Compact electronic nose to identify human lung diseases

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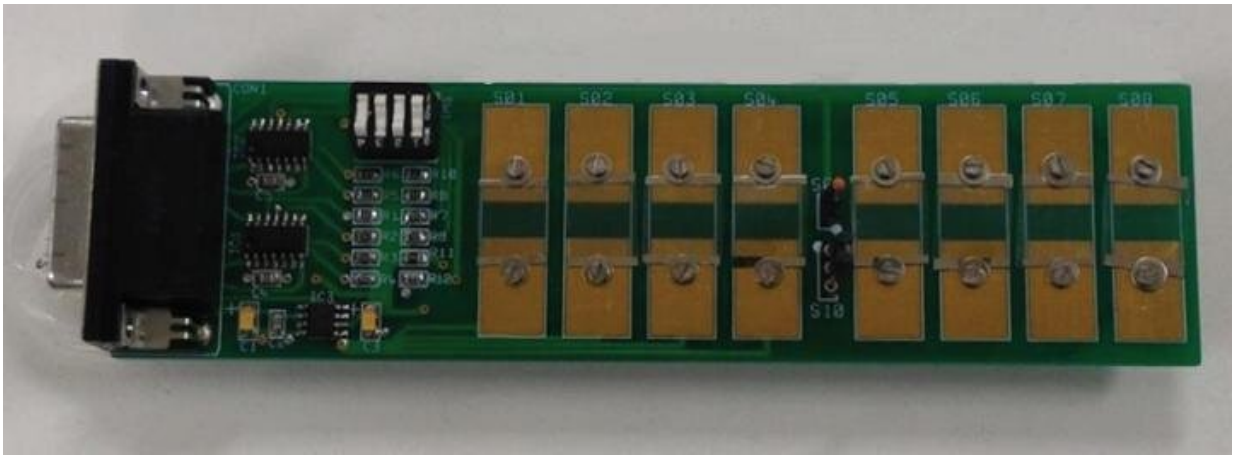

The electronic nose matrix board with eight sensors. Credit: Sonia Freddi et al / Advanced Healthcare Materials

Researchers from Russia and Italy have proposed a compact sensor system that can implement the functionality of an electronic nose device and have developed a reproducible technology for its manufacture. The device is a flexible electronics platform that can analyze exhaled air as well as identify pathologies of the respiratory tract and organs.

During the experiments, the device demonstrated high accuracy in determining patients with chronic obstructive pulmonary disease (COPD), an inflammatory disease of the respiratory tract, which

increases the risk of complications when during COVID-19 infection.

Chronic obstructive pulmonary disease (COPD) develops in the bronchial mucosa in response to pathogenic external factors and leads to a negative change in the functions of the respiratory tract. A person with COPD cannot receive the necessary oxygen because inhaled air flow is limited. COPD is commonly caused by gases and volatile particles such as dust, tobacco, cadmium and silicon particles, and others. The methods for detecting this disease are complex and time consuming, which is inextricably linked to a threat to the patient's health.

Conventional methods for breath analysis, such as gas chromatography and mass spectroscopy, are expensive and time-consuming, so new approaches are required that are notable for their low cost and speed of testing. COPD is an urgent problem, as the disease may lead to the limitation of physical performance and disability of patients. It is important to note that people with COPD are most at risk for complications if they become infected with COVID-19.

"Malfunctioning of human organs causes a change in a number of processes in the metabolism, which affects the composition of exhaled air. Its analysis can be used to identify diseases of the respiratory system as well as other internal organs, such as the stomach," explains Dr. Ivan Bobrinetskiy, project manager for the Russian Science Foundation grant, leading research associate of the National Research University of Electronic Technology. "The proposed concept of the electronic nose allows for operational monitoring and preliminary detection of diseases in just a few minutes. At the same time, the sensors are reusable, and the basic data and the identification of possible pathologies of organs are transferred from the device to digital mode using methods of statistical data analysis, including the capabilities of artificial intelligence. "

The system is based on modified carbon nanotubes (CNTs), which

allows the electronic nose to combine multiple properties. For example, flexible conductive films can be made from carbon nanotubes. Such films are needed in order to provide the system with an electronic structure layer responsible for the operation of the device. "CNTs were synthesized by aerosol chemical vapor deposition and deposited in the form of thin transparent and conductive films. This technology is highly reproducible, easily scalable and allows applying films of nanotubes to any surface," said Albert Nasibulin, professor at the Skolkovo Institute of Science and Technology and the Russian Academy of Sciences.

The study of the effectiveness of the new system involved 12 patients with COPD and nine healthy individuals in accordance with the rules of clinical trials. Breath sampling was carried out in disposable polytetrafluoroethylene (PTFE) plastic bags made of a very inert material and containing a sensor matrix. The subjects inhaled and inflated the bag as much as possible through a plastic straw. When the straw was removed, the packages were sealed. The sensor matrix inside the bag was in contact with exhaled air for about three minutes, so that all sensors could fully work and interact with the gas molecules that characterize the pathology. Then the system was cleaned with dry air for the next study. Samples were collected from each participant with an interval of one hour.

Since the system detected all people with COPD, it can be argued that the device is effective. In the exhaled air, an increased concentration of nitrogen dioxide was detected. It should be noted that the gas content is less than one molecule per million molecules of the exhaled air, which indicates high sensitivity of the developed sensors.

The researchers have also successfully tested their system on gases that can characterize other diseases. The volatiles selected for this study (ammonia, nitrogen dioxide, sodium hypochlorite, water, benzene, hydrogen sulfide, acetone, ethanol and 2-propanol) are associated with

specific diseases and can potentially be considered as their biomarkers. Thus, the content of 2-propanol, benzene, ethanol and acetone in exhaled air is increased in people with lung cancer, while acetone is found in patients with diabetes. A high concentration of ammonia in human breath is associated with liver or kidney diseases, and hydrogen sulfide has been proposed as a biomarker of asthma. The concentration of sodium hypochlorite is an increased content in exhaled air in children with bronchial asthma and cystic fibrosis.

More information: Sonia Freddi et al, Development of a Sensing Array for Human Breath Analysis Based on SWCNT Layers Functionalized with Semiconductor Organic Molecules, *Advanced Healthcare Materials* (2020). DOI: 10.1002/adhm.202000377

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