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Abstract

Optical Characterization of Acetone-Sensitive Thin Films of poly(vinyl alcohol)-g-poly(methyl acrylate) †

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Organic solvents are widely used as reaction media and/or for the separation and purification of synthetic products in chemical and pharmaceutical industries. Many of those solvents, among them being acetone, are considered to be harmful to human health. The detection of vapors of such volatile solvents present in the air can be achieved using multiple devices and materials [1], but the method of optical detection has a few important advantages, such as room temperature detection without the need for electrical power supply and easy detection when it is based on color/reflectance change. To achieve this, acetone-sensitive copolymers were designed by grafting poly(methyl acrylate) side chains onto poly(vinyl alcohol) precursors. Copolymer aqueous dispersions were used for thin-film deposition on silicon substrates by applying the spin-coating method. Optical properties of the film-refractive index, n, and extinction coefficient, k, as well as thickness, d, were determined from measured reflectance spectra, R, by using the two-stage nonlinear curve fitting method [2]. To evaluate the sensing properties of the films, they were placed in a quartz cell, and the atmosphere inside was constantly changed from air to argon to acetone using a homemade bubbler system (Figure 1).

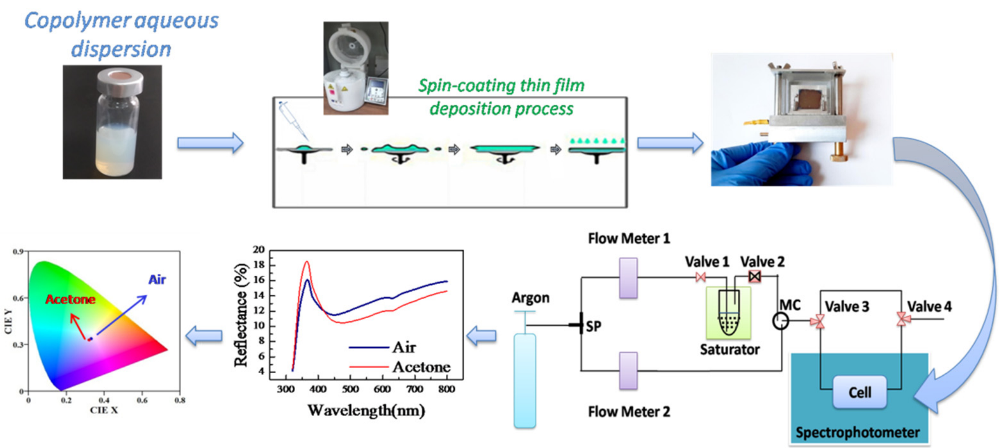

Figure 1. Scheme of the detection of acetone vapor process.

Reflectance spectra were measured before and during exposure to acetone vapors and were used to calculate optical constants and the thickness of the films in the presence of acetone vapors. When exposed to the vapors, the copolymer side chains swelled due to the absorption of acetone, and as a result, the film thickness increased while its refractive index decreased. This led to a shift of reflectance spectrum toward longer wavelengths and a subsequent change of the color of the film (Figure 1). The calculated sensitivity of polymer thin films was about $1.2 \times 10^{-4}\%$ per 1 ppm but could be further increased by two approaches. Firstly, the thickness of the polymer films could be optimized in order for the optical response to be maximized. Secondly, different multilayers structures could be designed using polymer films as building blocks.

According to the selectivity experiments, which are in progress, the initial results are very promising: the optical response of the films exposed to relative humidity of up to 80% RH is more than 10 times less as compared to acetone vapors response.

In conclusion, thin films of poly(vinyl alcohol)-g-poly(methyl acrylate) were successfully deposited using the spin-coating method on silicon substrates. A reaction toward acetone vapors and a very weak humidity response were demonstrated by measuring reflectance changes. Optimization approaches for sensitivity enhancement were discussed.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/CSAC2021-10416/s1.

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