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Recent advances in Materials development and design for Gas Sensing applications

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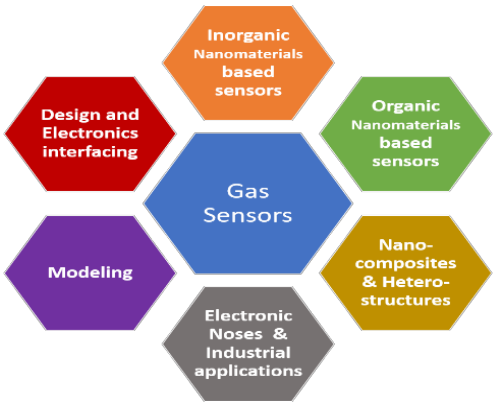
Editorial

ABSTRACT

The development of sensors using different materials play pivotal role in application of gas sensors in real time conditions. Many different type of materials have been studied, utilized and applied for the development of gas sensors. The compilation of research advances in the field of new gas sensors would provide better understanding towards applications of advanced functional materials. The current compilation encompasses recent trends in the area of nanostructured gas sensors. Various aspects of developing a gas sensor such as materials synthesis, characterization and optimization of sensor parameters, gas sensing methodologies, mechanistic studies, theoretical modeling and real-life applications are discussed. The research advances in form of concise reviews and original research articles in different gas sensing areas have been covered. The current research direction in developing novel materials, various technologies adopted to advance the sensing capabilities in order to realize an end user preferred device is elucidated. This effort is aimed at providing various avenues to a researcher where research can be focused in order to develop a gas sensor.



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INTRODUCTION

Gas sensors based on semiconducting materials are a well-researched topic for past three decades.[1] Various semiconducting materials have been studied world over for detecting various gases, vapors and odors which led to the applications in food quality assessment, detection of toxic gases and chemicals, explosives, environmental monitoring, etc.[2] Recently this field has progressed tremendously particularly in area of development of new materials including nanotechnology based materials for gas sensing. Nanomaterials, due to their surface to volume ratio, have significant applications in the field of materials for sensors. The compilation of recent research through collection of research works covering different aspects of gas sensing have been done here for better understanding and future advancing in this area.

The different components for making gas sensors are broadly classified as organic and inorganic nanomaterials. In organic nanomaterials, use of Carbon nanotube (CNT) based gas sensors have been widely explored owing to unique properties of CNTs.[3] The favorable properties of CNT such as high current density and carrier density have shown a great promise in the context of gas sensing applications.[3] Both the single walled and double walled CNTs based sensors are widely used for swift sensing a variety of analytes. In inorganic materials, traditionally used metal oxides such as ZnO, SnO_2, TiO_2, WO_3, In_2O_3 are at forefront in development of sensors for different gases including NO_2.[4] Sensor response tailoring using microstructure modification of nanostructured V_2O_5 and novel optical detection technique using SnO_2 provides specific advanced evaluation and application of metal oxides in gas sensing.[5,6] In order to improve the sensitivity and selectivity of semiconductor-based sensors, functionalization, decoration, alloying and hetero-structures are often used. The polymer-metal nanocomposites to detect various gases and toxic gases presents as a novel composite material for development of application in this field.[7] Further, recently interest has been shown towards hydroxyapatite nanostructures due to its environmentally friendly nature. Functionalized hydroxyapatites as potential materials for gas sensing with current research advances deliberation provide a thorough background possibility of

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application of such materials in gas sensing.[8] Heterojunction based gas sensors consisting of inorganic material (p-Co_3O_4) and organic material (carbon nanofibers) present a novel way of detection of ammonia.[9] Another class of materials which is in its nascent stages of development as a sensor material is MXenes. The SnO_2 decorated MXene nanostructures and TiO_2 decorated MXene have emerged as the lead materials for gas sensing application.[10,11]

In order to transfer these laboratory scale results to realize a prototype or product; a sensor has to pass rigorous device level specifications. Such sensors developed from a single material or composite often has cross-sensitivity to a range or other gases/vapors which can co-exist in real life situations. In order to circumvent this, sensor arrays and electronic noses are developed. The wide range of sensor response can then be mapped and individual gases or complex odors can be identified.[12] A research on development of user interface and gas sampling to obtain the different parameters have also been presented.[13] These electronic noses find applications in real life scenarios such as in agricultural produce and food industry. The various odors which emanate in such areas are chosen and suitable sensors developed. Thus, these sensors are put to use in domestic and industrial applications.[14–16]

Modeling a sensor response or material for a particular application is very essential in identifying suitable materials for specific applications. Such modeling is also helpful in understanding the sensing mechanism. Also the theoretical modeling eases the estimation of the performances of the sensors at different dopants, temperatures, ambience, etc. The research on detection of organic vapours (phenol and benzene) and LPG using novel 2D nanostructures (arsenene and phosphorene) provide in-depth ability of these materials in gas and vapour sensing applications.[17,18] These would propel interest in pursuing research in the new class of 2D materials.

Finally, efforts are underway in developing better gas sensing systems to simulate real life ambient. Improved lab scale gas sensing setups with better flow dynamics will simulate the actual ambient in a better way. Improved electronic circuitry to isolate the noise from the signal will help in designing better electronics for effective sensor readout.[19]

For the development of sensors, several components and disciplines have to work in unison. For a developing country like India, self-reliance can be achieved when different laboratories, institutes and research organizations come together. To see commercialization, proper linkage with industries should be established. Micro-electro-mechanical systems based miniaturized sensors are playing a vital role in all the fields starting from automotive to biological applications due to their accurate swift measurement and sensing performance. Scientists and industrialists are now working together for the development of sensors for particular needs. Also the field of computing and electronics paved the way for automation and Internet of Things (IoT) based systems. The future depends on the sensors in almost all areas for automation, IoT based systems and devices.[20] This special issue on the "Recent Trends in Gas Sensing Research in India" provides a glimpse of different ongoing research in the field of gas sensor development. We envisage, in the future, India will lead the globe in the field of Gas Sensor Development.

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