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PANi-SnO_2 nanocomposite films as highly selective, sensitive, and stable NH_3 sensors

Ganesh Khuspe[1]
[1] N. K. Orchid College of Engineering & Technology, Solapur
E-mail: ganesh.7940@gmail.com

Abstract:

Nanocomposites of polyaniline (PANi) and tin oxide (SnO_2) were prepared by adding SnO_2 nanoparticles in different weight ratios (10–50%) into the PANi matrix. The nanocomposites thin films were characterized for their structural and chemical properties using XRD, FESEM and TEM, which confirms the formation of polyaniline-SnO_2 nanocomposites. The room temperature gas sensing properties of nanocomposite films were studied for various reducing and oxidizing gases. We demonstrate that PANi-SnO_2(50%) nanocomposite films are highly selective to NH_3 along with maximum response and better stability at room temperature.

Key words: Polymer-composite, Nanostructure, Sensors, Stability.

Experimental methods

Polyaniline was synthesized by polymerization of aniline in the presence of hydrochloric acid as a catalyst and ammonium peroxidisulphate as an oxidant by chemical oxidative polymerization method. Tin oxide nanoparticles were synthesized by a sol–gel method using stannic chloride pentahydrate as a source of Sn. The PANi-SnO_2 nanocomposites were prepared by adding SnO_2 nanoparticles in different weight ratios (10–50%) into the PANi matrix. The prepared nanocomposites were dissolved in m-cresol and stirred for 11 hr to get casting solution. For the fabrication of thin film sensors, the casting solution of nanocomposites was deposited on glass substrates by spin coating method.

Structural analysis

The XRD pattern of PANi (see Fig. 1(a)) showed a broad, amorphous diffraction peak implied that the existence of polyaniline. The SnO_2 patterns in Fig. 1(b), all the peaks were in accordance with tetragonal crystallization structure of SnO_2. For PANi-SnO_2(50%) nanocomposites (see Fig. 1(c)), all the main peaks presented in the PANi and SnO_2 are also observed in the PANi-SnO_2(50%) nanocomposites, but the peaks are weaker than those of the SnO_2 and PANi, which may result from the interaction between PANi and SnO_2 [1].

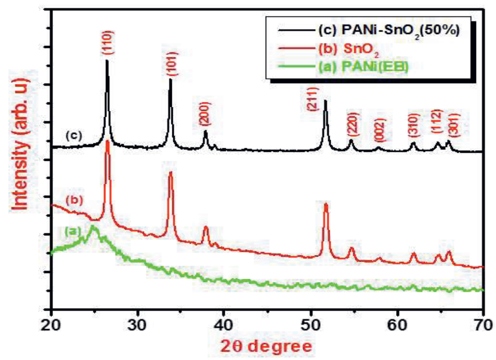

Fig. 1. X-ray diffraction pattern of (a) PANi, (b) SnO_2 and (c) PANi-SnO_2(50%).

Morphological analysis

FESEM image of PANi, SnO_2 NPs and PANi-SnO_2(50%) nanocomposite films are shown in Fig. 2. The surface morphology of the PANi film confirms the interconnected polyaniline nanofibers (see Fig. 2(a)). The fibers are relatively smooth with randomly distributed over the substrate [2]. Fig. 2(b) shows the surface morphology of the SnO2 NPs film is consists of uniformly distribution of nanocrystalline grains with randomly oriented morphology [20]. The image of PANi-SnO2(50%) nanocomposite is (see Fig. 2(c)) clearly shows the uniform distribution of SnO_2 NPs into PANi nanofibers, the NPs are closely packed and no bare nanoparticles are observed, which suggests the feasibility of this method to fabricate well dispersed nanoparticles with uniform coating

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layer. Such morphology is preferred for gas sensing application because it promotes adsorption of gas molecules through the film surface, so excellent gas response can be expected [3]. In Fig. 2(d) showed that the TEM of PANi-SnO_2(50%) nanocomposite particles are homogeneously distributed, with an average diameter of 26 nm benefits the properties, so excellent gas response can be expected [1].

