Colorimetric sensor for EtOH-sensing with one-dimensional photonic crystals based on metal-organic framework

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Abstract

Commercialized chemical sensors have been applied in various applications such as chemical threat detection, industrial process management, environmental monitoring and medical diagnosis. However, these sensors are being constantly studied to improve chemical sensing. In order to improve the optimized performance of the chemical sensors, physical and chemical characteristics such as sensitivity, reusability, materials stability, selectivity, and response time have been examined, respectively. Recently, researchers have been interested in chemical sensors of photonic crystals (PhCs) based on metal-organic framework (MOF) materials. The MOF materials, which can absorb various analytes, have large pore volume and surface area than other nano-porous materials [1-4]. The photonic crystals have been developed for the colorimetric sensors using structural and optical characteristics. The colorimetric sensors can be designed low-cost and low-power sensors that convert environmental changes into visual color changes [5].

Here, we suggest an ethanol (EtOH)-sensing colorimetric sensor utilizing one-dimensional (1D) PhCs based on a MOF using the 3D finite-difference time domain method (FDTD Solutions, Lumerical Inc., Canada) simulation. The MOF and calcium fluoride (CaF2) materials were alternately stacked as nanolaminate layers of a designed 1D PhC. Among the various MOF materials was selected the Hong Kong University of Science and Technology (HKUST-1). The HKUST-1 has large pore volume and surface area, and can adsorb a large amount of water. The HKUST-1 absorbed the EtOH or water has different refractive indices depending on the heating temperature. In addition, this material can be reused by removing EtOH or water absorbed at high temperatures due to reliable thermal stability [1], [6]. The 1D PhCs have optical properties that block and reflect light of a specific wavelength band through a periodic change in refractive index [7]. Utilizing this optical property, we can represent light components in the blue, green, and red wavelength bands in the visible light region.

The sensor was designed using the on/off of photonic band gap (PBG) according to the amount of absorbed EtOH or water inside the HKUST-1 film. The amount of adsorbed solvent is controlled by temperature. As the temperature increases, the refractive indices of 400 to 800 nm wavelength band decreases because the amount of absorbed EtOH or water is reduced [6]. The on/off of PBG was realized by applying these changes. The structure made use of reflected light of a designed 1D PhC. The simulation results exhibit that the peak intensity of the PBG has decreased according to increase temperature of HKUST-1 absorbed with EtOH or water. When the central wavelength of the PBG is a 550 nm, peak intensity has decreased from 20.3 % to 1.40 % at a wavelength of 545 nm. In addition, it has been confirmed that the color conversion in the color coordinates. These simulation results show that the designed colorimetric sensor with 1D PhCs sufficiently can be detected the EtOH or water with a simple optical structure.

Keywords: *Photonic band gap, Photonic crystals, Metal-organic framework, Nano-photonics, Colorimetric sensor*

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Biography

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