

Electro-Optical Gas Sensing Characteristics of PEDOT:PSS Thin Films

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Summary:

A gas sensor was developed by depositing a PEDOT: PSS thin film onto glass-based platforms with interdigitated electrodes. Its properties were evaluated at room temperature (24 °C) using UV-Vis spectroscopy and electrical measurements towards various gases at a fixed concentration of 40 ppm. The sensor exhibited promising optical and electrical responses to hydrogen and acetone, while ethanol and ethylene showed weaker responses. These findings demonstrate the potential of PEDOT: PSS-based sensors for electro-optical gas sensing and improved selectivity.

Keywords: PEDOT: PSS, Optical gas sensing, Resistive gas sensing

Background, Motivation and Objective

Poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS) is a conductive polymer known for its unique electrical and optical properties, including sensitivity to various gases. However, its inherently low conductivity limits its sensing performance, necessitating modifications through solvent treatment. In this study, dimethyl sulfoxide (DMSO) was used to enhance the electrical and optical properties of PEDOT: PSS by influencing its structure and conductivity [1]. PEDOT: PSS holds considerable promise for gas sensing applications in diverse fields, including environmental monitoring, agriculture, and chemical detection. Improving its electrical and optical properties is key to enhancing its sensitivity and selectivity, especially for detecting specific volatile organic compounds (VOCs) such as alcohols, aldehydes, and isoprene [2]. This work presents the fabrication of a microsensor by depositing a PEDOT: PSS thin film onto a glass-based platform with interdigitated electrodes. The sensor operates at room temperature and demonstrates promising electrical and optical responses to gases/vapors such as hydrogen, ethanol, acetone, and ethylene, highlighting its potential for practical gas sensing applications.

Results

The SEM image of the PEDOT: PSS film (Figure 1-A), deposited via drop-coating on a silicon substrate using DMSO as the solvent, reveals a uniform film with excellent substrate coverage. The UV-Vis analysis of the PEDOT: PSS film (Figure 1-B) showed a sharp peak at 303 nm, corresponding to the PSS component, indicating well-defined absorption characteristics. Additionally,

the PEDOT component exhibited a broad absorption spanning the visible to near-infrared range (400–1200 nm), reflecting its delocalized charge carriers and conductive nature.

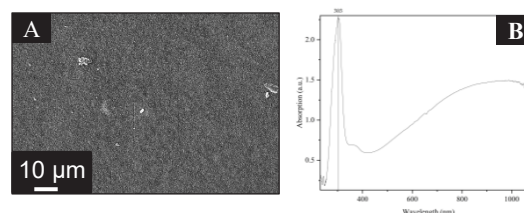


Figure 1. A- SEM image of PEDOT: PSS film deposited by drop-coating on a silicon substrate, with a scale bar of 10 μm. The image reveals a uniform film with excellent substrate coverage, indicative of successful deposition and film integrity. B- UV-Vis absorption spectrum of PEDOT: PSS film showing a sharp peak at 303 nm corresponding to the PSS component and a broad absorption band in the 400–1200 nm range attributed to the PEDOT component.

The surface of the PEDOT film was analyzed using X-ray photoelectron spectroscopy (XPS). The survey scan identified the primary elements in the film, including carbon (C), oxygen (O), and sulfur (S), with minor peaks for silicon (Si) and sodium (Na). The presence of Si is attributed to the silicon substrate, while Na is a result of its use in the PEDOT synthesis process. This analysis provides valuable insight into the film's elemental composition and the contributions of both the PEDOT material and the substrate.

For gas sensing applications, PEDOT: PSS was drop-coated onto a glass-based platform with conductive ITO electrodes. Electrical and optical

measurements were conducted at room temperature under a fixed gas concentration of 40 ppm. Optical measurements were performed at two key wavelengths: 299 nm, corresponding to the PSS component, and 1002 nm, corresponding to the PEDOT component. The film was exposed to hydrogen, ethanol, acetone, and ethylene gases. As shown in Figure 2, hydrogen and acetone elicit the strongest electrical and optical responses, with lower responses observed for ethanol and ethylene.

