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Simple fluorescent sensor for simultaneous selective quantification of benzene, toluene and xylene in a multicomponent mixture

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Abstract

A simple fluorescent sensor utilizing a material based on dibenzoylmethanatoboron difluoride ($DBMBF_2$) fluorophore capable of forming exciplexes with benzene, toluene and xylenes (BTX) has been developed. A physicochemical model for the dependence of the sample emission spectra on exposure to vapors of aromatic compounds was used to formulate criteria which should be fulfilled to detect individual analytes in a multicomponent mixture. It is experimentally demonstrated that after calibration the sensor provides simultaneous quantification of benzene, toluene and *p*-xylene in three-component mixtures. The approach proposed can be applied to a wide range of fluorescent sensor materials based on donor-acceptor interactions in the excited states.

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Keywords: sensors, selective, optochemical, BTX, fluorescent, optical, benzene, toluene, xylene, aromatics,fluorecence, exciplex, $DBMBF_2$

1. Introduction

Due to their toxicity even at parts-per-billion concentrations, aromatic compounds can present serious medical and environmental dangers. Although various approaches have been proposed to develop low-cost sensitive sensor devices for BTX, detection at trace levels of components in multi-analyte mixtures is still a challenging task which involves the use of laboratory equipment. Recently, $DBMBF_2$ has attracted a great deal of attention due to ability to form charge-transfer complexes with simple aromatic compounds in the ground and excited states. The fluorescence

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properties of the $DBMBF_2$/methylbenzene exciplexes strongly depend on the nature of aromatic moieties and can be used to achieve their selective detection. The high sensitivity to methylbenzene vapors has been previously demonstrated with materials based on $DBMBF_2$ [1]. However, discrimination between methylbenzenes and quantification of individual components in a BTX mixture has not been considered. The aim of the present work was to develop a method for on-line simultaneous quantification of methylbenzenes in a BTX mixture by decomposition of the total fluorescence spectrum into spectral components.

2. Experimental

The sensor used in this study is schematically represented in figure 1. The sensor comprises a sensing material deposed on a glass slide. A bifurcated fiber-optic probe is attached to the backside of the slide. The glass slide is located in a hermetic experimental cell to which vapor mixtures are supplied from a mixture generator based on permeation tubes. The probe is attached to a UV LED (λ = 375 nm) and a fiber-optic spectrometer USB-4000. To reduce the $DBMBF_2$ degradation, a pulsed signal detection scheme was used with a duration of 200 ms and a period of 200 s. More details about mixture preparation and experimental setup can be found elsewhere[2]. The sensing material consists of silica gel microspheres containing surface-adsorbed $DBMBF_2$ molecules (figure 2). The procedures for preparation of the microspheres with adsorbed $DBMBF_2$ was described elsewhere[3]. The water dispersion of microspheres (14 wt %) with 0.7 wt % polyvinylpyrrolidone was deposited on a glass slide using custom-made ink-jet printer based on micro-valves (The Lee Company).

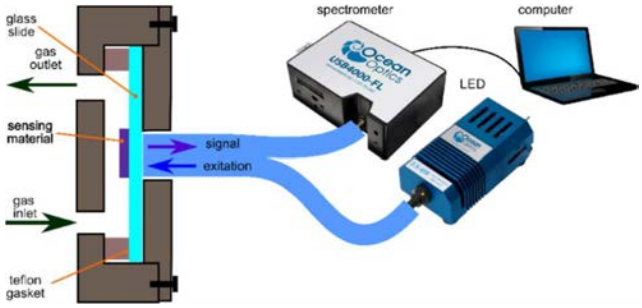

Fig. 1. Schematic representation of the sensor used in the study.

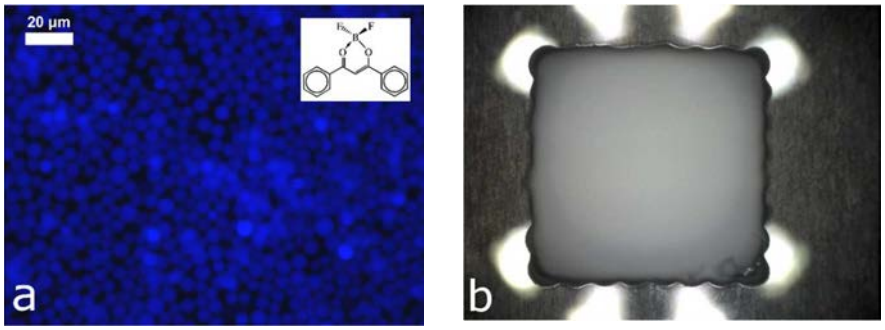

Fig. 2. (a) Fluorescence microscope image of a sensing film and chemical formula of $DBMBF_2$ fluorophore; (b) Photography of a slide with deposited sensing material.