Compositional engineering of VOPcPhO-TiO$_2$ nano-composite to reduce the absolute threshold value of humidity sensors

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Abstract

This research work demonstrates compositional engineering of an organic-inorganic hybrid nano-composites for modifying absolute threshold of humidity sensors. Vanadyl-2,9,16,23-tetraphenyl-2913,311H-phthalocyanine (VOPcPhO), an organic semiconductor, doped with Titanium dioxide nanoparticles (TiO$_2$ NPs) has been employed to fabricate humidity sensors. The morphology of the VOPcPhO/TiO$_2$ nano-composite films has been analyzed by atomic force microscopy (AFM) and field emission scanning electron microscopy (FESEM). The sensors have been examined over a wide range of relative humidity i.e., 20-99% RH. The sensor with TiO$_2$ (90 nm) shows reduced sensitivity threshold and improved linearity. The VOPcPhO/TiO2 (90 nm) nano-composite film is comprised of uniformly distributed voids which makes the surface more favorable for adsorption of moisture content from environment. The VOPcPhO/TiO2 nano-composite based sensor demonstrates remarkable improvement in the sensing parameter when equated with VOPcPhO sensors.

1. Introduction

Relative humidity (RH) is a critical parameter, which requires accurate and reliable assessment in industry. A humidity sensor should possess characteristic features such as high sensitivity, wide operating range, very low hysteresis and fast response and recovery time. Fabrication of such devices requires humidity sensor materials, which are not likely to contract, expand or peel off under different RH levels. The sensitivity and absolute threshold of a humidity sensor rely on the amount of water adsorbed, which primarily depends upon surface morphology of the active layer.

As far as the materials for humidity sensors are concerned, researchers have previously reported enhanced humidity sensing behavior of semiconductor nanostructures and thin films through composites or nano-composites [2,3]. Crucially, modification of morphology of the sensing film has resulted in affected hygroscopic sensitivity of fabricated sensors. Various methods have been adopted to improve morphological properties of the active sensing films, thereby, significantly enhancing sensitivity of fabricated devices [9]. Hygrometric properties of sensors employing oxide/polymer nanocomposites, for nanostructuring the active layer, have been extensively studied [10-15]. In the present research work, organic semiconductor VOPcPhO, and TiO$_2$ NPs have been employed in the fabrication of the organic nano-structured hygroscopic sensing films based sensors. VOPcPhO is a low molecular weight organic material, which has shown better stability and good sensitivity [16]. The previous studies on VOPcPhO have shown its sensitivity toward different moisture levels [17]. Whereas, TiO$_2$ is a class of metal oxides which has found application in a variety of electronic devices ranging from photovoltaics to sensors [18]. Earlier investigations revealed that TiO$_2$ has been used as a matrix in the sensing layer of humidity sensors [19]. TiO$_2$ is capable of absorbing great amount of water molecules by the virtue of its porosity which can be controlled quite easily [20].

Owing to such interesting properties of both VOPcPhO and TiO$_2$...