Fraunhofer IPM

Colorimetric gas sensors

Small, flexible, and energy efficient

Small, selective, and cost-effective: QR codes with gas-sensitive color change layers can be evaluated using a smartphone.

Colorimetric gas sensors are used in all applications where there is only a limited amount of energy available and cost-effective sensors are required. For example, this applies to operation in safety technology (fire and occupational safety), environmental analysis or air quality monitoring. In such applications, colorimetric sensors can reliably detect gases such as carbon monoxide, nitrogen dioxide or hydrogen. The energy efficient sensors can be integrated in sensor networks and combined with other sensor principles.

"Low-power" gas sensors

Fraunhofer IPM is developing new types of "low-power" gas sensors based on the color-change principle. A dye in combination with a matrix reacts when it comes into contact with the target gas and changes its color. This color change correlates with the concentration of the gas and has no interaction with other gases. The reaction takes place at room temperature thus meaning that no heating power is required. The power consumption is in the range of a few milliwatts. Depending on the measurement cycle, the system can therefore manage without battery replacement for several years.

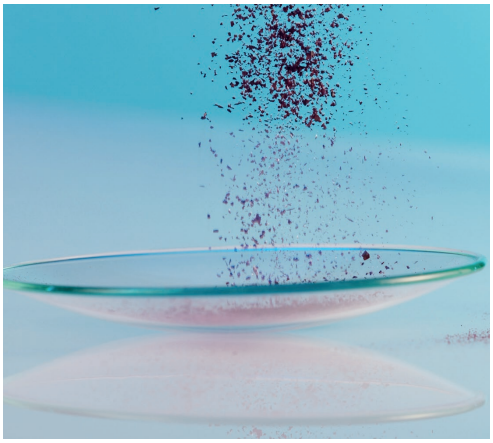
Various system concepts

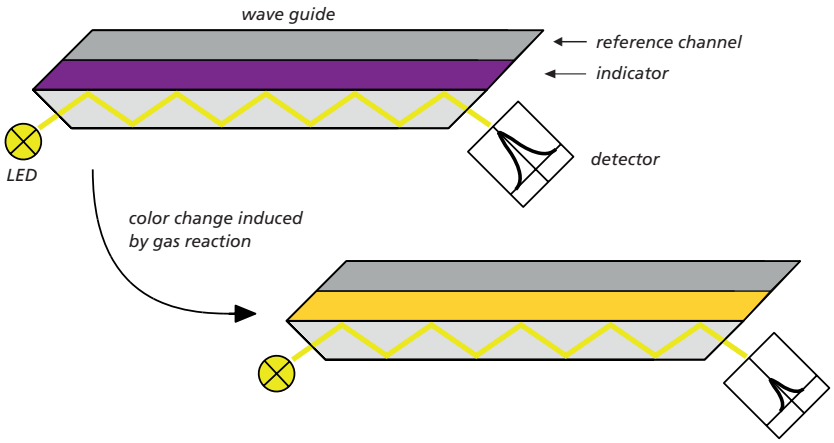
The sensory principle is based on a change in color of the gas-sensitive layer when it comes into contact with the target gas. Fraunhofer IPM develops special system concepts in order to be able to detect a color change automatically.

In one concept, for example, the color change material is deposited on an optical waveguide. Light, which is coupled in on the front side, passes through the waveguide by total internal reflection and is focused on a photodetector on the opposite side. A change in color of the gas-sensitive material corresponds directly to the change in absorption of the light. This reaction occurs in the visible wavelength range. The measurement signal is generated from the change in voltage in the photodiode. For the purposes of stabilization, the sensitive material is embedded in a matrix. This dye matrix is applied to the waveguide using microsystems technology methods – e.g. rotary coating, screen printing or inkjet printing. Depending on the application scenario, the

Our offer

- Customer- or application-specific sensor system concepts
- Gas-dependent characterization of sensors and benchmark tests
- Creation of production concepts
- Technological consulting





Left: Various dye granules are used for detection. Right: Operating principle of the colorimetric gas sensor.

color reaction of the colorimetric sensors is designed to be reversible or irreversible, and readout can be in transmission or reflection – with integrated components or even via smartphone camera.

Gasochromic dyes

For the detection of gases such as carbon monoxide, nitrogen dioxide, ammonia or hydrogen, for example, dyes such as metal complexes, quinonimines or pH indicators are used.

Carbon monoxide (CO)

The gasochromic reaction of a binuclear rhodium complex can be used for the CO reaction: The CO reaction takes place through a two-step ligand substitution of the axially bound acetate groups. The color change runs from purple (initial condition) through orange (unilateral substitution) to yellow (bilateral substitution). The measuring range of these CO sensors is between 10 and 1,000 ppm.

Nitrogen dioxide (NO_2)

One color change material for the detection of NO_2 is dye N,N,N',N'-tetramethyl-p-phenylenediamine. The para-phenylenediamine is classified in the quinone family. Oxidation with NO_2 leads to the formation of "Wurster's blue". The color change is from brown to blue. The measuring range of these NO_2 sensors is between 100 ppb and 5 ppm.

Ammonia (NH_3)

Fraunhofer IPM uses, among other things, bromophenol blue for detecting NH_3. These dyes are used primarily as pH indicators. The acid-base reaction splits off the proton of the hydroxy group. The protonated form then has a different color than the deprotonated form. In the case of bromophenol blue, the protonated form is yellow and the deprotonated form is blue. The measuring range of these NH_3 sensors is between 0.5 and 50 ppm.

Hydrogen (H_2)

Redox dyes are used for the detection of hydrogen. In combination with suitable catalysts, the dye is reduced in the presence of hydrogen and a color change takes place. A wide variety of redox indicators can be used for this purpose. This technique can be used to detect leaks in pipes as well as the overstepping of explosive limits.

The range of target gases and gasochromic dyes is wide – on behalf of our clients, we evaluate and develop dyes for colorimetric sensors tailored to specific applications.

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