ABSTRACT

Monolayers and few layers of two dimensional layered materials, particularly transition metal dichalcogenides (TMDs) (e.g. MoS_2, WS_2, WSe_2 etc.), have recently gained popularity due to their exciting electrical, mechanical and optical properties.Among these, WS_2 has not been much explored so far; even though recent research shows it can be a promising candidate for various applications such as batteries, supercapacitors, gas sensors etc.However, to date most studies of layered 2D materials have been based on materials produced by mechanical cleaving which is a serendipitous method, thus its throughput is seriously limited. For commercialization, scalable, low-cost, high-yield production of active channels and compatibility with conventional semiconductor fabrication processes are essential.In this work mono/few layer of WS_2 nanosheets was synthesized using liquid exfoliation techniques. Precisely three synthesis techniques were developed; (i) a green synthesis route was utilized for WS_2 exfoliation in water which is considered as universal solvent. Pre-freezing and subsequent quenching results in few-layered thick WS_2 nanosheets (ii) WS_2 was exfoliated by using mixture of polar protic and polar aprotic solvents and (iii) WS_2 was also exfoliated by simple ultrasonication in acetone/alcohol blend. The nanosheets obtained by these routes werefound to be stablefor months (i.e. no precipitation observed). These nanosheets were further utilized in gas sensing. It is known that humidity measurement remains a challenging area of research due to its application in agricultural, biological, and industrial application. Most of the present humidity sensors are capacitive in nature whose structure is complex and suffers from long term reliability. Transition metal dichalcogenides such as VS_2, and MoS_2 have shown excellent response in humidity sensing at room temperature which was the motivation behind using WS_2 nanosheets in humidity sensing. Further, the performance of

WS_2 based humidity sensors were enhanced by utilizing nanohybrids with TMDs like WSe_2 and organic 2D materials like graphene oxides.

The ammonia sensing properties of these nanosheets were also studied by developing chemiresistive sensors. Since, the intrinsic n-type behaviour of WS_2 suggests that the conductivity of the material could be modulated in presence of reducing or oxidising gases. However, these sensors are challenged by current ammonia sensors in the market, majority of which are electrochemical sensors. These sensors are bulky and not compatible with silicon technology. Metal oxide ammonia sensors are resistive but their high operating temperature (300-500°C) remains constraint. However, the performance enhancement of WS_2 nanosheets based sensors was necessary due to their low response. Nanocomposite and nanohybrids formation is one of the approaches to enhance its properties due to their synergistic behaviour. Nanocomposite of PANI/ $WS_2$was utilized for ammonia sensing which was found to be highly selective towards ammonia at room temperature. Nanocomposites of WS_2 with noble metal nanoparticles were also investigated and they were found to be stable at room temperature. Nanohybrids of WS_2 with metal oxide i.e. WO_3 have shown high excellent ammonia sensing at high temperature (250°C).

The extensive research carried in this work suggests that bulk WS_2 can be easily exfoliated into nanosheets by liquid exfoliation which is really inexpensive. Further, simple chemiresistive gas sensors could be fabricated with these materials (and their nanocomposites and nanohybrids) which are economical though reliable.

Keywords: Tungsten Sulfide, exfoliation, nanocomposites, nanohybrids, humidity sensors, ammonia sensors