< Sensors for detecting combustible gas mixtures, such as those used in the process industry, traditionally operate at high temperatures. In order to tap into new markets such as electric vehicles, hydrogen technology, or safety monitoring in technologically advanced buildings, decentralized, low-power sensors are needed.

Micro-pellistors – new sensors for combustible gases

Is a gas atmosphere explosive or not? This question commonly arises in industrial process metrology, for example to ensure that processing equipment runs safely. Catalytic combustion sensors, known as pellistors, are often used to detect combustible gases and explosive gas mixtures. Fraunhofer IPM has developed innovative micro-pellistors based on new materials which make combustible gas detection especially reliable and both, energy and cost efficient.

What is the distinguishing characteristic of combustible gases? That's right, they burn! But while it may initially seem straightforward, detecting these gases proves more complex in practice. After all, sensor systems have to be able to determine the combustibility of a gas without triggering a fire or an explosion. Pellistors are an example of a safe sensor. They detect combustible gases such as methane, propane, or hydrogen by adsorbing the gas on the surface of a catalyst, where it oxidizes in a contained reaction process. The catalytic oxidation of the gas causes the temperature to rise, which in turn changes the resistance of a platinum-based heater. In a predefined application scenario, the presence of a specific combustible gas and a rough estimate of its concentration can be derived from this measurement signal.

Catalytic sensors – inexpensive and reliable, but not without drawbacks

Catalytic sensors offer three main advantages. They are easy to install, can be calibrated reliably, and operate based on a simple principle. But even cutting-edge pellistors have several drawbacks, including high operating temperatures of more than 400 °C, high power consumption, and a high susceptibility to catalyst poisons. Due to their significant power consumption, pellistors have found only limited use in mobile applications, where battery life is short. Fraunhofer IPM's goal was thus not just to develop a miniature pellistor, but in particular to lower the operating temperature and with it the power consumption.

Since pellistors primarily rely on a catalytic layer for detecting gases, reducing the operating temperature requires the use of highly active catalysts. Methane is one of the most inert combustible gases, meaning that either especially active catalysts or very high operating temperatures (over 450 °C) are needed for its detection. These high operating temperatures cause the difficulties in reliable methane detection.

New materials for new sensors

To lower the operating temperature of pellistors, new catalytic materials have to be found – in particular for methane detection. Only with the introduction of catalytic materials offering improved activity will it be possible to design new, highly energy-efficient pellistors with the same level of stability. However, developing such catalysts is anything but easy, for three reasons. Firstly, the catalysts used in sensors are complex systems consisting of a catalytic material and various additives that are essential for integration into the sensor and for the mechanical stability of the catalytic layer.

A **SIMULTANEOUS THERMOGRAVIMETRY-DIFFERENTIAL THERMAL ANALYSIS SYSTEM** enables the characterization of new catalytic materials. Thermogravimetry is used to measure the change in a material's mass during a known heating or cooling process. At the same time, a differential thermal analysis is performed, which involves recording the quantity of heat emitted or absorbed by a material when it is heated or cooled.

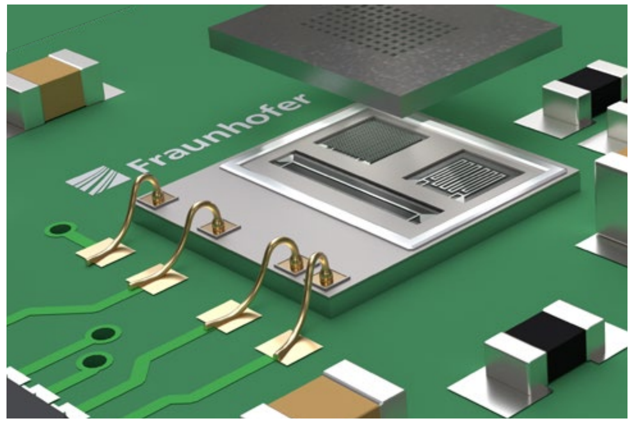
Not only can these additives influence both the activity and the stability of the catalyst, but their effect is difficult to identify using gas sensor characterization. Secondly, the reaction captured by a sensor is itself a complex reaction that is determined by the entire sensor system. And thirdly, preparing individual sensors is a very extensive process.

Reliable measurement methods for analyzing catalytic materials

To overcome these limitations affecting the development of pellistor gas sensors, Fraunhofer IPM turned to a simultaneous thermogravimetry-differential thermal analysis system in combination with a quadrupole mass spectrometer. This enables a systematical analysis of how the particle size distribution and morphology of Co_3O_4 influence its thermal stability and its catalytic activity for methane oxidation. The results achieved with this measurement technology demonstrate the method's reliability as a way of narrowing down the potential catalysts for use in catalytic gas sensors. Metal oxides with spinel structures, such as Co_3O_4, $Ni_xCo_{3-x}O_4$, $Co_{3-x}Cu_xO_4$ or $Co_{3-x}Zn_xO_4$, are particularly suitable for the catalytic combustion of methane, allowing innovative new micro-pellistors to achieve significant reductions in temperature for catalytic reactions.

Promising applications

With these innovative methods for designing new catalytic materials, Fraunhofer IPM has laid the foundation for the next generation of micro-pellistors that operate at temperatures of under 350 °C. This makes it possible to design especially energy-efficient sensors that can function with less than 100 mW of power. Dimensions of under 3 mm² and the option of cost-efficient series production open up excellent opportunities in traditional markets such as mining, gas and fuel storage, and the petrochemical industry. But there are also good prospects in growth markets including smart home and consumer applications, electromobility, hydrogen technology, and infrastructure protection.



This is how it shall look like: Close-up of the low-power radio system's micro-pellistor for the detection of combustible gases.

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