# $MoS_2$ Based Gas Sensor for Ammonia and Humidity Detection


## ABSTRACT

Gas sensor is a device that can detect toxic gases and volatile organic compounds (VOCs) present in the environment. Such sensors comprise of a transducer and an active sensing layer, which convert the chemical information into another form of electronic signal (like change in frequency, current or voltage). Modern days air quality monitoring has become increasingly essential due to the higher pollution level particularly at urban areas. Most of the present days' commercial gas sensors are electrochemical in nature, bulky (due to requirement of electrolyte) and expensive (due to semi-automated fabrication process and separate interface electronics). In this respect, resistive gas sensor (change in resistance of the sensing layer in presence of gases) can be advantageous, because their simpler structure is easier to miniaturize and integrate with CMOS technology, which will improve compactness and reduce cost. However, resistive sensors mostly use metal oxide sensing layer, which requires high temperature ((200°C-500°C), i.e. high power) to detect gases. Thus the objective of our research work is to develop a low power resistive sensor for sensing gases, particularly ammonia and humidity.

In this research work, few-layered Molybdenum disulphide ($MoS_2$) nanoflakes were exfoliated from bulk powder in a mixed solvent and used as the sensing layer to develop resistive gas sensors. Because of its large surface to volume ratio and presence of defect sites, $MoS_2$ was believed to be potential sensing element for gas sensing at much lower temperature. The sensors were developed on interdigitated electrodes (IDEs on ceramic substrate) and flexible substrate (e.g. Polyethylene terephthalate (PET)). The response of as-exfoliated $MoS_2$ nanoflakes increased from 8.525% at 50 ppm to ~70.4% at 480 ppm of ammonia gas at 125°C. The selectivity towards $NH_3$ was low when tested against NO and some other VOCs. The sensor also showed reasonable response towards humidity (16 times at 75% relative humidity (RH) at room temperature (RT)). To improve the sensitivity and selectivity towards ammonia and humidity, the $MoS_2$ nanoflakes were functionalized with other nano-materials. For example, in case of ammonia, reduced graphene oxide (rGO), Cu nanoparticles (NPs) and gold NPs were used. It was found that gold doped $MoS_2$ demonstrated highest sensitivity (~150% at 500 ppm) and selectivity towards $NH_3$, faster response and recovery times at 90°C compared to other samples. In case of humidity sensing, Pt NPs decorated $MoS_2$ showed record high response of ~4000 times at 85% RH with negligible hysteresis. The synthesis, material characterizations, gas sensing experiments and sensing mechanisms have been discussed elaborately in the thesis. A prototype of humidity sensor on printed circuit board using microcontroller for acquiring and transmitting sensor data to an Android application was also developed. Thus, it is believed that this research work would lead to the development of highly efficient $MoS_2$ based low power, handheld gas sensors.



**Keywords**: Molybdenum disulphide ($MoS_2$), $MoS_2$ Functionalization, resistive gas sensors, ammonia sensors, humidity sensors, interfacing electronics.