

Design of an Optical Methane Gas Sensor Based on an Extended Light-Matter Interaction Device

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Monitoring of methane gas is important for environmental and industrial circumstances. A small fraction of increase of methane gas concentration can lead to an explosion especially in gas mines and around oil wells. Thus, real time continuous tracing of a small change in methane gas concentration is crucial where immediate safety precautions can be performed. In this work, five perforated silicon ridge waveguides are designed to enhance light-matter interaction with the methane sensitive film cladding layer for boosting the sensitivity of the methane gas sensing.

The device is designed through utilizing five silicon ridge waveguides on a SOI wafer at 1550 nm wavelength that is coated with 300 nm thickness of a methane sensitive film (UVCFS) (Liu H., Zhang X., Zhao B., Wu B., Zhang H., Tang S. Simultaneous Measurements of Refractive Index and Methane Concentration through Electromagnetic Fano Resonance Coupling in All-Dielectric Metasurface. *Sensors* 2021, 21, 3612). Increasing of methane gas concentration by 1% leads to a decreasing of the refractive index of the coated methane sensitive film by 0.0038. The total range of decrease of the refractive index of the methane sensitive film is from 1.4478 to 1.4364 which indicates the increasements of the methane concentration from 0% to 3%.

The core of device is constructed using five perforated silicon ridge waveguides that are brought close to each other to allow mode coupling which slows the light at the stationary inflection points (SIPs) (R. Almhadi, "Slow Light Mode at the Degenerate Band Edge for True Time Delay Applications," in *IEEE Photonics Technology Letters*, vol. 34, no. 12, pp. 657-660, 15 June 15, 2022). Slowing down electromagnetic waves increases light-matter interaction where a small fractional change in the cladding refractive index can be clearly identified. The five perforated silicon ridge waveguides are fine tuned to provide double SIPs in their dispersion relation. The frozen light mode at the SIP is widespread over the whole five ridge waveguides which increases the sensitivity of the device to realize the small changes in the methane gas concentration. Simulated results, stack up and analysis of the device will be provided in the conference.