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Microstructure Technology

An electronic nose for many applications

Sensory organs are sophisticated masterpieces of nature. That is why humans have often tried to copy them. Be it cameras or microphones - there are technical objects that have always been based on natural models such as the eye or the ear. For a long time, however, no artificial sense of smell has featured in the technical repertoire. Now researchers at the Karlsruhe Institute of Technology (KIT) have developed an electronic nose. It can "smell" gas mixtures and can be used, amongst other things, to diagnose diseases or for food control.

The sense of smell, also called olfactory sense, is a chemical sense and it functions in a very complex way. It is located in the nose and consists of several million olfactory cells that are found in around 400 different types of receptors. In humans, the sense of smell is considerably less developed than in other mammals and cannot match, for example, the performance of a dog's nose. Nevertheless, a well-functioning sense of smell can save lives, for example in the event of fire and smoke, or protect us against spoiled food.

To perceive an odour, the corresponding gas mixture reaches the olfactory mucosa on the roof of the nasal cavity along with the inhaled air where the assigned receptor type recognises it based on certain chemical structural features. The different degrees of receptor activation are sent to the brain as a signal pattern characteristic of the respective odour. In the brain, scents are classified by comparing them to previously learned reference odours.

Inexpensive eNose suitable for daily use is based on a natural model

Dr. Martin Sommer is a researcher at KIT and has developed the electronic nose together with his colleagues.
© KIT

Many years ago, researchers at the Karlsruhe Institute of Technology (KIT) got the idea of creating an electronic nose based on their ambition to technically implement the ability of the biological nose to detect and analyse gas mixtures. "Humans have sensors for all kinds of things and they have already served as models for many technical developments," explains Dr. Martin Sommer, who heads the work on the electronic nose in a project called "smelldect" at the KIT's Institute of Microstructure Technology (IMT). "The sense of smell has long been missing in the technical portfolio. And since our work has always been focused on chemical analysis, we started to develop an electronic counterpart. The analysis of odours is actually just a continuation of gas analysis."

The researchers from Karlsruhe focused the eNose development work as much as possible on the biological model: "We did not require our odour sensor to be able to determine gas concentrations or carry out a complete gas analysis. If you enter a room with rotten eggs, your nose will never carry out an accurate substance analysis or determine the concentration of the substance. It just perceives the stench. And that is what the researchers wanted eNose to do. Highly precise, and hence expensive gas analyses are completely unnecessary for quite a lot of applications. This opens up the possibility of developing an end-user device that is suitable for daily use and in which the actual chip only costs a few euros."

After a few years of research, the researchers had developed an electronic nose only a few centimetres in size. The eNose contains the entire operating electronics, including the technology for data analysis. The electronic nose consists of a sensor chip with many individual sensors on which tin dioxide nanowires are attached. "Our odour sensor only has 16 subsensors –

not 400 like the biological model – which are all slightly different so that signal patterns can be formed," says the scientist. "Due to the small dimensions of the subsensors, we would be able to expand the nose as required. But this is not necessary at the moment as 16 subsensors are enough to be able to distinguish a broad range of different odours."

Many ideas for possible applications

eNose consists of a chip with 16 individual sensors with tin dioxide nanowires.
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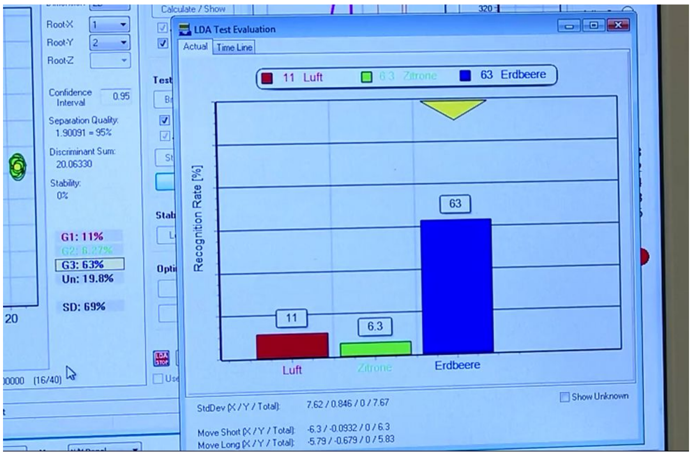

