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Fluorinated Carbon Nanohorns – Based Nanocomposite as Sensing Layer for Resistive Nitrogen Dioxide Sensor

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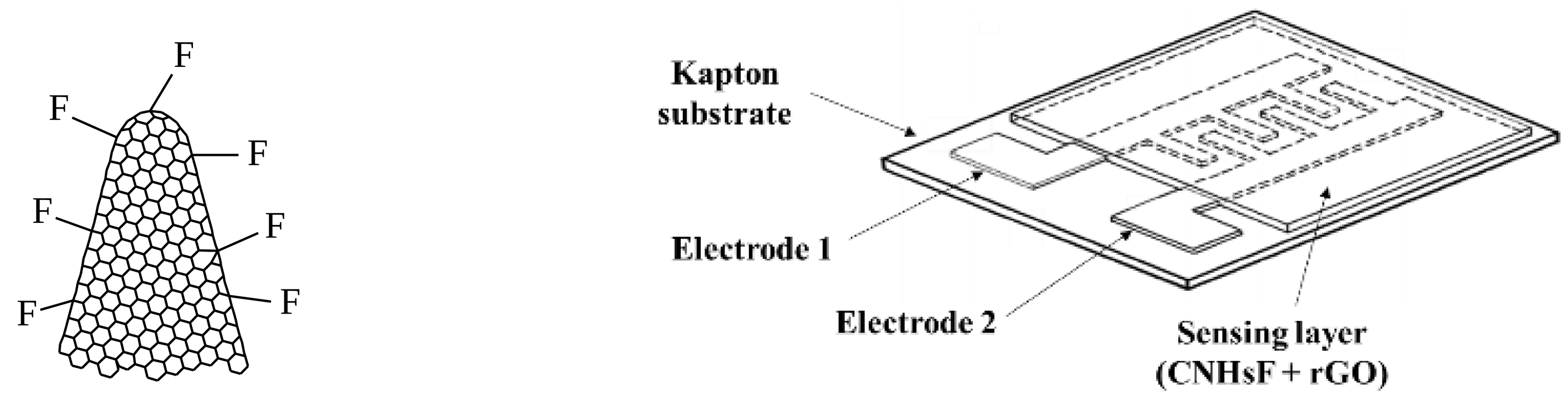
Scope:

Development of new sensitive layer consisting of a nanocomposite mixture containing fluorinated carbon nanohorns, to be embedded in an innovative resistive nitrogen dioxide sensor.
Measuring the nitrogen dioxide (NO_2) content in atmosphere is important for various applications in public health and environmental protection (*i.e.* air quality monitoring, industrial safety, and automotive emissions control, etc.)

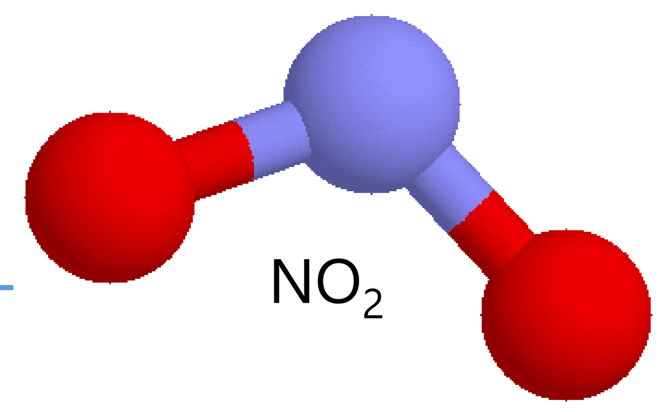
Sensor architecture:

- the experimental setup for developing a resistive nitrogen dioxide sensor, uses a sensing layer based on a *binary matrix nanocomposite* comprising fluorinated carbon nanohorns (CNHs-F) and reduced graphene oxide (rGO);
- the sensing device consists of several components: a metallic interdigitated dual-comb structure fabricated on a Kapton substrate with gold electrodes (Figure 1); electrodes may be linear, or have an interdigitated configuration;
- the NO_2 monitoring capability is investigated by applying a constant current between the two electrodes and measuring the voltage at different values of the NO_2 concentration existing in an atmosphere where the sensing layer is exposed.



a) **b)**

Figure 1. a) Structure of fluorinated carbon nanohorns, and b) Sensing device architecture with interdigitated electrodes



Context:

- NO_2 is a harmful air pollutant; inhalation of nitrogen dioxide may have serious health effects on humans: *i. short-term exposure to elevated NO_2 levels* can cause respiratory problems, including irritation of the respiratory tract, coughing, and difficulty breathing, and can exacerbate pre-existing respiratory conditions such as asthma and bronchitis*; ii. extremely high levels of exposure* (above 150 ppm for 30 min to an hour) can be fatal; *iii. long-term exposure* can add negative effects to chronic respiratory or cardiovascular diseases, and on the nervous system.
- Resistive sensors are known for their relative *low cost and simple design*, and thus may play a critical role in air quality monitoring systems to detect and quantify NO_2 pollution: in industrial settings for the safety of workers, in automotive applications to monitor the emissions etc; however, existing NO_2 resistive sensors may have *limited selectivity* and thus may lead to false readings in certain conditions.

Original approach and advantages of the novel NO_2-sensitive layer for resistive nitrogen dioxide sensor:

- fluorine functionalization of a substrate for NO_2 sensing is a technique used to enhance performances of nitrogen dioxide sensors; thus, fluorine functionalization may *increase the sensitivity* of the substrate to NO2 molecules, *improve the selectivity* of the sensor, *stabilize* the sensor's *performance over time*, *reduce the drift* to ensure consistent and reliable measurements, and *accelerate the response time* of the sensor;
- interaction of NO2 molecules with reduced graphene oxide and fluorinated carbon nanohorns may be interpreted from the perspective of the HSAB theory; both fluorinated carbon nanohorns and reduced graphene oxide are *p-type semiconductors*, they conduct electricity mainly through holes; when the sensitive layer is exposed to polluted atmosphere, the physi-sorbed and chemi-sorbed molecules of NO2 (an oxidizing gas) will act as *electron acceptors*, leading to an increase in the concentration of holes in both nanocarbon materials, thus leading to a decrease in the electrical resistance;
- fluorinated carbon nanohorns and reduced graphene oxide give a high specific surface/volume ratio, as well as a variation in the resistance of the sensitive layer upon contact with NO2 molecules;
- the new synthesized sensing layer provides several significant advantages: detection at room temperature, chemical and thermal stability, and superior mechanical properties.

Acknowledgments

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