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Sensitivity Improvement of Optical Ring Resonator for Strain Analysis with the Direction of Strain Recognition Possibility

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Abstract : Optical sensors became attractive due to preciseness, low power consumption, and intrinsic electromagnetic interference-free characteristic. Among the waveguide optical sensors, cavity-based ones attended for the high Q-factor. Micro ring resonators as a potential platform have been investigated for various applications as biosensors to pressure sensors thanks to their sensitive ring structure responding to any small change in the refractive index. Furthermore, these small micron size structures can come in an array, bringing the opportunity to have any of the resonance in a specific wavelength and be addressed in this way. Another exciting application is applying a strain to the ring and making them an optical strain gauge where the traditional ones are based on the piezoelectric material. Making them in arrays needs electrical wiring and about fifty times bigger in size. Any physical element that impacts the waveguide cross-section, Waveguide elastic-optic property change, or ring circumference can play a role. In comparison, ring size change has a larger effect than others. Here an engineered ring structure is investigated to study the strain effect on the ring resonance wavelength shift and its potential for more sensitive strain devices. At the same time, these devices can measure any strain by mounting on the surface of interest. The idea is to change the" O" shape ring to a "C" shape ring with a small opening starting from 2π/360 or one degree. We used the Mode solution of Lumbrical software to investigate the effect of changing the ring's opening and the shift induced by applied strain. The designed ring radius is a three Micron silicon on isolator ring which can be fabricated by standard complementary metal-oxide-semiconductor (CMOS) micromachining. The measured wavelength shifts from1-degree opening of the ring to a 6-degree opening have been investigated. Opening the ring for 1-degree affects the ring's quality factor from 3000 to 300, showing an order of magnitude Q-factor reduction. Assuming a strain making the ring-opening from 1 degree to 6 degrees, our simulation results showing negligible Q-factor reduction from 300 to 280. A ring resonator quality factor can reach up to 108 where an order of magnitude reduction is negligible. The resonance wavelength shift showed a blue shift and was obtained to be 1581, 1579,1578,1575nm for 1-, 2-, 4- and 6-degree ring-opening, respectively. This design can find the direction of the strain-induced by applying the opening on different parts of the ring. Moreover, by addressing the specified wavelength, we can precisely find the direction. We can open a significant opportunity to find cracks and any surface mechanical property very specifically and precisely. This idea can be implemented on polymer ring resonators while they can come with a flexible substrate and can be very sensitive to any strain making the two ends of the ring in the slit part come closer or further.

Keywords : optical ring resonator, strain gauge, strain sensor, surface mechanical property analysis
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