Ternary nanohybrid for resistive relative humidity monitoring

Agenția de Stat pentru Proprietatea Intelectuală a Republicii Moldova
Expoziția Internațională Specializată INFOINVENT
22-24 noiembrie 2023
Ediția a XVIII-a

Romanian Patent Application A100355, RO, OSIM, 23.06.2022

Assignees: National Institute for Research and Development in Microtechnologies - IMT Bucharest
Valahia University of Targoviste
Inventors: Bogdan-Cătălin Șerban, Octavian Buiu, Marius Bumbac, Cristina Mihaela Nicolescu

Field of invention

In the last decades, relative humidity (RH) sensors have gained increasing interest due to their relevance in a wide variety of industrial, commercial, and residential applications such as building ventilation control, food/beverage processing, the medical field , pharmaceutical processing (quality control of drugs), agriculture (soil moisture control during irrigation), nuclear power reactors, meteorology, mining industry, robotics, textiles, paper industry, etc.

Original approach

- This patent application refers to the development of resistive relative humidity (RH) sensor, employing a sensing layer based on a ternary nanocomposite comprising oxidized carbon nanohorns (CNHox) / KCl / polyvinylpyrrolidone (PVP) in the following ratios: CNHox / KCl / PVP=7/1/2, (abbreviated as K1) CNHox / KCl / PVP=6.5/1.5/2, (abbreviated as K2), CNHox / KCl / PVP=6/2/2 (abbreviated as K3), mass ratios (w/w/w/w).
- RH sensor includes a silicon (470 microns) substrate coated with SiO_2 (1 micron), interdigitated electrodes and a sensing layer obtained via drop casting method. The electrodes were connected by the successive deposition of Cr (10 nm) and Au (100 nm). The width of the electrodes is about 200 microns, with a separation of 6 mm between them. They can be linear (Figure 1) or have an interdigitated configuration.
- The RH monitoring capability of the sensing layers was investigated by applying a current between the two electrodes and measuring the voltage at different values of the oxygen concentration at which the sensing layer was exposed.
- The resistance of the sensitive layer varies with RH level (Fig. 2, 3, 4). The performance of the manufactured sensor was compared with that of a commercially available Honeywell RH sensor, which was placed in the same humid nitrogen.

Sensor manufacturing

The recipe for the preparation of the hybrid nanocomposite solid-state sensing films based on CNHox, KCl and PVP with different weight ratios was performed by applying a procedure in following steps.

1. PVP solution was prepared, by dissolving 2 mg hydrophilic polymer in 10 mL isopropyl alcohol under stirring in the ultrasonic bath for 10 minutes.
2. an amount of holey carbon nanohorns (7 mg) was dispersed in the obtained PVP solution, and subjected to stirring in the ultrasonic bath for six hours, at room temperature.
3. KCl powder was added in the resulted suspension according to the desired mass ratios (1 mg), and a continuous stirring was performed in the ultrasound bath for another time period of six hours, also at room temperature.
4. In the end, the sensing layer was obtained by the drop-casting method, depositing the annealed mixture on the support structure, while its electrical contact areas were masked before addition of the sensing dispersion.
5. Sample was dried at 373 K for 60 minutes prior to electrical measurements

