Necessity of Gas Sensing In Daily Life: Graphene/Metal Oxide Nanocomposites for Carbon Monoxide Sensing

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With the expansion of scientific and technological boundaries, we are living in an environment where plenty of hazardous and flammable gases are being supplied through various pipelines / passages as part of various industrial and household applications. Our environment is changing daily and it needs to be monitored closely. Here are a few case studies which the need to monitor the environment. The Bhopal gas tragedy (1984) which occurred at Union Carbide India Limited (UCIL), in Bhopal, Madhya Pradesh, was an eye-opening incident. The methyl isocyanate (MIC) leakage had caused 3,787 deaths and 5, 58,125 injuries. The MIC is a highly toxic gas which is extremely hazardous to human health. This incident continues to haunt the coming generations as many are suffering from the side effects and are born with disabilities. The Chasnala mining disaster (1975, Dhanbad) was the worst of its kinds in the history of Indian mining. The explosion happened due to a spark hit on a methane gas pocket. This incident had taken the lives of 372 miners, who were buried alive inside the cave. In May 2017, the poisonous gas named Chloro (methyl) diphenylsilane leaked in a container depot at Tughlaqabad and 475 students along with nine teachers had to be hospitalized from two nearby schools. The inhalation of Chloro (methyl) diphenylsilane causes eye and throat irritation and acute dizziness. C gas leakage in a water treatment plant in Karnataka (May 2018) led to the hospitalization of 20 workers. A similar incident occurred in Vadodara district, Gujarat, where chlorine leakage from a cylinder affected 25 employees with severe eyes and throat irritation. In March 2017, in a horrific accident,

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ammonia leaked from a chamber of a cold storage facility in Shivrajpur, Kanpur. The roof of the building collapsed trapping around 24 people. Also ammonia is a highly corrosive and hazardous gas. The carbon monoxide (CO) leakage in Bhilai steel plant (Raipur, Chhattisgarh) was another fatal accident. Around 6 people were dead ng 2 officials and nearly 40 people got were affected. In a similar way, CO gas leaked in a Brazilian -owned steel plant in Andhra Pradesh on July 12, 2018, while employees were busy with maintenance work. The incident led to 6 deaths due to CO inhalation. CO leakage cannot be detected as it is a colour -less and odourless gas. Inhalation of CO causes dizziness. Excess inhalation leads to brain damage and death. Apart from this, presence of several other toxic gases in our surroundings cannot be detected by human sensory organs Moreover, there must be so many more accidents that go and are buried in history.

In order to detect them, there should be something which can smell/detect these gases easily and alert people. If the hazardous, toxic or flammable gases are detected early, it can save lives and government's money. The question is how do we detect the gases in advance? Indeed, it is possible with the support of "electronic nose" which is technically called a "chemiresistive gas sensor".

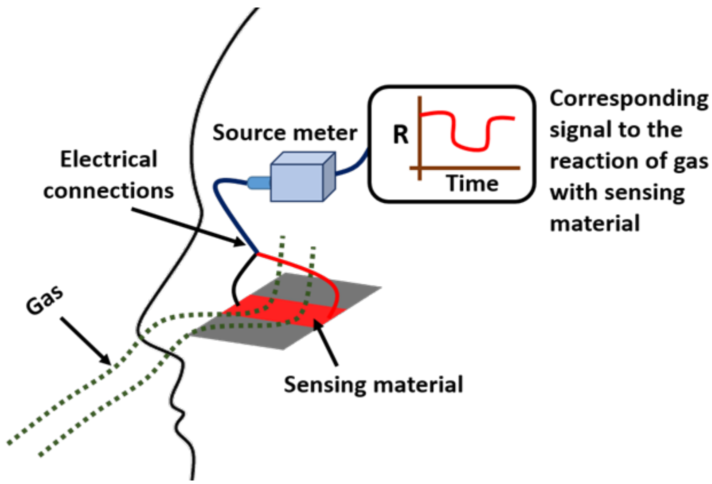

Fig.1. A visualization to explain how a chemiresistive gas sensor works

Electronic nose/Chemiresistive gas sensor device contains a material which shows differences in their electrical conductivity upon change in surrounding ambient. When the surrounding react with this material, it alters the electronic states of the material through which the conductivity change occurs. While the electrical conductivity of this material is being measured on continuous basis. This change in conductivity will be used as the signal to alarm by connecting to any siren. The reaction capability of material depends on the material's nature and corresponding gaseous environment it is reacting with. Generally, metal oxides are well explored materials for gas sensing. However, the poor conductivity properties of materials can be overcome with the addition of some other highly conductive material. Our group is working on the development of sensing materials which provides better response against various hazardous, flammable and organic vapours.

Our main theme of production is making composites of various metal oxide nanostructures with graphene. Firstly, what is graphene? In simple terms, the graphene is a layered material with single atomic thickness derived from graphite. Possessing higher electrical conductivity with larger available surface area is one of its unique features. This supports the metal oxide and helps in providing better sensing response. Recently, we have synthesized a composite material with titanium oxide (TiO2) and graphene for CO sensing. We have followed a waste management approach to synthesize graphene used in this process by extracting graphite electrodes from waste Zn-C batteries.

The graphene synthesis requires graphite as a preform material. Dry cell batteries are primary kind of non-rechargeable which are being used for various remote controls, electronic devices and household applications. Yearly, million tons of these batteries are being dumped after their usage. The inert graphite rod placed in the center of these dry cells can be used for the synthesis of graphene. It serves three purposes at the same time. One is waste management, second is graphene production and the last one, it reduces resources and efforts utilized in graphene production industries. The quality of graphene produced using comparative with other existing routes. Also, we have filed a patent on this work (Application No: 201821006507 A).

The graphene synthesized from the above mentioned process was used in making composite with TiO2 nanoparticles. The material was tested against the CO of 100 ppm and 200 ppm concentrations in a closed chamber. When the CO comes in contact with TiO2, it donates electrons by adsorbing on the O-lattice site. Due to this increase in electron carrier density, the material shows increase in conductivity. Here, graphene helps in this change in conductivity to measure at room temperature. The composite material had shown significant response to the both concentrations. The work has been published, titled, "In-situ TiO2–rGOnanocomposites for CO gas sensing," in Bulletin of Material Science (Bull. Mater. Sci. (2018) 41:115). In addition, we are also trying to develop various kinds of such materials to test against different gases.

Finally, the gas sensors (electronic noses) made of appropriate materials could be used in high density population areas to prevent accidents occurring due to gas leakages. Once the sensor detects the gas in the environment, corresponding disaster management department can take the necessary actions in a quick manner to save more lives.