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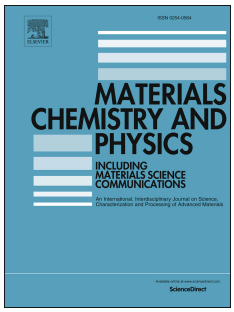

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Polystyrene photonic crystals as optical sensors for volatile organic compounds

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Abstract

We have synthesized self-assembled photonic crystals (PCs) based on polystyrene nanospheres having average diameters of 250 nm. Samples were obtained by drop-casting technique and subsequent self-assembly on pre-treated glass substrates to increase the surface wettability. Films showed a very good reflectance band with a maximum at 600 nm. We studied the reflectance peak changes as a function of time in presence of vapours of different alcohols. Specifically, we investigated methanol, ethanol, 1-propanol, isopropanol and n-butanol in order to test the potentiality of the system as optical gas sensor for volatile organic compounds (VOCs). We found a considerable redshift of the reflectance band in the presence of the alcohols that cannot be explained only on the basis of the different refractive index of the solvents. We attributed this behaviour to a cooperative effect due to an increase of the effective refractive index and to a swelling process of the polystyrene nanospheres induced by the contact with the alcohols. A different behaviour was found for water due to the hydrophobic properties of the surface of the polymeric photonic crystals. This property was exploited to test the polystyrene PCs for the measurement of the relative concentration of ethanol vapour in a closed volume exploiting different ethanol/water concentrations for a possible use as breathalyzer. The estimated limit of detection (LOD) of ethanol vapour for our system was 2% (v_{Ethan}/v_{tot}) corresponding to 1167 ppm.

Keywords: photonic crystals; polystyrene nanoparticles; volatile organic compounds; alcohol's sensors; optical sensors.

1. Introduction

Environmental pollution such as the poisoning of drinking water and the air contamination is a huge problem for human and planet health [1,2]. Between the most common contaminants an important role is represented by heavy metals [3-6], inorganic gases and volatile organic compounds (VOCs) [7], which come from industrial processes or from the use of pesticides and fertilizers in agriculture. These chemical toxic compounds, once released into the environment (in water, air or soil) do not remain confined to restricted areas, but easily expand into larger areas. Thus, every day we are exposed to pollutants through the air, water and the food [8, 9], causing serious allergies and pathologies like asthma or in some cases worse diseases such as cancer.

As mentioned, VOCs are a class of toxic compounds, which have high vapor pressure at room temperature and are very common as contaminants [10]. If a proper ventilation of indoor spaces is not provided, the volatile compounds stagnate and people can be exposed to high VOCs concentration for long times, with dangerous risks for health. In fact, data from various samples in the United States show that within residential and workplace environments, people are exposed to many different kinds of VOCs [11]. Alcohols are a class of VOCs, of which the most common are methanol, ethanol, 1-propanol, isopropanol and n-butanol. Each of these alcohols causes different deleterious effects on the human body by contact, ingestion or inhalation. For instance, 100 ml of pure methanol can lead to death if ingested [12], isopropanol causes serious eye irritation and it may lead to drowsiness or dizziness [13], n-butanol is harmful if swallowed and it causes skin irritation