Integrated semiconductor optoelectronic devices for real-time and indicator-free detection of aqueous nitric oxide

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ABSTRACT

Sensing films specific to nitric oxide and zinc were fabricated by embedding respectively indicator 1,2-diaminoanthraquinone (DAQ) and 11,16-Bis(phenyl)-6,6,21,21-tetramethyl-m-benzi-6,21-porphodimethene (BPDM-H) in hydrogel host poly(2-hydroxyethyl methacrylate). The sensing film contains DAQ, which responses to nitric oxide, shows stability in acid environment. The sensing film contains BPDM-H responses to zinc. The electrospinning technique was also utilized to fabricate the fibrous film.

Keywords: probe, organic electronic devices

1. INTRODUCTION

Zinc and nitric oxide are important signaling molecules in human body. Nitric oxide plays important roles in many physiological processes, such as smooth muscle relaxation and blood pressure regulation [1]. Immune system also generates nitric oxide as a defense against pathogens [2]. Synaptically released Zn^{2+}, functions as a transmembrane signaling molecule, can diffuse across the synaptic cleft and stimulate the post-synaptic membrane [3]. Using organic optoelectronic devices as components of sensors have been demonstrated to be a way to reduce the size of sensors [4-8]. An organic light-emitting diode (OLED) and an organic photo detector (PD) were integrated with a sensing film for oxygen and glucose sensing [4]. The OLED is used to excite the sensing unit, and the PD is used to detect the photoluminescence (PL) of the sensing unit as shown in Fig. 1. However, there is no sensing film specific to nitric oxide or zinc ion, therefore, integrated sensors for nitric oxide and zinc ion are still lacking. In this work, we realized sensing films for nitric oxide and zinc by blending indicator 1,2-diaminoanthraquinone (DAQ) and 11,16-Bis(phenyl)-6,6,21,21-tetramethyl-m-benzi-6,21-porphodimethene (BPDM-H) in hydrogel host poly(2-hydroxyethyl methacrylate). Sensing properties of these sensing films were characterized.

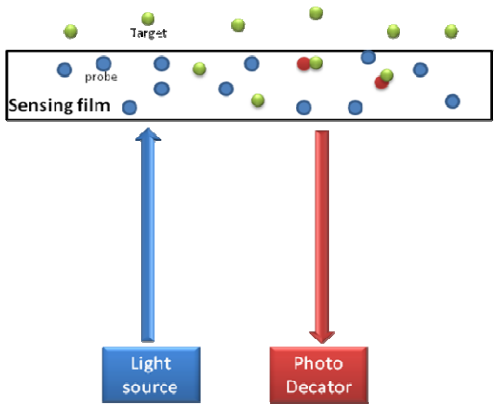

Figure 1. The structure of an integrated sensor composed of a light source, a photo detector, and a sensing film.

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2. EXPERIMANTAL

The sensing film is prepared from a mixture of probe (DAQ or BPDM-H), 2-hydroxyethyl methacrylate (HEMA), ethylene glycol dimethacrylate (EGDMA), and azobisisobutyronitrile (AIBN). BPDM-H is synthesized through an acid catalyzed condensation reaction at room temperature [9]. Figure 2 shows the image of the sensing film contains DAQ. pHEMA with three-dimensional network is synthesized by utilizing HEMA as hydrophilic monomer, EGDMA as a hydrophobic cross-linker, and AIBN as an thermal initiator. The sensing film is prepared by pouring the blending solution into a cell and annealing at 80 °C for 10 min. The chemical structures of DAQ, BPDM-H, HEMA, EGDMA, and AIBN are shown in Fig. 3.

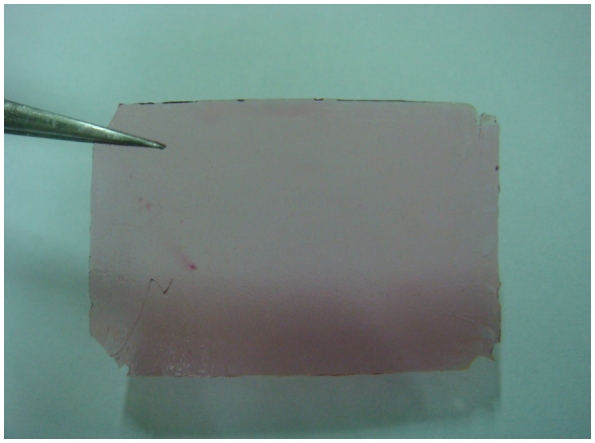

Figure 2. The image of the sensing film contains DAQ.

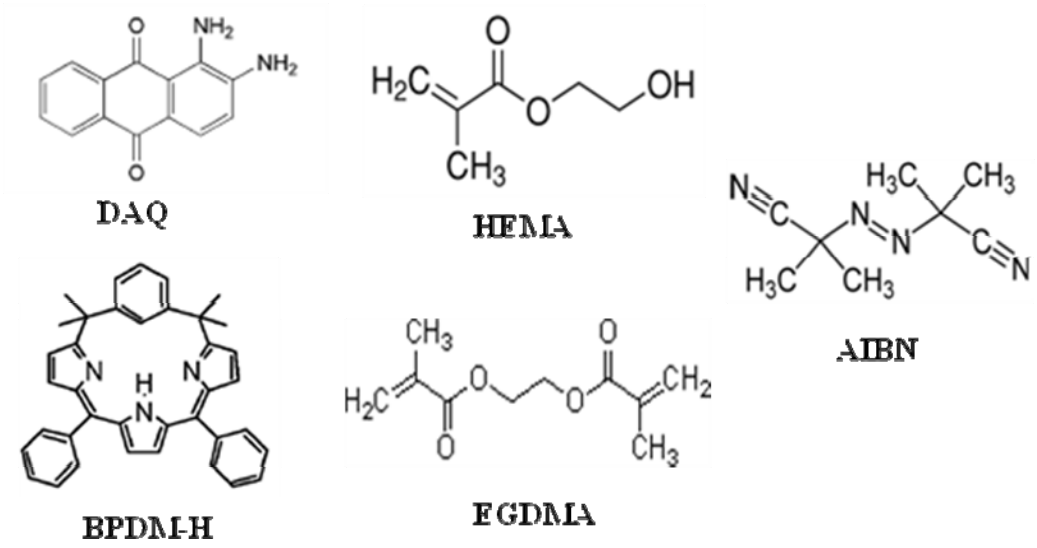

Figure 3. The molecular structures of DAQ, BPDM-H, HEMA, EGDMA, and AIBN.

3. EXPERIMENTAL RESULTS

For the sensing film that contains DAQ, the response of the film to the nitric oxide was monitored by recording the absorbance with time. The absorbance of the sensing film dose not change until the nitric oxide was bubbled into the buffer solution (Fig. 4). The stability of the sensing film that contains DAQ was also tested by introducing the same volume of acid solution (pH value=2.69) into cuvette. The absorbance of the sensing film keeps the same feature ever being treated by acid solution for 30 min as shown in Fig. 5.

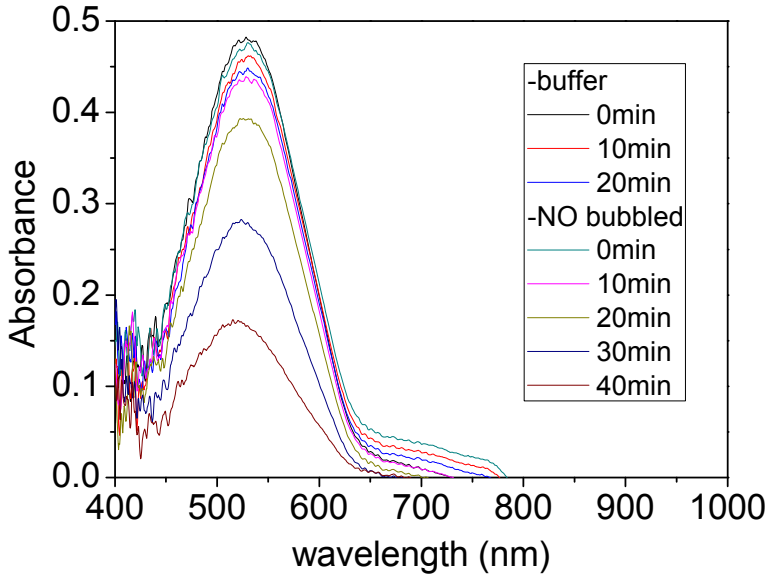

Figure 4. The absorbance of the sensing film contains DAQ before and after bubbling nitric oxide.

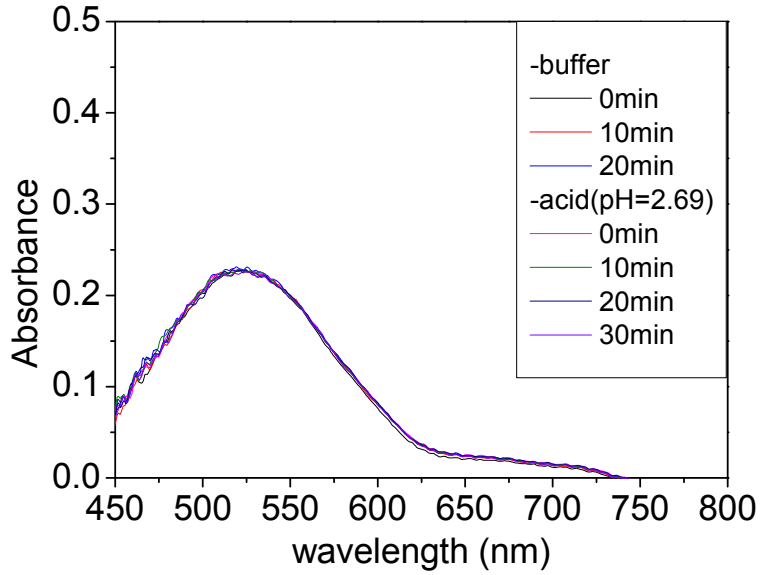

Figure 5. The absorbance of the sensing film contains DAQ under acid environment.

