Abstract

Volatile organic compound (VOCs) being virulent, noxious and carcinogenic critically threaten the human health and ecological environment. This work primarily aims at the development of carbon-metal oxide nanocomposites based devices for the detection of VOCs. The work was carried by the development of two different types of nanostructures of TiO_2 having opposite type of conductivity. First, 1-D TiO_2 nanotubes were developed by electrochemical anodization which exhibited *n*-type behaviour. Secondly undoped TiO_2 nanoparticles were synthesized by sol gel method which exhibited *p*-type behaviour. Both the pure TiO_2 nanostructures were thoroughly studied and further utilized for the formation of nanocomposites with different nanoforms of carbon. Two different nanoforms of carbon i.e. 2-D graphene and 0-D fullerene were considered for the nanocomposite formation with TiO_2 nanostructures. Nanocarbon-TiO_2 composites were synthesized by using different techniques like hydrothermal, sol gel, and electrochemical anodization etc. Nanocomposites including the pure nanoforms were subjected to different characterization techniques to study their morphology, chemical composition and structure etc. Oxygen vacancy modulation in TiO_2 nanotubes were performed via two different techniques – cathodic polarization and chemical reduction. TiO_2 nanotubes reduced by cathodization exhibited a high response magnitude of 90 % to 100 ppm of ethanol at 150 ˚C. Whereas the chemically reduced TiO_2 nanotubes showed a moderate response magnitude of 75.4 % at 150 ˚C. These reduced TiO_2 nanotubes sensors having vertical structure offered a dynamic range to detection from 20 ppm to 200 ppm selectively towards ethanol.

Different device structures were fabricated for efficient VOC sensing. Three different device structures were proposed according the three different nanostructures ~ 0-D,1-D and 2-D. The 0-D nanostructures (nanoparticles) were implemented in planar structured device. The 1-D nanostructures (nanotubes) were implemented in Metal Insulator Metal (MIM) sandwiched structured device. The 2-D nanostructures were implemented in field effect transistor (FET) type device structure. FET device structure was preferred in back gate structure to keep the sensing surface exposed to the ambient. The proposed device structures were well suited for the synthesized nanoforms.

Two types of GO-TiO_2 nanostructures composites were fabricated which offered promising sensor performance towards alcohols. GO-TiO_2 nanotube composite depicted room temperature methanol sensing with good response magnitude (28 %) and fair response/recovery time (34 s/40 s). GO-*p*-TiO_2 nanoparticle composite based back gated FET

sensors depicted a high response magnitude (115 %) towards 100 ppm ethanol at 100 ˚C at appropriate gate voltage (0.7 V). Moreover, GO-*p*-TiO_2 nanoparticle composite depicted a high I_{ON}/I_{OFF} ratio of $2.8\times10^{3,}$ with acceptable transconductance of 0.286 µS and high transport gap of 54.2 meV at room temperature

Functionalized fullerene C_{60}-TiO_2 nanostructures composite sensors were synthesized which were highly sensitive and selective towards formaldehyde. Four C_{60}-TiO_2 nanotube composites with varied concentration of fullerene (0.006 wt%, 0.01 wt%, 0.02 wt% and 0.05 wt%) were synthesized through hydrothermal method. All the MIM structured C_{60}-TiO_2 nanotube composite sensors showed excellent response magnitude (>92%) to 100 ppm of formaldehyde at 150 ˚C. Sensor having 0.05 wt% of fullerene showed the highest response of 99.6% towards 100 ppm formaldehyde at 150°C where as sensor having 0.02 wt % of fullerene showed fastest response/recovery of 4 s/ 7 s among all the sensors at the same conditions.

C_{60} encapsulated TiO_2 nanoparticles composite was also synthesized via chemical route by using hydrated fullerene-C_{60} and sol-gel derived undoped *p*-type TiO_2 nanoparticles. The planar structured C_{60} encapsulated TiO_2 nanoparticles sensor depicted more than double response magnitude (117 %) than the pure TiO_2 nanoparticle (48%) and pure C_{60} particles (40 %) and appreciably fast response/ recovery (12 s /331 s) towards 100 ppm of formaldehyde at 150 ˚C. Flow diagram, indicating all the essential steps has been shown below.

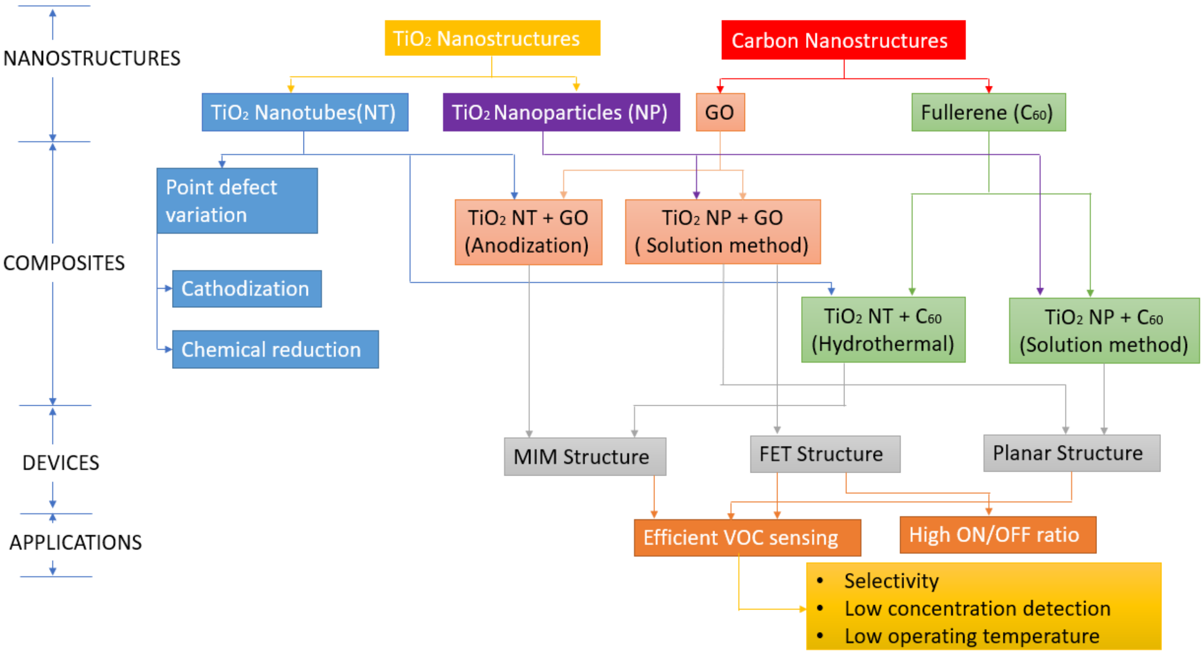

Fig. i. A flow chart of complete thesis work