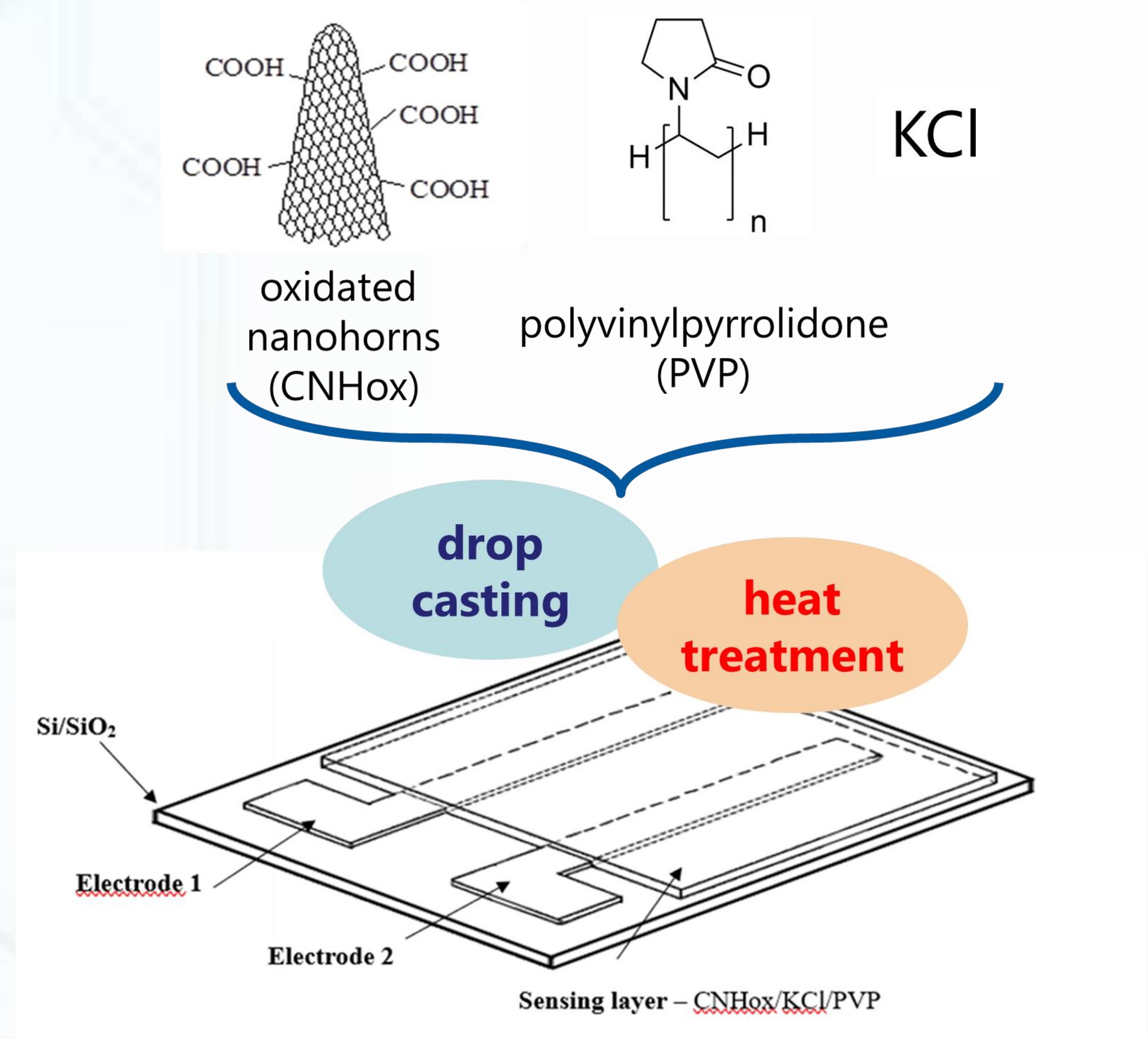


Figure 1 - **The structure of sensor with linear electrodes**

