CVD growth of unique vertical MoS_2 flakes and monolayer pyramid MoS_2 flakes and their application to develop high-sensitive and room temperature gas senors

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Abstract

Here, we developed H_2 and NO_2 gas sensor by modifying the growth of MoS_2 flakes from in-plane to vertical aligned MoS_2 flakes and monolayer pyramid MoS_2 flakes. Highly uniform vertical aligned MoS_2 flakes, mixed MoS_2 flakes and monolayer pyramid MoS_2 flakes were utilized for developing fast and highly recover H_2 and NO_2 gas sensing. These unique growth structures synthesized by modified chemical vapor deposition technique. Detailed characterizations were carried out to reveal the growth of MoS_2 flakes. It has been found that in-plane MoS_2 work as seed layer for initial growth of vertical MoS_2 and leads to growth of an interconnected vertical MoS_2 flakes with increased gas flow rate. The gas flow rate plays a vital role for the morphology variation of MoS_2 flakes.

Here, highly uniform electrically connected vertical aligned MoS_2 flakes and monolayer pyramid flakes based H_2 sensor operating at room temperature developed. The 1 % H_2 gas concentration studied in the temperature range of 28-150 °C, well below the explosion limit of 4 % H_2 gas concentration. The lowest response time 14 s (11.3 s) and fast recovery 108 s (125.3 s) for vertical aligned MoS_2 flakes (pyramid MoS_2 flakes) was observed. The sensitivity 1 % and 6 % was found for vertical aligned MoS_2 flakes and pyramid MoS_2 flakes at RT, respectively. The role of MoS_2 edges verified by depositing thin ZnO layer (2-3 nm) on vertical MoS_2. We found a decrease in relative response of MoS_2-ZnO hybrid structures. The photoactivated NO_2 sensor developed by mixed in-plane and vertical p-MoS_2 flakes (mixed MoS_2). The sensor showed fast response with sensitivity of ~10.36 % for 10 ppm of NO_2 at RT without complete recovery. The UV assisted NO_2 sensing showed an improved performance in term of fast response and complete recovery kinetics with enhanced sensitivity to 10 ppm NO_2 concentration. The detailed gas sensing mechanism is proposed in the light of detail surface morphology and density function theory (DFT). This study reveals that tailoring the favourable adsorption sites in 2D materials is helpful to develop the highly sensitive and fast gas sensor for next generation safety devices.

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Figures

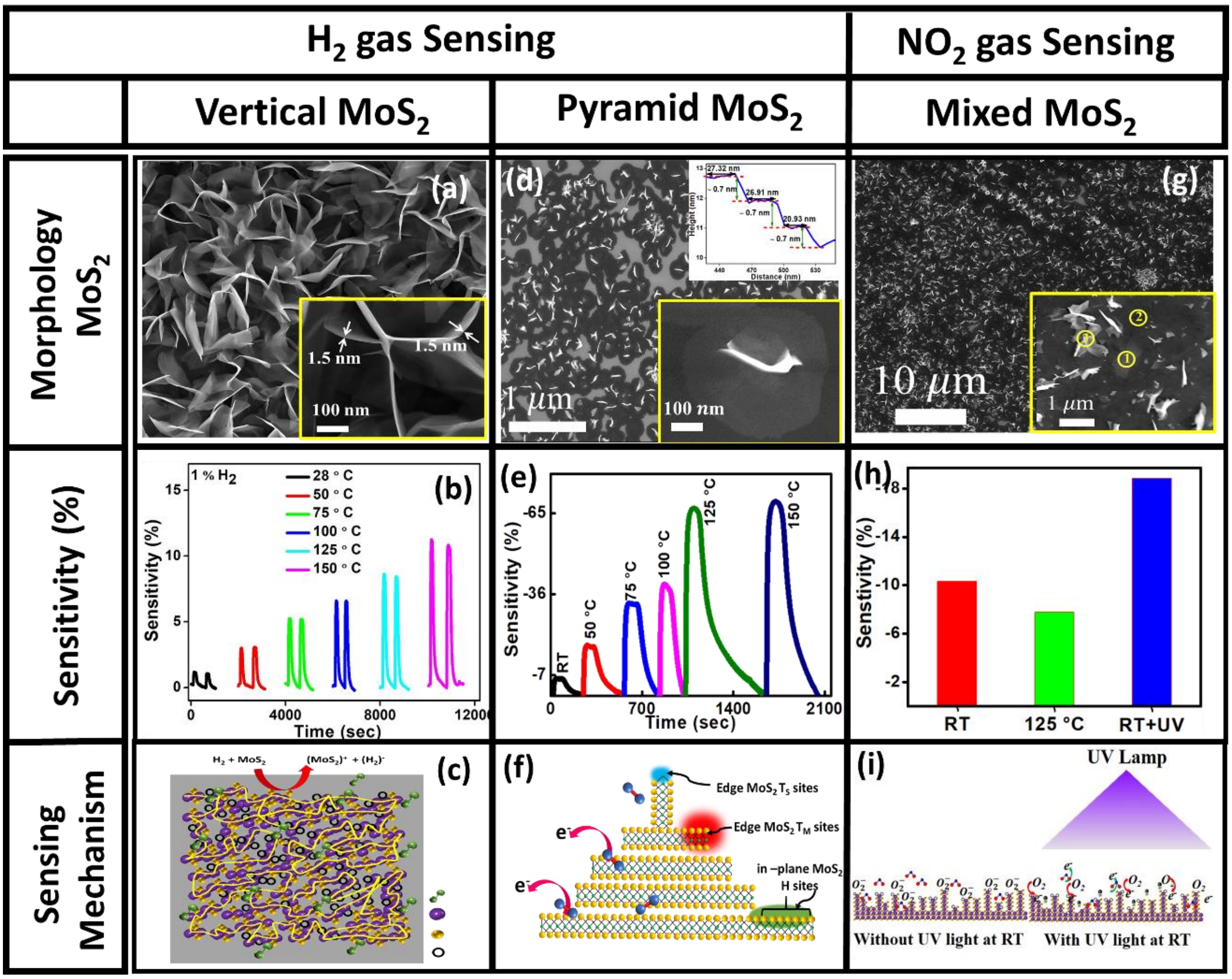

Figure: (a-c) Vertical MoS_2 flakes based H_2 gas sensor. (d-f) Pyramid MoS_2 flakes based H_2 gas sensor. (g-i) Mixed MoS_2 flakes (combination of in-plane MoS_2 and vertical MoS_2 flakes) based NO_2 gas sensor.