To investigate the freshness of food, the reference odour must first be determined and of course differ from others.
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The electronic nose needs to be trained to detect odours. "It is trained by exposing it to a reference odour for a few seconds so that it can take a few 'sniffs'," says Sommer. "The result is a signal pattern of the 16 sensor types, which looks different for every odour. This pattern is then titled and saved, indicating that the odours have been learnt so that the electronic nose can recognise them within seconds if necessary." The chip calculates the specific signal patterns based on the changes in resistance of the individual sensors, which in turn depend on the molecule mixture in the ambient air.

There are many possible areas of application for the electronic nose. One very important area where the eNose is already working quite well, is the final inspection of products. Sommer explains: "A product that has just been manufactured needs to smell the same today as it did yesterday. All you have to do is to programme the reference odour as effectively as possible. Any differences from the reference odour will then indicate potential discrepancies during production. For example, you can evaluate the freshness of milk using three or four standard odours of milk of different ages. This works equally well for fruit such as apples."

The eNose can also be used for safety and health applications. Sommer says that the researchers have quite a few ideas for this. For example, electronic noses could be used to detect explosives or drugs for airport security or smart fire monitor modules could be used to detect fire for catastrophe prevention.

Medical diagnostics using breath analysis

Using the eNose to diagnose a broad range of diseases is also conceivable. It has long been known that some diseases affect not only internal organs or the metabolism, but also change the composition of exhaled air. Diabetes patients, for example, exhale relatively high amounts of volatile organic substances such as acetone. Equipped with an easy-to-use odour sensor, the eNose could be used to determine blood sugar levels and thus monitor the diabetes settings. "Breath analysis of this kind is actually thousands of years old," reports Sommer. "Diabetes is associated with a fruity-sweet smell of the breath; an ammonia odour indicates kidney problems and liver problems lead to breath that smells of fish. These concentrations would be high enough to be detected with the eNose. But we will not be able to sniff out cancer like some dogs' noses are said to do. The particle density of marker molecules is too low for this. However, the eNose will be suitable for detecting alcohol concentrations. It is conceivable to have a car that would only start when the alcohol level does not exceed a certain value."

Licensee commercialises the eNose

SMELLDECT GmbH produces and sells the eNose - a small device consisting of a chip, electronics and ventilation. The photo shows a fire monitor module that can be attached to computer cabinets.
© SMELLDECT

A start has already been made on the concrete application of the artificial nose. It is marketed by KIT’s partner, a company called SMELLDECT GmbH in Deckenpfronn. "SMELLDECT is a licensee that was specifically founded to produce and sell the sensor," reports Sommer. "It is still a small company, but it is already very active. It has already initiated application studies with gas suppliers and dairy companies. We are not yet talking large-scale production, but we are well on the way."

In the next few weeks and months, the researchers will be busy dealing with reality and teaching the eNose subtleties. "For example, there are different nuances to the odour ‘lawn,’" explains the expert. "We humans also have other senses that enable us to distinguish between wet, freshly mowed or dry lawns. Training the eNose is a very elaborate process – it does not yet have the necessary intelligence to train itself."

In future, the experts are also planning to integrate an eNose into smartphones: "Smartphones are already sensor carriers with many functions," says Sommer. "You could easily add a small, inexpensive sensor and the cell phone could use odours to assess a whole range of situations. Technically, this wouldn't be a problem. It is just a question of how socially viable this would be as it would lead to a completely different dimension in data protection."

Article

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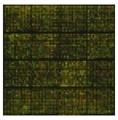

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