Monitoring of Vehicular Emissions: Highly Selective and Sensitive Chemiresistive Gas Sensors

KID: 20220409

Air pollution is one of the most concerning public health topics of the 21st century. According to statistics, more than seven million people die annually due to air pollution, especially in low- and middle-income countries, where people suffer from the highest exposure. Alongside, since the mid-20th century, climate change has also become a hotly debated topic because of the impact of global warming on the Earth's climate, which is caused by increasing levels of greenhouse gases (GHGs). This is actually occurring on Earth due to increased air and environmental pollution, which is mainly caused by vehicle emissions. In fact, various air pollutants such as Inhalable micrometer particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2) and carbon monoxide (CO), and GHGs such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs) and ozone (O3). Therefore, effective methods for monitoring these gases and VOCs are in great demand for atmospheric environmental measurement and control, as well as human well-being and health monitoring.

These gases can therefore be accurately quantified using highly sensitive analytical techniques such as spectrophotometry, gas chromatography (GC) and high-performance liquid chromatography (HPLC). While these techniques are accurate and precise, they are generally expensive, unportable, and power-intensive. Further, such methods frequently require complex and time-consuming pretreatment steps, as well as highly skilled operators. Therefore, to replace these conventional methods, alternative systems for monitoring these gases are needed. In this aspect, electrically-transduced chemiresistive sensing platform are considered due to their simplicity, non- line-of-sight detection, compatibility with wireless transmissions and standard electronic equipment, the possibility of continuous monitoring, and portability.

Here, in our studies, we chose two air pollutants (CO and NO2) as shown in **Fig 1** and two GHGs (CO2 and CH4) because these gases are mainly emitted from various sources including vehicle emissions. To monitor vehicle emissions, we need an increased spatial coverage system because vehicle emissions are a mobile source. Therefore, we have successfully fabricated a four different chemiresistive sensors to detect these air pollutants and GHGs. These four sensors exhibited the following characteristics, such as the largest sensing response to the target gas, high selectivity with respect to interfering gases, adequate detection limits for ambient levels, short response time and recovery time, and good long-term stability. Figure 1 illustrates a summary of the gas sensing performance of the fabricated sensors for monitoring two types of gases.

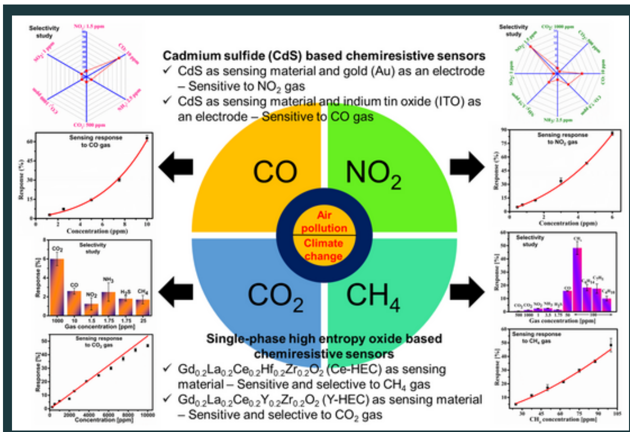

Figure 1. Summary of the gas sensing performance of the fabricated sensors for monitoring two types of gases.

Initially, to detect CO and NO2 gases, we fabricated three chemiresistive sensors with three different electrode materials (silver (Ag), gold (Au) and indium tin oxide (ITO)) using cadmium sulfide (CdS) as the sensing material. Interestingly, the CdS-based sensor with Ag electrode showed a response to CO and NO2 gases due to the formation of ohmic contact between CdS and Ag. Therefore, to improve the selectivity of CdS sensor, we transformed the contact from ohmic to Schottky by using electrode materials to Au and ITO. As a result, the CdS-based sensor with Au electrode showed a maximum response to NO2 gas due to the large potential barrier height between CdS and Au and the highly reactive nature of NO2 gas. While the CdS-based sensor with ITO electrode displayed a response only to CO gas only but not NO2, due to low potential barrier height between CdS and ITO and the non-reactive nature of CO gas. On the other hand, we also fabricated two chemiresistive sensors by using two different single-phase high entropy oxides as sensing materials to detect CO2 and CH4 gases.

References:

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[1] Mr Venkata Ramesh Naganaboina
PhD Scholar
[2] Dr Shiv Govind Singh
Professor,
Department of Electrical Engineering