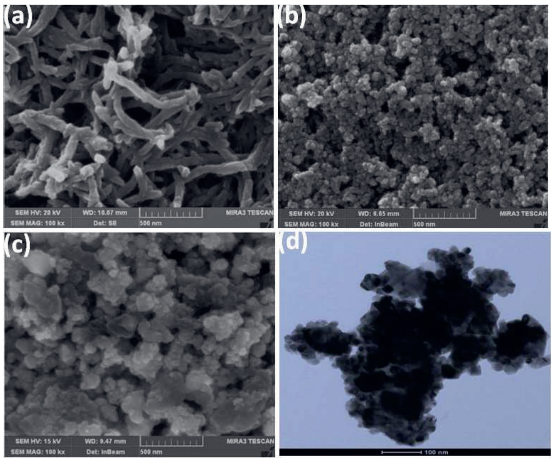

Fig. 2. FESEM images of (a) PANi, (b) SnO_2 and (c) PANi-SnO_2(50%) & (d) TEM images of PANi-SnO_2(50%).

Gas sensing performance

Fig. 3(a) shows the gas response of PANi-SnO_2 (10-50%) nanocomposites to 100 ppm NH_3 concentration at room temperature. It was observed that among all of the films, PANi-SnO_2(50%) nanocomposite film shows maximum response 72% to 100 ppm NH_3 at room temperature. The enhanced gas sensing performance of the nanocomposites is due to porous microstructure of the nanocomposites. The responses of PANi-SnO_2(50%) nanocomposites film for 100 ppm to NH_3, CH_3OH, and H_2S at room temperature are shown in Fig. 3(b). It is observed that the nanocomposites film showed more selective for NH_3 compared to CH_3OH and H_2S at room temperature [26]. The gas response study of PANi-SnO_2(50%) nanocomposite film to 10 - 100 ppm NH_3 was carried out at room temperature (see Fig. 3(c)). It was observed that the response increase with the increase of NH_3 concentration and nanocomposite showed the maximum response to 100 ppm NH_3 at room temperature, which suggests that the PANi-SnO2 (50%) nanocomposite is a potential sensor for detection of very low concentrations of NH_3 gas at room temperature. The PANi-SnO_2(50%) sensor was measured at a level of 100 ppm NH_3 after ageing for 40 days at room temperature in order to test the stability. The results were shown in Fig. 3(d), which can be seen that the nanocomposite exhibited constant response to NH_3 even after 40 days (86% stability). It suggested that nanocomposite have promising application in gas sensor field.

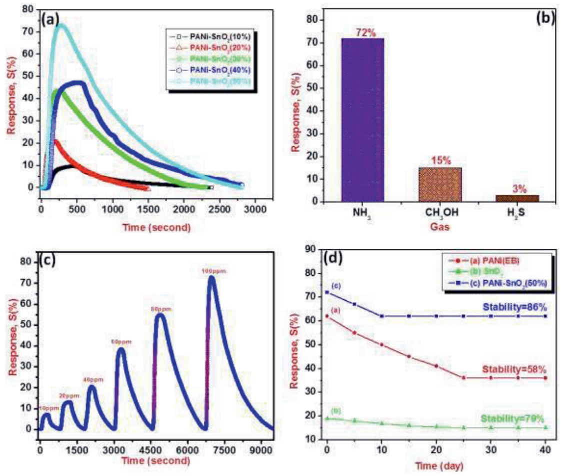

Fig. 3. Response of (a) PANi-SnO_2(10-50%) nanocomposites to 100 ppm NH_3 at room temperature (b) PANi-SnO_2(50%) sensor film to different gases at room temperature, (c) Dynamic response of PANi-SnO_2(50%) nanocomposite film to different NH_3 concentration, (d) Stability of (a) PANi, (b) SnO_2 and (c) PANi-SnO_2(50%) sensors to 100 ppm NH_3 gas.

Conclusion

The nanocomposites films of polyaniline and tin oxide prepared by spin coating technique have shown high response to NH_3 at room temperature. PANi-SnO_2 composites had better selectivity and response than PANi and much lower working temperature than SnO_2. Among all of the PANi-SnO_2 nanocomposites, PANi-SnO_2(50%) showed the maximum response (72%) and better stability (86%) to 100ppm NH_3 at room temperature. It is expected that such material with excellent gas sensing properties at room temperature may have potential application as gas sensor.

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