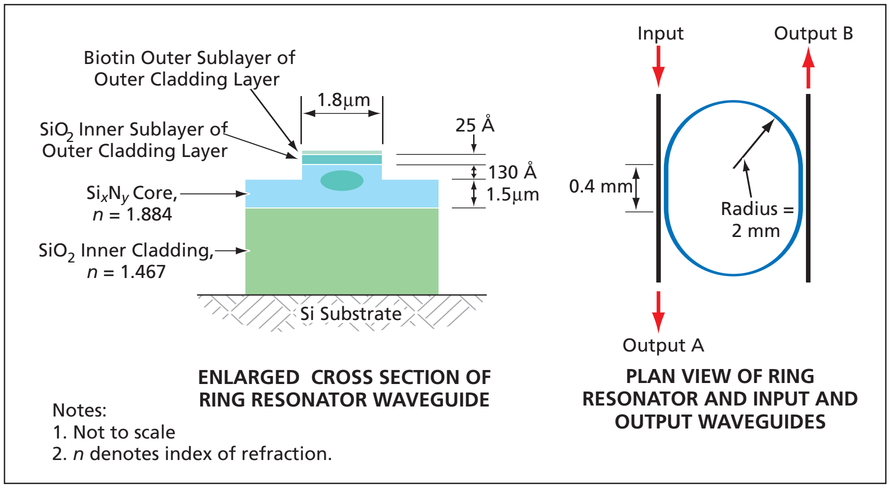
Prototype transducers based on integrated optical ring resonators have been demonstrated to be useful for detecting the protein avidin in extremely dilute solutions. In an experiment, one of the transducers proved to be capable of indicating the presence of avidin at a concentration of as little as 300 pM in a buffer solution — a detection sensitivity comparable to that achievable by previously reported protein-detection techniques. These transducers are serving as models for the further development of integrated-optics sensors for detecting small quantities of other proteins and proteinlike substances.

The basic principle of these transducers was described in "Chemical Sensors Based on Optical Ring Resonators" (NPO-40601), *NASA Tech Briefs*, Vol. 29, No. 10 (October 2005), page 32. The differences between the present transducers and the ones described in the cited prior article lie in details of implementation of the basic principle. As before, the resonator in a transducer of the present type is a closed-circuit dielectric optical waveguide. The outermost layer of this waveguide, analogous to the optical cladding layer on an optical fiber, consists of a layer comprising sublayers having indices of refraction lower than that of the waveguide core. The outermost sublayer absorbs the chemical of interest (in this case, avidin). The index of refraction of the outermost sublayer changes with the concentration of absorbed avidin. The resonator is designed to operate with relatively strong evanescent-wave coupling between the outer sublayer and the electromagnetic field propagating along the waveguide core. By virtue of this coupling, the chemically induced change in the index of refraction of the outermost sublayer causes a measurable change in the spectrum of the resonator output.

The figure depicts one of the prototype transducers, wherein the ring resonator is a dielectric optical waveguide laid out along a closed path resembling a racetrack. The waveguide includes a core of Si_xN_y formed on an inner cladding layer of SiO_2 on a substrate of Si. The outer cladding layer comprises an inner sublayer of SiO_2 and an outer sublayer of biotin. (The SiO_2 sublayer is needed for binding the biotin to the Si_xN_y core.) The selectivity of the sensor depends on the use of biotin, which binds specifically to avidin, immobilizing avidin on the outer surface and thereby changing the index of refraction. The portion of the cross section occupied by the propagating electromagnetic mode is confined laterally by the rib portion of the core and is shown in the figure as an oval. In addition to the ring resonator, there are straight input and output waveguides separated from the straight segments of the ring resonator by an evanescent-wave-coupling gap of 1.6 µm.



A **Biotin-Clad Optical Ring Resonator** acts as an avidin sensor in that the resonance spectrum becomes shifted in wavelength when the biotin absorbs avidin.

In operation, the transducer is mounted in a flow cell on a copper chuck. The temperature of the chuck (and, thus, of the transducer) is monitored by use of a thermistor and controlled by use of a thermoelectric cooler. A solution containing avidin is pumped through the flow cell. Through the straight input waveguide, the resonator is illuminated at a wavelength of 633 nm by a He-Ne laser. The length of the closed optical path of the resonator ring varies with the temperature, and the temperature is adjusted to keep the path length an integer multiple of a wavelength: that is, the temperature is adjusted to maintain operation at one of the resonances. As the biotin coating absorbs avidin, the resulting change in the index of refraction manifests itself as a change in the resonance wavelength and, hence, in the temperature needed to maintain the chosen resonance. Hence, further, the change in the controlled temperature can be taken as an indication of the amount of dissolved avidin to which the transducer has been exposed.

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

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