They are like the minds of gas detectors: electrochemical sensors, which identify hazardous substances and measure their concentration in order to then raise the alarm and **PROTECT HUMAN LIFE**. They can be produced in particularly small dimensions – mostly by hand.

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They look like confetti in a black-and-white film, yet they could save lives: the electrodes for gas sensors are cut from a paper-thin plastic foil using a special hole punch. The foil is made from the fluorocarbon PTFE (polytetrafluoroethylene) and plays a key role – its microporous structure repels moisture but allows gas and vapors through.

“The electrode is the core element of our electrochemical sensors,” says Axel Silz, who oversees production of several hundred thousand sensors of various shapes and sizes (for a wide range of gases) in Lübeck every year. A few dozen employees are involved in the process: “It takes about a year of training to learn how to assemble all 140 different types – virtually blindfolded,” according to Silz’s observations. A retail salesman by trade, Silz is also an example of how the company spots and nurtures talented people and appoints them to the right positions. Among other things, this can be seen in the fact that the staff fluctuation rate in this division is practically zero. Many years of experience is needed in the production of these sensors, the smallest and most modern of which (type: XXS) could be hidden behind a headache tablet. It is made up of a number of individual mechanical parts and houses an electrochemical laboratory able to robustly withstand environmental influences. The company itself has had experience in
the production of electrochemical gas sensors since the 1970s and holds a number of related patents.

The sleuths, which are as sensitive as they are reliable, are used in the area of mobile and fixed gas detection technology, which in turn protects people from the effects of carbon monoxide, nitrous oxide, and other hazardous substances – including explosive gases. With a catalytic process the electrochemical sensors use the reactivity of these gases. They are designed in a similar way to a battery or a capacitor: a nonwoven fabric impregnated with a conducting liquid and a tiny amount of sulfuric acid separates the two electrodes from each other. Certain gases cause a chemical reaction as a result of the specific structure and chemistry of electrodes and electrolyte, generating a current between both electrodes. An electronic circuit fitted downstream within the gas detector permanently measures the current and analyzes changes – until it gives an acoustic and visual warning.

What is already fascinating in the laboratory must function just as reliably during oil exploration activities in the permafrost of Alaska as in gas liquefaction plants in the searing midday heat of the Gulf region, on drilling rigs with all their vibrations, and in space – because sensors designed to detect hydrazine are also built in Lübeck. This highly reactive liquid is used as an efficient rocket fuel but is extremely carcinogenic, which means that reliable gas detectors are indispensable on the ground in the area of space travel – NASA also relies on Dräger sensors here. And the element at their heart starts life as a sheet of off-white PTFE foil no larger than a piece of A5 paper, which is carefully stored in a protective environment to keep the dust away.

Various precious metals in each electrode

In the next step a specially prepared mixture, which is freshly blended on each occasion, is printed onto the foil. It contains various precious metals such as platinum, gold, and ruthenium. “This mixture,” explains Axel Silz as he holds a small laboratory beaker and its blackish-gray contents with a honey-like consistency up to the light, “only retains its properties for a short period of time. After that, the next batch is mixed (according to a special recipe) by chemical
laboratory assistants, ensuring that it corresponds exactly to the gas being detected.” It goes without saying that every production step is documented. The batch of mixture used, for instance, can be traced from the number that is later printed on the sensor.

Using a spatula, the mixture is applied very thinly to the foil, which, once printed, is peppered with a number of dots; several hundred of them fit on the A5-sized surface when electrodes for the smallest (XXS) sensors are produced. The electrodes for sensors used in fixed gas measurement technology are much bigger and there are also designs other than circular, as in the case of double electrodes. The foil is weighed beforehand and weighed again afterwards to check whether each electrode point really has received precisely the desired quantity of the mixture. The printed sheets of foil are then “baked” for several hours and the individual electrodes are cut out of the foil – by hand and with an eye so precise that not even the tiniest irregularities on the surface or minimal discoloration escapes the inspector’s attention. “We immediately put any rejects in the special waste for recycling,” explains Silz. After

How the sensor sleuths

The principle: the air passes through the membrane with its filter function and reaches the measuring electrode. Like the counter electrode, it is embedded in an electrically conducting liquid (“electrolyte”). This allows a current to flow between them, which is analyzed (“display”). Filters and gas-specific coatings ensure that certain gases cause a reaction on the electrodes. This alters the voltage between them. The change in voltage is an indication of the concentration of the gas in question.
all, they contain various precious metals, which is why it is important to reclaim them.

While the electrodes are made in this way, the other elements of the gas sensor are simultaneously prepared. In the case of the XXS version, a plastic casing later surrounds the sensor so that just the uncoated side of the foil is in contact with the environment. In contrast, the coated side is in constant contact with the electrolyte – irrespective of the position within the gas detector. Further foils partially filter the external air. These include selective foils, which, in the event of a mixture of gases, block the gases for which the sensor is not designed, yet could also impair the signal of the gas in question (“cross-sensitivity”).

**Dandruff-like boulders**

The gold contacts for the electrical connection with the gas detector are initially pressed into the resin mold of the sensor. This is then connected to a few micrometers of thin platinum wire, whose shock-resistant spiral design ensures contact with the electrodes. Specially shaped nonwoven fabrics are inserted alongside the electrodes. This assembly is also performed manually under the microscope with the help of two pairs of tweezers – a focused and almost meditative task which affects even the breathing of the employee. “It goes without saying that this work can only be done in a clean room,” says Axel Silz. “Even if just one flake of dandruff falls onto the sensor, the foil bulges in this microscopic world as if it were bearing the weight of a boulder.”

A sealing compound is spread along the edge of the sensor. It remains paste-like and prevents the electrolyte from leaking.
through the edge of the cover, which is pressed into place in the next stage of the process. There is a tiny hole located in it, through which the electrolyte is poured until the now almost finished sensor is around a third full – most raindrops are bigger. As soon as the hole is sealed, general data (type, use) and individual information (such as the batch number) are printed on it. Outwardly the sensor is now finished and fully functional – for between 12 and 60 months depending on the type and what it will be used for.

Hundreds of thousands of sensors per year
It is now time for the targeted aging process (“running-in”). This takes place at a specific temperature and humidity and lasts between 12 hours and four days. Only afterwards it is possible to verify whether the sensors meet the promised specifications. To this end, each of the several hundred thousand sensors produced every year is exposed to the corresponding test gas and its reaction measured and documented over a certain time period. The sensors then leave the production facilities, which are efficiently managed using the kanban system. “We produce components here like in a factory – this isn’t possible without sound judgment, experience, and manual dexterity,” summarizes Silz. Most of the sensors end up being used in the production of the company’s own gas detectors. They are used in various applications. These not only include mobile and fixed gas measurement technology but also Alcotest devices as well as emergency and transport ventilators – for extra safety made in Lübeck layer by layer.

Production with sound judgment, experience, and dexterity

Colorful mix: the XXS sensors designed for different gases signal the detected hazardous substance via their three gold pins on the end device.