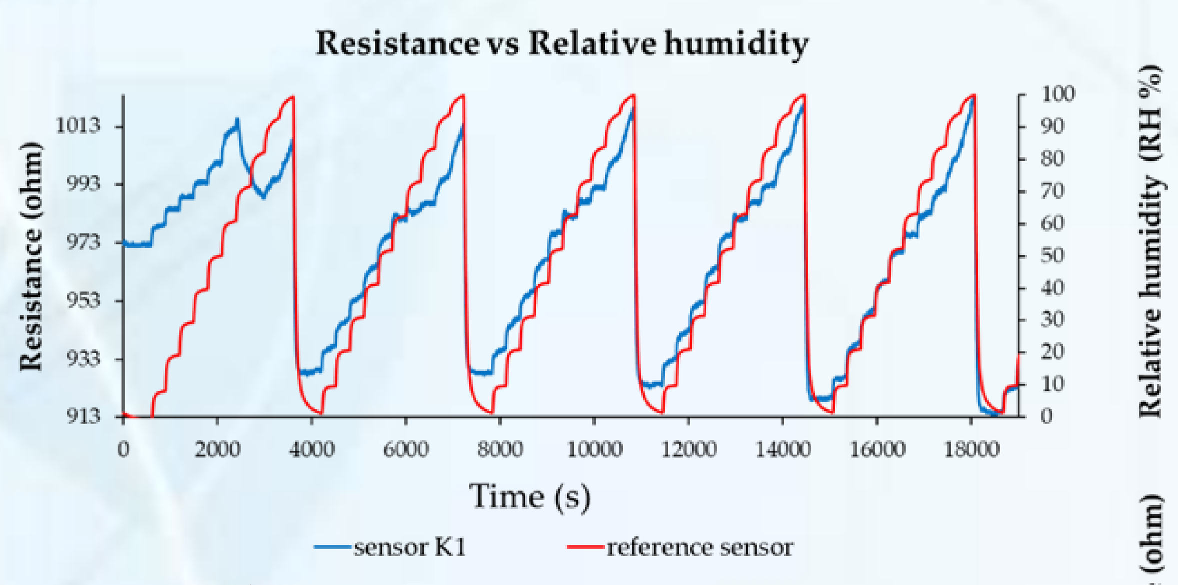
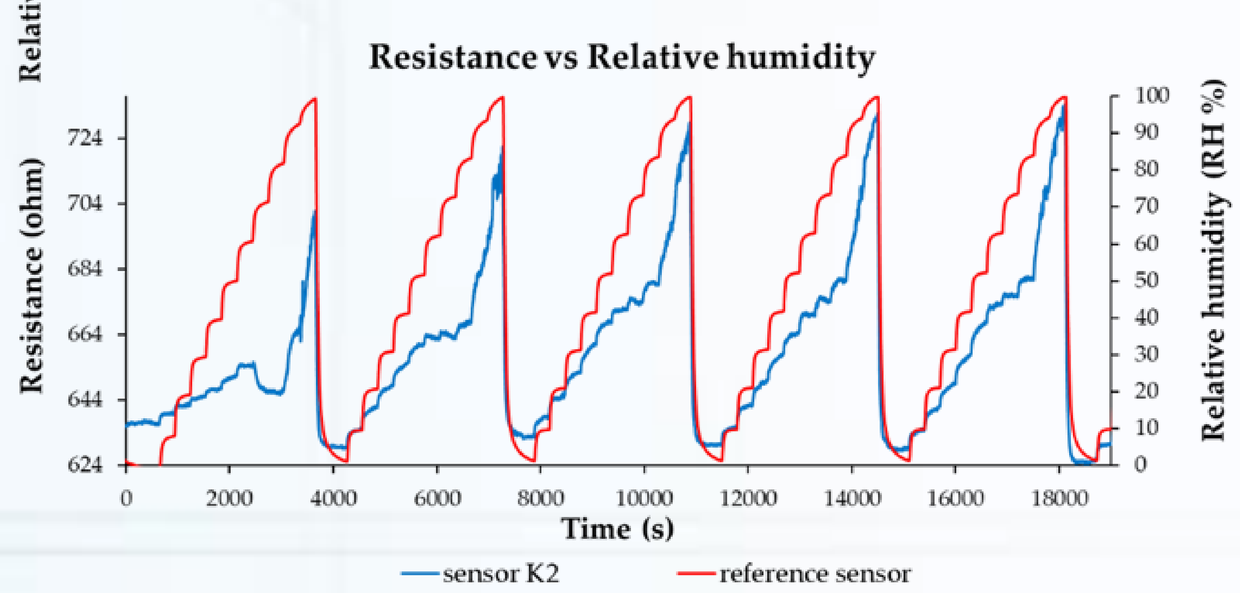


