GRATED WAVEGUIDE-BASED OPTICAL CAVITIES AS COMPACT SENSORS FOR SUB-NANOMETRE CANTILEVER DEFLECTIONS, AND SMALL REFRACTIVE-INDEX CHANGES

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The paper reports on theoretical and experimental results of integrated optical (IO) cavities defined by grated waveguides in Si_3N_4 and Si, for the accurate detection of cantilever deflection and bulk index changes.

Microcantilever-based sensors can be used to detect molecular adsorption, which causes changes in the surface stress [1], leading to deflection of the cantilever. We propose a novel and highly sensitive integrated read-out scheme to detect small deflections of a cantilever in close proximity to a grated waveguide structure.

It is well-known that a partly grated waveguide defines a cavity in the grated region for wavelengths outside the stopband. In particular, for wavelengths next to the stopband sharp spectral features can be observed, which are related to the strong dispersion in that wavelength region. A cantilever, if placed in the evanescent field region of the grated waveguide, will lead to the occurrence of propagating modes for wavelengths inside the stopband, and so to resonances inside the stopband, as shown in fig. 1. As can be seen from the figure, on decreasing the gap between grating and cantilever the first near band-edge resonance peak is pulled inside the stopband; simultaneously its spectral width goes down. This effect can be used for the detection of cantilever displacements. Assuming that a peak shift can be detected with a resolution $\delta\lambda$ of 0.001 times its spectral width, it follows from fig. 1 that a displacement of $\delta g = (\partial g / \partial\lambda)\delta\lambda = (50/2)0.2\ \mathrm{pm} = 5\ \mathrm{pm}$ can be detected with the considered compact device having a length of only 98 μm. As an example to the above, theoretical results for a hydrogen trace-gas sensor, utilizing palladium as an H_2 absorbing material, will be presented during the conference.

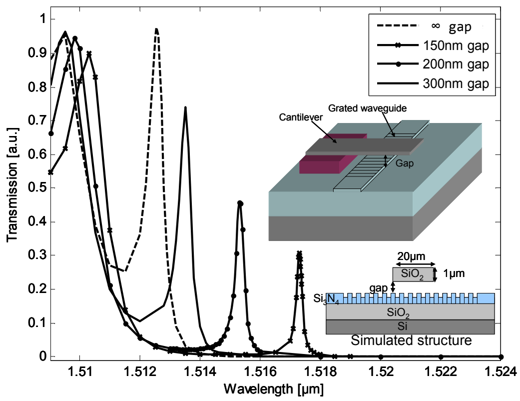

Figure 1. Simulated transmission spectra with cantilever position as parameter, using a 2D bidirectional eigenmode propagation method [2]. Insets show device structure and its 2D model.

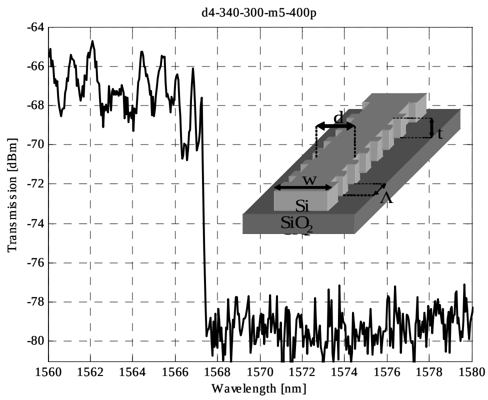

Figure 2. Measured transmission spectrum of a 400 periods long Si grating. Waveguide widths *w* and *d* are of the order of 300nm.

Grated waveguides can also be used as refractometric sensors [3]. Silicon photonic wires are particularly interesting for evanescent field sensors, since such waveguides may have high sensitivity to cladding index changes [4], and the potential compactness of such devices enables a dense functional integration.

Photonic wire gratings have been fabricated with deep UV lithography using the IMEC standard 248-nm deep-UV lithography process for photonic structures [5] (fig. 2).

The sharp near band-edge slope in fig. 2 corresponds to a (3 dB) spectral width of ~40 pm. From this value it can be deduced, similarly as above, that the resolution for modal index changes is given by $\delta N = (\partial N / \partial \lambda)\delta\lambda \sim 4 \cdot 10^{-8}$ (with $\delta\lambda \sim 10^{-3} \cdot 40\ \mathrm{pm}$), which implies a resolution for cladding index changes of $\delta n \sim 10^{-6} - 10^{-7}$.

The above results apply to relatively short gratings of only 180 µm. In general, the sensitivity of such grated waveguides grows much faster than linear with the device length [3], provided that the propagation and reflection losses are not too large. More experimental results will be presented during the conference.

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