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Planar Polymer Optical Waveguide Coated with Metal-Organic Framework for CO_2 Sensing Application

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The need for the detection, sensing and monitoring of the greenhouse gas carbon dioxide (CO_2) for environmental protection has fostered the development of many different types of sensors with regard to the operation conditions and application fields [1,2]. A gas sensor works based on the active interaction between the sensing layer and the target gas. To date, gas sensors with high sensitivity and selectivity, compact size and low power consumption are increasingly demanded. Metal-organic frameworks (MOFs), which are porous crystalline materials that are assembled by the coordination of inorganic building units by organic linker molecules, exhibit great potential in advancement of novel gas sensors with improved performance due to (i) their high porosity, large surface area and tailor-made pore sizes, relevant for materials issue and (ii) the properties of minimal drift, high gas specificity to other gases, relevant for the optical gas sensing issue [3,4].

In this work, we propose a simple and resource- and cost-efficient gas sensor based on a planar polymer optical waveguide with a coated zeolitic imidazolate framework (ZIF)-8 thin film for CO_2 detection and sensing at the near infrared wavelength 850 nm. ZIF-8 has a large surface area of 1947 m^2/g, a narrow pore aperture diameter of 3.4 Å, as well as higher thermal and chemical stability than other MOFs, which enables its efficient adsorption of different gases [5]. A low-cost and efficient hot embossing technique was introduced for the fabrication of the proposed waveguide structure together with an easy-to-implement technique for the realization of the MOF film. A microscope image of the prepared structure is shown in Fig. 1a. Nitrogen (N_2) and CO_2 were used as the reference gas and the target sensing gas, respectively.

Experimental results show that the waveguide sensor exhibits rapid optical response and good sensitivity to pure CO_2 (see Fig. 1b) as well as CO_2 with different concentrations (see Fig. 1c). The sensing device also exhibits adsorption time of 6 s and desorption time of 16 s to CO_2, respectively. A sensitivity of approx. 2.5 µW/5vol% and limit of detection down to 5vol% were obtained. In addition, the sets of cycling experiments demonstrate the reversibility and reproducibility of the sensing performance of the proposed planar polymer waveguide sensor. This proof-of-concept study enables a more flexible fabrication of polymer waveguides, simplifies the introduction of MOF-based optical devices and thus opens up new application potentials of this material combination for selective gas detection and sensing.

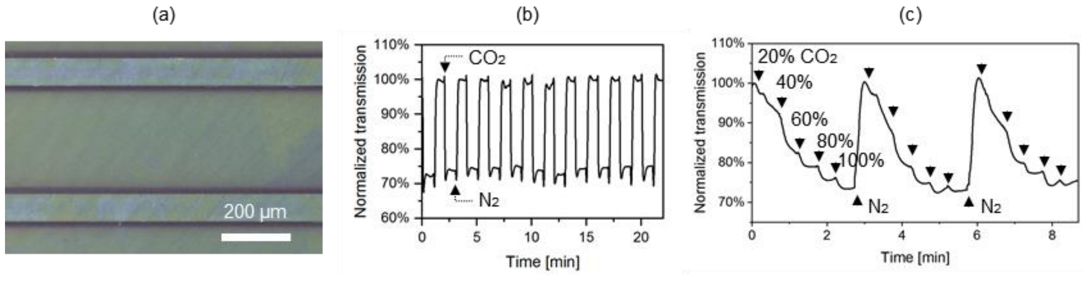

Fig. 1 (a) Microscope image of ZIF-8-coated polymer optical waveguide, which exhibits green color under optical microscope. (b) Dynamic response of ZIF-8-coated waveguide sensor to CO_2. (c) Dynamic response of ZIF-8-coated waveguide sensor to CO_2 with different concentrations.

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