As for the sensing film that contains BPDM-H, the photoluminescence (PL) response of the film to the zinc ion was monitored by recording the PL with time. Before the addition of zinc, there is no feature around 670 nm in the PL spectrum of the sensing film that contains BPDM-H. After adding zinc, the PL increases with time as shown in Fig. 6. We also adopted the electrospinning technique to fabricate the fiber. The diameter of the fiber is about 1 micrometer as shown in Fig. 7. Figure 8 shows the PL response of the fibrous film which was recorded in a microfluidic channel with 405 nm laser as excitation source.

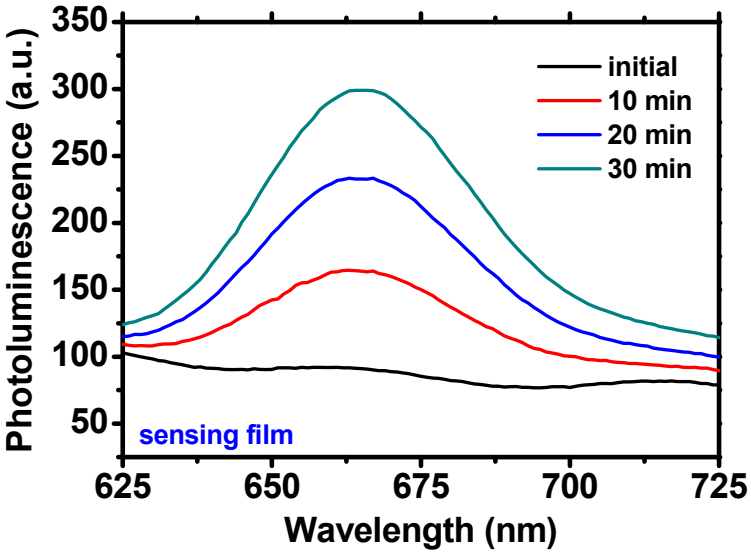

Figure 6. The PL spectra of the sensing film contains BPDM-H before and after the addition of zinc.

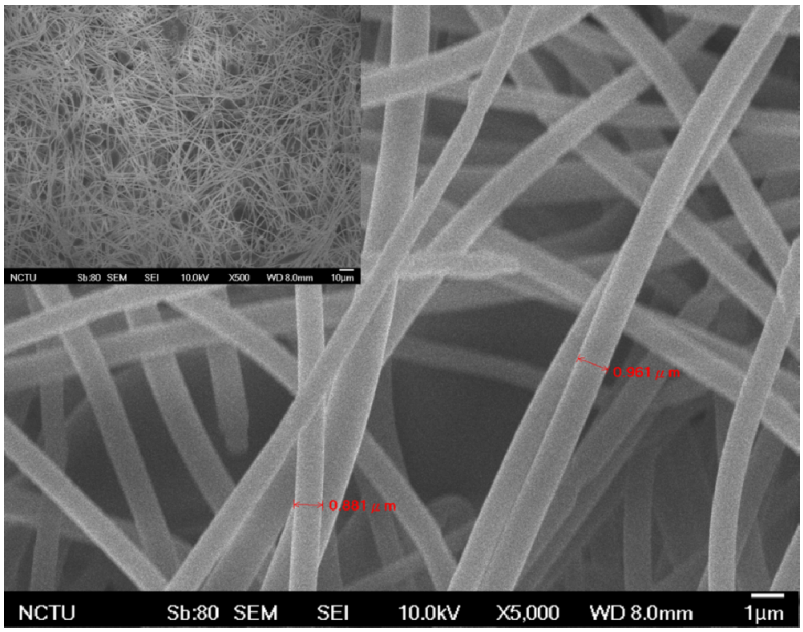

Figure 7. The SEM images of the fibrous film.

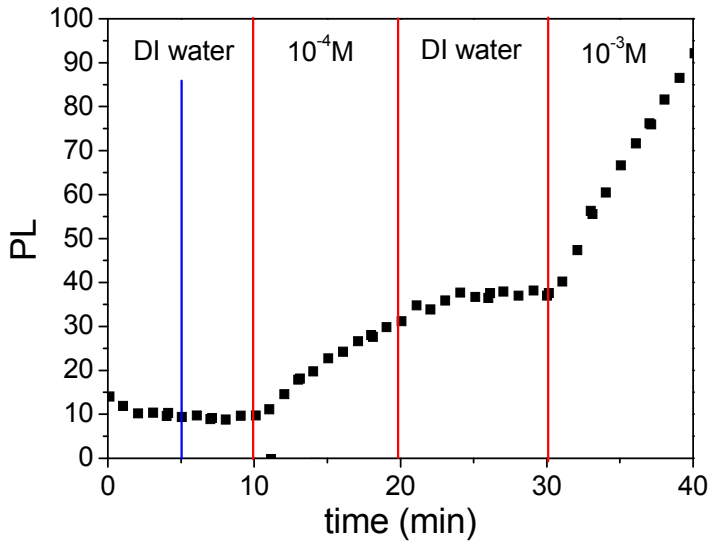

Figure 8. The PL of the fibrous film contains BPDM-H under various zinc concentrations.

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