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# Pd-Doped Tin-Oxide-Based Thick-Film Sensor Array for Detection of $H_2$, $CH_4$, and CO

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In the present work, a palladium (Pd)-doped tin oxide ($SnO_2$) thick-film sensor array has been developed by using solid state reaction-derived pure $SnO_2$ powders (starting with two initial tin precursors: $SnCl_2{\cdot}2H_2O$ and $SnCl_4{\cdot}5H_2O$). The crystal structure of the powders and the morphology of the thick films have been characterized by using x-ray diffraction and field-emission scanning electron microscopy, respectively. Initially, the sensitivity of all the sensors of the array was studied for hydrogen ($H_2$), methane ($CH_4$), and carbon monoxide gas, followed by detailed analysis of the transient response of a 1 wt.% Pd-doped $SnO_2$ sensor prepared by using $SnCl_4{\cdot}5H_2O$ as a starting tin precursor, as it possessed better sensitivity for all the test gases. It is found that this sensor exhibits fast response and recovery times (1 min and 3.05 min) along with good repeatability for test gases; however, for $CH_4$ gas, it shows very much longer response and recovery times. The high response towards $H_2$ gas has been correlated well with the smallest crystallite size (18 nm) as well as the porous structure of the thick-film surface.

**Key words:** Thick film, sensor array, tin oxide, palladium

## INTRODUCTION

Gas sensors have an important impact in many areas such as environmental monitoring, public security, domestic safety, automotive applications, sensor networks, etc. Due to this vast range of applications, the need for cheap, small, low-power-consuming, reliable gas sensors has grown over the years. Generally, there are two techniques for manufacturing such sensors: (i) thin-film and (ii) thick-film technology. However, thick film technology-based gas sensors have many advantages over other types of technique, such as low cost, simple construction, small size, and good sensing properties.[1] In thick-film form, sensors based on tin oxide ($SnO_2$, 3.6 eV at 300 K) have emerged as potential devices for detection and discrimination of various toxic and explosive gases such as hydrogen ($H_2$), carbon monoxide (CO), and methane ($CH_4$), owing to their rugged design, ease of fabrication, and sensitivity to a large number of compounds.[2] However, the main problems with gas sensors based on pure $SnO_2$ are poor stability at high operating temperature, low sensitivity, and poor selectivity.[3,4] The performance of such sensors is appreciably influenced by the structure and morphology of the sensing material. When the effective surface area of the base sensing material increases, there is an increase in the number of surface adsorption sites and hence an increase in the oxygen species presented for reaction. This decreases the sensor resistance, resulting in higher sensitivity.[5] To obtain such high specific surface area, nanosized $SnO_2$ particles are a very popular material.[6,7] Xu et al.[8] reported that the sensitivity begins to increase sharply as the grain size decreases below a critical value of ~6 nm, which is equal to twice the thickness of the Schottky barrier penetration into the $SnO_2$ grains. Under such circumstances, the whole particle is depleted of electrons. As a result, the sensitivity of the sensor increases. Recently, a variety of techniques have

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