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BINARY NANOHYBRID OF NITROGEN-DOPED CARBON NANOHORNS WITH COPPER OXIDE AS FORMALDEHYDE RESISTIVE SENSOR

Bogdan Catalin Serban[1], Octavian Buiu[1], Marius Bumbac[2], Cristina Mihaela Nicolescu[3], Mihai Brezeanu[4]

[1]IMT Bucharest, National Institute for Research and Development in Microtechnologies, 126A Erou Iancu Nicolae, 077190 Voluntari, Romania
[2]Valahia University of Targoviste, Faculty of Sciences and Arts, 13 Sinaia Alley, 130004 Targoviste, Romania, marius.bumbac@valahia.ro
[3]Valahia University of Targoviste, Institute of Multidisciplinary Research for Science and Technology, 13 Sinaia Alley, 130004 Targoviste, Romania
[4]National University of Science and Technology POLITEHNICA Bucharest, Faculty of Electronics, Telecommunications and IT, 1-3 Iuliu Maniu Blvd., district 6, 061071, Bucharest, Romania

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Introduction

Formaldehyde is a volatile organic compound (VOC) that is flammable, colorless, and has a strong odor. It serves as a valuable intermediate in various industries, including chemical and light industries. Common sources of formaldehyde include forest fires, vehicle exhaust, and cigarette smoke. Additionally, materials like pressed wood products, chipboards, and those often used in furniture manufacturing contain urea-formaldehyde resins, which gradually release significant amounts of formaldehyde over time. Exposure to formaldehyde poses several health risks, including watery eyes, irritation of the eyes and throat, nausea, and respiratory difficulties. It has been recognized as a significant contributor to sick-building syndrome (SBS) and is classified as a human carcinogen by the International Agency for Research on Cancer (IARC). Given the widespread presence of formaldehyde and its high toxicity, there has been growing interest in developing sensors to detect this compound in recent decades.

The sensor substrate is made of Si/SiO_2 and has a size of 5 mm, the electrodes being made of gold. The width of the electrodes is about 200 microns, with a separation of 6 mm between them. The formaldehyde monitoring capacity is investigated by applying a constant current between the two electrodes and measuring the voltage at different values of the formaldehyde concentration to which the sensitive layer of the binary nanohybrid type carbon nanohorns doped with nitrogen – copper oxide is exposed.

Materials and methods

The raw materials required for the synthesis of the CuO / N-CNHs sensitive film are: $Cu(CH_3COO)_2 \cdot 2H_2O$, a mixture of isopropanol (solvent) and diethanolamine (stabilizer), and carbon nanohorns doped with nitrogen N-CNHs.

The molar ratio $Cu(CH_3COO)_2 \cdot 2H_2O$: isopropanol is 1:3, while the mass ratio acetate/stabilizer is 1/1.

The raw materials are mixed by magnetic stirring, which is done sequentially, in two stages: (I) at a temperature of 60 ºC, for 1 hour; (II) -at a temperature of 70 ºC, for 2 hours. Nitrogen-doped carbon nanohorns N-CNHs are added in the second stage of magnetic stirring. The obtained dispersion is subjected to magnetic stirring for three hours, at room temperature and deposited by drop casting method on a Si/SiO_2 substrate with linear electrodes or interdigitated electrodes (Figure 1).

The densification of the sensitive layer is carried out sequentially, in two stages, by thermal treatment, as follows: (I) In the nitrogen atmosphere, for 10 minutes, at a temperature of 300 ºC, and (II) In the nitrogen atmosphere, for 1 h, at a temperature of 400 ºC.

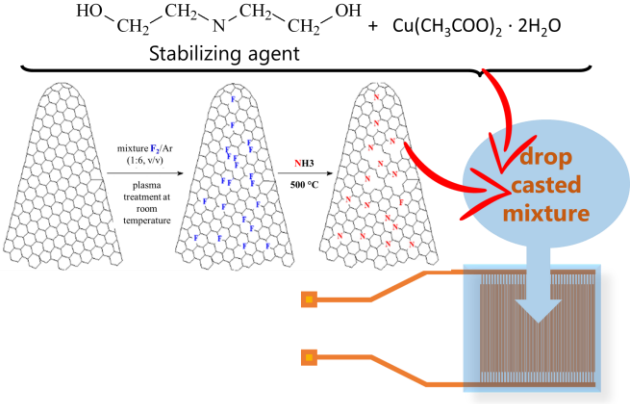

Figure 1. Formaldehyde resistive sensing device

Results and conclusions

The sensitive film described in this invention, which is used to obtain resistive formaldehyde sensors, is a binary nanohybrid of the N-CNHs / CuO type.

The mass percentage of nanocarbon material in the sensitive layer varies between 70 and 90%. From the point of view of the detection principle, the resistance of the sensitive layer increases with the formaldehyde concentration level.

The decrease in conductivity is explained by the fact that formaldehyde donates electrons to the sensitive layer, reducing the concentration of holes.