Integrated optics ring-resonator chemical sensor for detection of air contamination

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Abstract: We report a silicon nitride-based ring resonator chemical sensor with sensing polymer coating. Its sensitivity to isopropanol in air is at least 50 ppm – well under the permissible exposure level of 400 ppm.

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The array detection of chemical contaminants in air relies on correlation of the response of several partially specific sensing polymer films to a target chemical [1]. Currently, the polymers are used as 'chemoresistors', i.e. a thin film of insulating polymer is loaded with a conductive medium so that the presence of the target chemical causes a change in the conductivity. In contrast, our approach is based on optical evanescent wave interaction and does not rely on loading the polymer with conducting particles, which is not always possible. The sensing polymer plays the role of the top cladding in our waveguides (see Figure 1A). Therefore, changes in the polymer refractive index due to the presence of the target chemical influence positions of resonances in the ring.

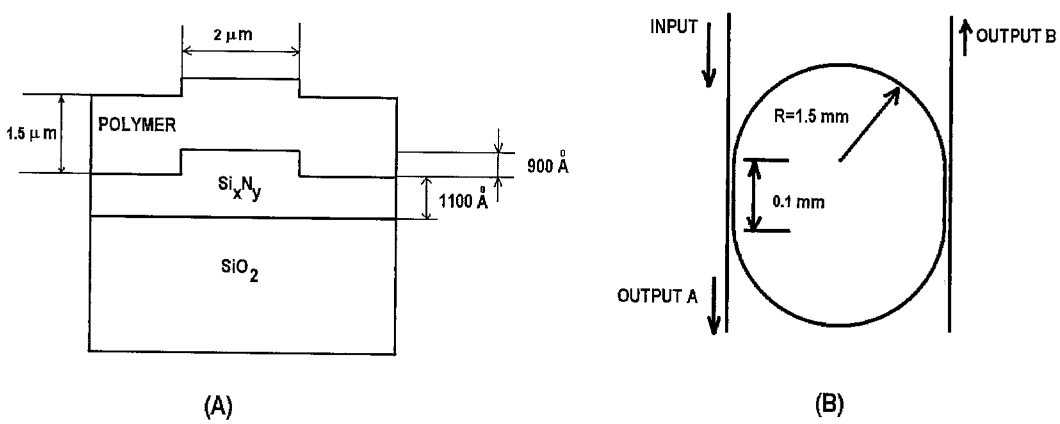

Figure 1. (A) Cross section of the waveguide. (B) Layout of the ring resonator. The waveguide separation between the straight section and the racetrack structure is 2 μm.

Our readout is based on tracking the position of one of the resonances using a tunable diode laser. The ring resonator layout is presented in Figure 1B. It was fabricated on a Si substrate covered with 5 micrometers of thermal SiO_2. The waveguide structure shown in Figure 1A was fabricated using plasma enhanced chemical vapor deposition and conventional photolithography. A solution of ethyl cellulose in 1,3-dioxolane was spread over the resonator using a conventional photoresist spinner and dried. In Figure 2 we show the result of a sensor test. The sensor was packaged in an air tight enclosure with fiber pigtails; a controlled mixture of air, water vapor (at 3000 ppm), and isopropanol was pumped through the package at the rate of 0.1 l/s. Isopropanol was introduced every 120 minutes in 60 minute pulses at various concentrations between 100 and 50 ppm.

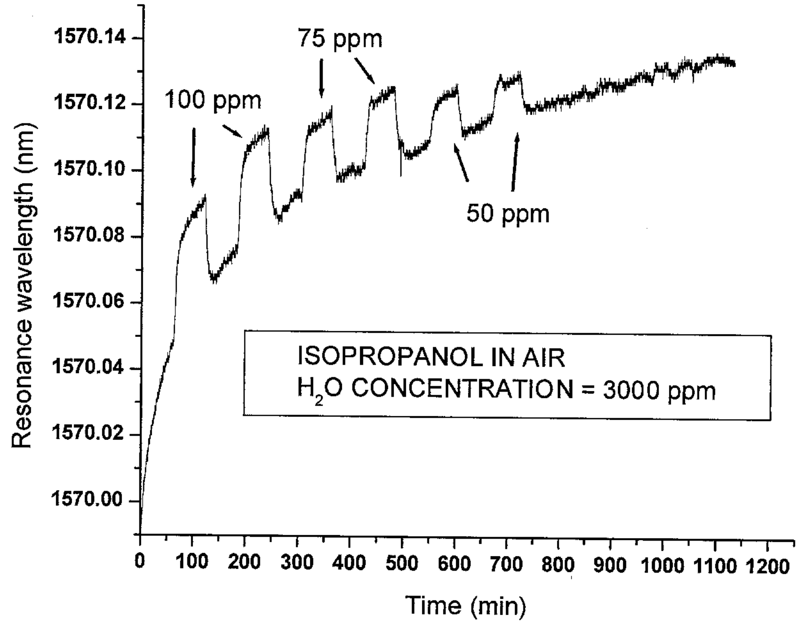

Figure 2. Results of the chemical exposure experiment.

The results demonstrate the promise of the ring resonator based chemical sensors. This technique may be applied to array sensing or to fabrication of single non-specific indicators. The demonstrated sensitivity to isopropanol is 50 ppm as compared with the 400 ppm permissible exposure limit set by the U.S. Occupational Safety and Health Administration which makes this sensor immediately useful for health related air monitoring.

1. M.A. Ryan, M.L. Homer, M.G. Buehler, K.S. Manatt, B. Lau, D. Karmon and S. Jackson. "Monitoring Space Shuttle Air for Selected Contaminants Using an Electronic Nose" in *Proceedings of the 28th International Conference on Environmental Systems,* paper no. 981564 (Society for Automotive Engineers, Warrendale, PA 1998)