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Electronic Micronoses to Enhance Safety at the Workplace

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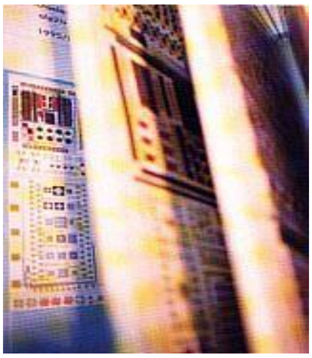
Miniaturized Noses modeled on the human olfactory organ can help to warn against toxic and harmful substances in the air, control bioengineering processes and monitor odor nuisances.

Fireworks of the most diverse odors are set off in our palate whenever we bite into a juicy apple, taste a fine wine, or let a creamy and sweet confection melt in our mouth. The nose registers this and tells the brain what delicious tidbit we are in the process of indulging in. Our olfactory organ recognizes hundreds of chemical substances at such a moment and helps us to distinguish between a Boskop and a Cox's Orange, a Moselle and a French Chablis, or one brand of chocolate and another.

In order to develop the micronose the researchers had to combine knowledge of chemistry with semi-conductor technology.
(Photo: Friedrun Reinhold)

The human olfactory organ can perceive an estimated 10,000 different odors. It is supported by about 1000 different kinds of olfactory receptors, which occur in multiples and which form millions of olfactory cells in the mucous membranes of the nose.



At the ETH Zurich there is a special library in which the design of the microsensors is documented.
(Photo: Friedrun Reinhold)

It's no wonder that scientists and engineers are striving to artificially imitate such a wonderful organ. There would be very practical applications of this: a system for measuring od ors could monitor the quality of air in closed rooms, for example, or provide a warning system against harmful or toxic substances, or track down the source of unpleasant odors. In a sense it could even be better than the human nose, since the human nose has two disadvantages: Firstly, it doesn't perceive some, even highly toxic substances, such as high concentrations of carbon dioxide or carbon monoxide, which is particularly poisonous. Secondly, our olfactory organ doesn't calculate amounts of odor: we merely notice that one smell is stronger than another or is unpleasant.

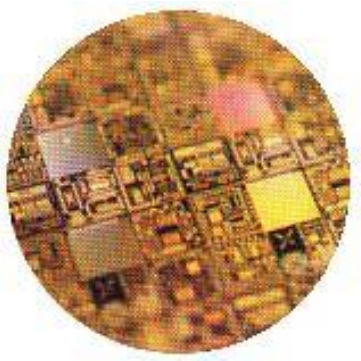
Furthermore, perception is subjective and depends on an individual situation: No one can say that so and so many grams of a certain substance are present per cubic meter air. For these reasons Prof. Dr. Wolfgang Göpel and his co-workers at the Institute for Physical and Theoretical Physics of the University of Tübingen began working to develop artificial noses. The result was the "modular sensor system for smells, gases, and aromas" – in short MOSES. MOSES is a universal apparatus – a kind of "super nose" that can register all kinds of chemical substances in the air. However, it is the size of a small tower which, including the processor, just about covers a desk. This was when Göpel, the smell sensory expert, benefited from the acquaintance of Professor Dr. Henry Baltes, a microsensor expert.

In the past 10 years Baltes and his co-workers at the Institute for Quantum Electronics at the National Technical College in Zurich have developed numerous sensory chips for various purposes, for example, for air circulation, temperature, air pressure, magnetic fields, infrared and ultraviolet radiation, viscosity, ultrasound, and level readings. We are talking about silicon chips in which tiny sensory elements with electronic circuits have been integrated. It is possible to cost effectively mass produce these chips essentially at already existing manufacturers.

Henry Baltes, Massimo Rudan und Wolfgang Göpel (from left) (Photo: Friedrun Reinhold)

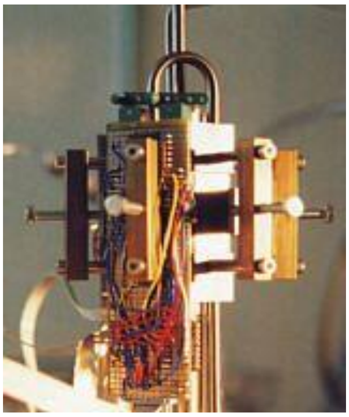
Baltes and Göpel met in Tübingen and Zurich to discuss these issues and then decided to pool their experience and to work together in the area of chemical sensors, first of all to develop prototypes of microstructured systems which could be cheaply produced. The micronose was to be a product of this – a unit the size of a pocket calculator suitable for this specific purpose and easy to handle and transport. However, another specialist was needed who could transfer the complicated mathematical operations needed to evaluate the olfactory signals on to an integrated circuit. And so Baltes and Göpel persuaded the computer design expert Prof. Dr. Massimo Rudan of the University of Bologna to join them. This established the basis for the project “Electronic Micronoses for Volatile Organic Bonds" which received the Körber European Science Prize this year and the prize money of 700,000 DM.

This is how the new micronose works: the so-called transducers – small sensors on the chip – are coated with certain polymers (synthetic compounds) on to which the odor molecules can bond and send specific electric signals to the computer. There are three different types of transducers: one is an oscillating tongue, whose resonance frequency changes when chemical molecules are deposited. The second type measures temperature change, since heat is released when an odor molecule is deposited. The third type has the capacity to conduct alternating current as soon as the odor molecules come into contact. There are nine kinds of polymers which each bind different groups of odor molecules, although they do not detect any one odor highly specifically. Each of the three types of transducers are coated with one of the nine polymers so that there is a total of three times nine, i.e., 27, sensors on a chip.



A chip is fitted with several plastic-coated sensors. (Photo: Friedrun Reinhold)

The 27 sensors send signals with a specific pattern when a specific odor bonds to it. This signal pattern is evaluated with complicated computer algorithms and in this way the odor molecules are identified.



Using specifically channelled odours the researchers can train their micronose chips for particular olfactorial tasks (Photo: Friedrun Reinhold)

The strength of the signal depends on the amount of odor molecules so that the concentration of the substance in the air can be objectively determined. There certainly isn’t a lack of conceivable applications for such a micronose. “We’re presently thinking of two applications," explains Prof. Göpel. “The first is in the area of personal safety and health: For example, hydrocarbons, which can present a risk for employees in certain kinds of plants, perchloroethylene in refineries or toxic or bothersome fumes from brand new textiles or automobiles. The second area involves monitoring and directing the fermentation of beer or aging of yoghurt or cheese according to the odors which develop."

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