Abstract

Vanadium pentoxide (V_2O_5), a transition metal oxide has shown its great potential due to its specific physical and chemical properties. It is a promising material or metal oxide due to its semiconducting nature, optical, electrical and magnetic properties with thermal and chemical stability. Among the all transition metal oxides, V_2O_5 has gained huge research interest due to its layered structure, environment friendly nature, and cost effectiveness. In the present time, air pollution is the global problem for human being due to its abrupt increase because of its vast industrialization and fuel vehicle transportation. For controlling or monitoring the air pollutants, low cost and smart sensors are needed, as well as which can be operated at low working temperature. For this purpose, V_2O_5 shows the interesting results in the field of gas sensing. We set our first aim to find out the physical characteristics such as electrical and magnetic properties of hydrothermally synthesized microstructures to determine its charge carrier dynamics. After this work, we set our second aim to investigate the gas sensing application of V_2O_5 metal oxide with specified morphology such as micro flowers. Next, we compare the different morphology, micro flowers and nanoparticles to find out the best response for NO_2 gas sensing applications.

In the beginning of work, vanadium pentoxide V_2O_5 is successfully synthesized by hydrothermal method. The structural study explained the growth of prepared V_2O_5 sample in orthorhombic phase. The Raman study revealed the layered structure of V_2O_5 sample. Further, the morphological analysis of prepared V_2O_5 sample showed the flower like microstructures self-assembled by nanorods with diameter 3μm. The crystalline nature of the microstructures was confirmed by SAED pattern. The electrical transport measurement confirmed the semiconducting nature of the V_2O_5 microstructure with activation energy 185 meV in the high temperature range 285 K to 380 K. whereas, the variable range hopping conduction is found in the low temperature

range 200-285 K. The experimentally observed behavior of V_2O_5 microstructure has been discussed in this work. It is evident from the MH plot that system shows the paramagnetic behavior along with small component of ferromagnetic behavior due to presence of V^{+4} oxidation state of vanadium. The magnetic characteristics of V_2O_5 microstrures also showed its anomalous behavior in narrow temperature range 45 -65 K, where the magnetic ground state is antiferromagnetic.

Subsequently, we prepared the V_2O_5 metal oxide sample by hydrothermal method with specific morphology for the gas sensing application, which is well known topic in the field of research in the recent time. The morphological analysis confirmed the flower like structures (micro flowers self-assembled aby nanoplates). The structural study showed the orthorhombic phase and layered structure of V_2O_5 micro flowers. In addition, SAED pattern further confirms the poly crystalline nature of the micro flowers. The electrical transport analysis of micro flowers showed the semiconducting nature in the whole temperature regime (170 - 380 K) with the activation energy 103.2 meV. In the gas sensing application part of V_2O_5 micro flowers, it illustrates the sharp increment in the resistance when the gas flow is switched on and reaches to the saturation value over 10 minutes NO_2 gas exposure time. The sensing result also shows the better selectivity and sensitivity for the trace amount of the NO_2 gas at optimum operating temperature.

In the next part of the work, first we optimized the morphology of V_2O_5 metal oxide by hydrothermal synthesis method at different synthesis temperatures such as 150, 170, 190 ^oC (using the same synthesis precursors) to obtained the nanoparticle morphology of V_2O_5. The structural characterization of all the optimized samples showed the orthorhombic phase formation of V_2O_5 sample with the layered structure. The morphological study confirmed the formation of nanoparticles at the temperature 190 ^oC with dimension of 100 nm. The electrical transport study confirmed the semiconducting nature of the nanoparticles in the temperature regime 170 - 380 K with activation energy 100 meV. In the subsequent part of this work, both morphology V_2O_5 micro flowers and nanoparticles morphologies were compared in terms of their crystal structure, surface area, activation energy and further for NO_2 gas sensing applications. The sensing measurements were performed for 10 ppm NO_2 gas at 50 to 250℃ for 5 minutes' gas exposure time. The result showed the better response for micro flowers morphology as compared to nanoparticles and the reason was explained on the basis of morphology, the high surface area of V_2O_5 micro flowers (9.12 m^2/g) as compared to nanoparticles (2.19 m^2/g), calculated by BET analysis. Hence, our finding suggest that the V_2O_5 micro flowers is the promising candidate for high response NO_2 gas sensing application.