Figure 2 – **Sensor K1 response *vs.* reference sensor**

Figure 3 – **Sensor K2 response *vs.* reference sensor**



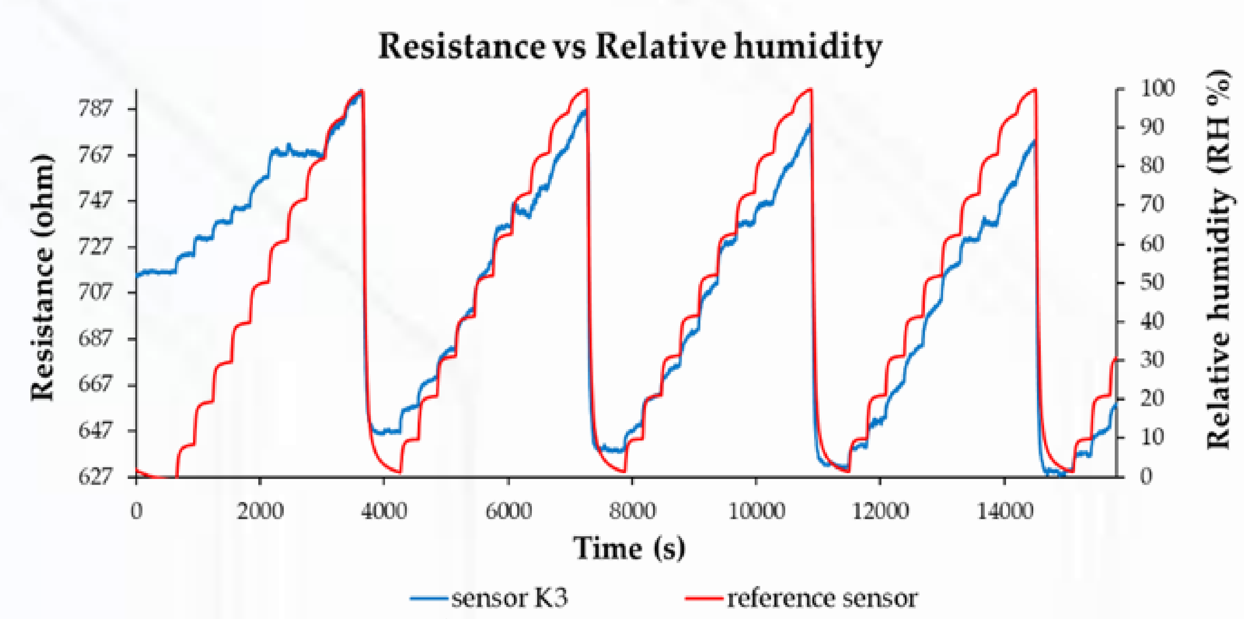


Figure 4 – **Sensor K3 response *vs.* reference sensor**

Advantages of the proposed sensing layer

The new synthesized sensing layer used in the manufacturing of resistive oxygen sensor have several significant advantages:

- The interdigitated sensing structure presented in this work exhibits a linear response and good RH sensitivity when varying RH from 0% up to 90% in humid N_2 environment. The sensor response time and stability are comparable to that exhibited by a commercially available Honeywell RH sensor.
- The presence of CNHs-ox ensures a high specific surface area / volume ratio as well as a substantial affinity for water molecules, detection at room temperature, rapid response of the sensor to variations of RH level.

Acknowledgments

IMT authors would like to acknowledge the financial support provided by the Romanian Ministry of Education and Research via the "MICRO-NANO-SIS PLUS" Nucleu program, grant number PN 19 16, and the project 673 PED/2022 (CARESS), financed by The Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI).