Optical refractometric sensors based on embedded nanowire microcoil resonators

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Abstract: We present a novel, robust, and compact refractometric sensor based on a high Q-factor embedded nanowire microcoil resonator with an intrinsic fluidic channel. Ideally, sensitivities as high as 1000 nm/RIU and a refractive index resolution of 10^{-9} can be achieved.

Sub-wavelength diameter optical wires and nanowires have been proposed as ideal sensors because of their low cost, low loss, and very large evanescent fields. They can also be coiled into self-coupling high-Q microresonators [1]. In this paper we investigate theoretically the properties of an embedded nanowire microcoil resonator (ENMR) as a high sensitivity sensor. An ENMR can be fabricated by wrapping a nanowire on an expendable rod, coating it with a low loss polymer such as Teflon AF1600, and then removing the rod. The final structure is shown in fig.1. It is a compact and strong device with an intrinsic fluidic channel to deliver samples to the sensor, unlike most ring or microsphere resonators which need an additional channel. The mode propagating in the nanowire has an evanescent field extending into the analyte channel and therefore the microcoil resonances and effective index are affected by any changes in the analyte refractive index. We calculate the effective index n_{eff} of the coated nanowire by a finite element method, and the self-coupling of the ENMR by coupled-mode theory [1]. From this we derive the homogeneous sensor sensitivity S defined as $S=\lambda/n_{eff}\cdot\partial n_{eff}/\partial n_a$ where λ is the operating wavelength and n_a is the analyte refractive index. The dependence of S on the nanowire radius r was calculated for two values of the thickness d of the Teflon layer between the nanowire and the analyte (10 and 100nm) and for two wavelengths λ (600 and 970nm) as shown in fig. 2. Here we assumed refractive indices of 1.451 for the nanowire, 1.311 for Teflon, and 1.332 for the analyte. The sensitivity increases when r decreases or d decreases, because the fraction of power propagating in the evanescent field increases. S can be as high as 500nm/RIU (where RIU denotes refractive index units) at r=200nm and λ=600nm, 700nm/RIU at r=300nm and λ=970nm, and even higher at longer λ (above 1000nm/RIU at λ=1550nm). We note that this is higher than values for most microresonator sensors. Assuming a spectral resolution of 1/20 of the resonant bandwidth at critical coupling and propagation losses of 0.02 dB/mm, we obtain a refractive index resolution of 10^{-9}, lower than values reported in the literature for current sensors.

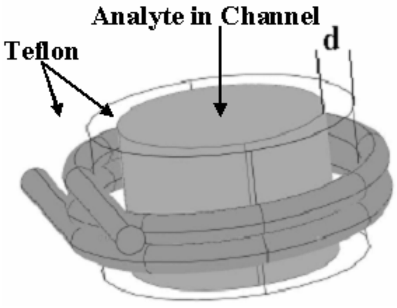

Fig. 1

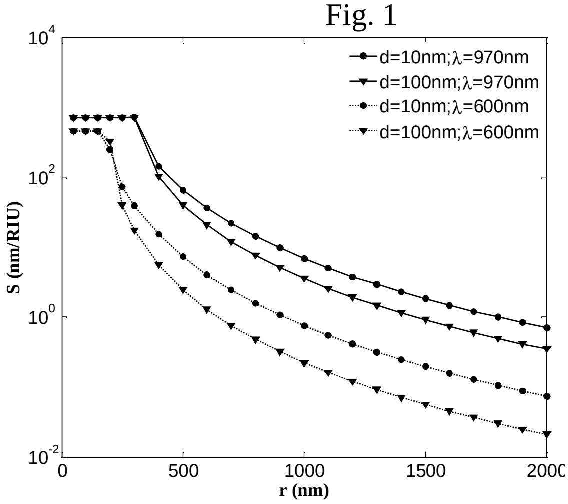

Fig. 2

Reference
[1] M. Sumetsky, Opt. Express **12**, 2303-2316 (2004)