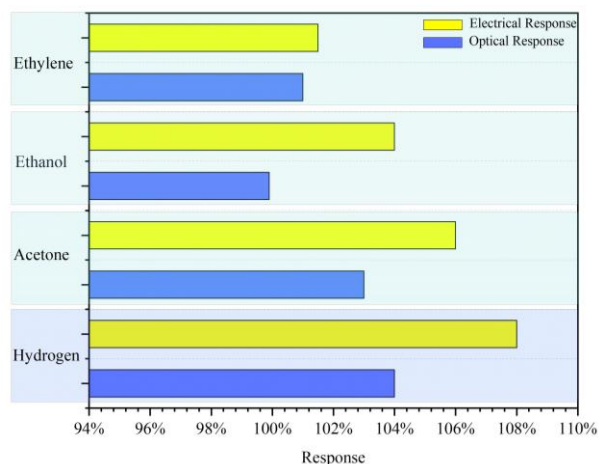


Figure 2- Electrical and optical responses of PEDOT:PSS film exposed to hydrogen, ethanol, acetone, and ethylene gases at a fixed concentration of 40 ppm. The results indicate that hydrogen and acetone elicit the strongest electrical and optical responses, with ethanol and ethylene showing comparatively lower signals.

In the electro-optical diagrams for hydrogen (H_2) and acetone (Ac), both the optical and electrical responses are shown together in a single plot (Fig. 3). The X-axis represents time, illustrating the progression of optical and electrical changes (Y-axis) during gas exposure. The sections corresponding to the presence of each gas are highlighted, facilitating easier comparison of the optical and electrical responses.

This presentation enables a clear comparison of the film's behavior under hydrogen and acetone exposure. The stronger sensor response to hydrogen is attributed to its higher polarity compared to ethanol, which enhances its interaction with the PEDOT: PSS film. Likewise, the smaller molecular size of acetone relative to ethylene allows for easier diffusion into the film, resulting in greater charge transfer and enhanced sensor responses. The results demonstrate significant potential by integrating two distinct response outputs—electrical and optical—within a single device. This dual-mode sensing approach could of-

fer key advantages, such as enhanced gas discrimination and improved selectivity. By combining these outputs, the need for large sensor arrays typically used in electronic noses can be reduced, simplifying system design while maintaining or even increasing performance.

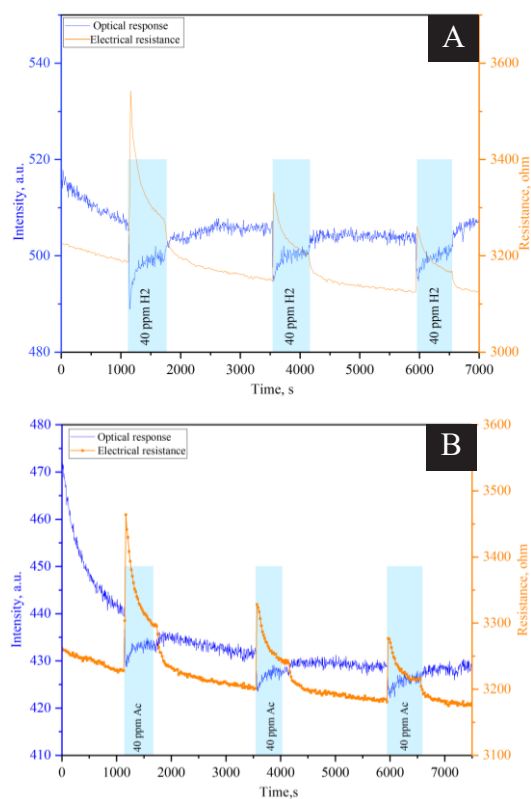


Figure 3- Electro-optical response of the PEDOT: PSS film upon exposure to 40 ppm hydrogen (A) and 40 ppm acetone (B) at 299 nm. The plots illustrate simultaneous optical and electrical measurements over time, with highlighted sections indicating gas presence.

References

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