Non-invasive Optical Oxygen Sensing for Life Sciences and Environmental Monitoring

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Oxygen is one of the most often monitored parameters in research, medicine and industry. CSEM has developed a new generation of non-invasive optical oxygen sensors based on a dual hierarchical porosity that significantly improve the response of the sensing layer. This contactless sensing technology is available in various systems such as objective-like device for microscopes or fiber-based for further implementation in existing setups.

Oxygen is involved wherever there is life and, therefore, control of oxygen level is of particular importance in the biotech, pharma and medical sciences. The portable systems paired with smartphones are especially attractive for environmental applications.

Traditionally, oxygen concentration is measured electro-chemically, while more recently optical sensors have become more widely used. The working principle of these optical sensors is based on selective quenching of fluorescent dyes in the presence of oxygen. One of the biggest challenges for oxygen sensing is to maintain efficiency, stability and accuracy under different conditions of temperatures, humidity levels, or salts concentrations for liquid environments.

CSEM's patented sensing solution is based on the functionalization of thin mesoporous silica-based films with selective dye indicators [1]. A dual hierarchical porosity is created by infiltrating the first coated mesoporous porous layer with a second microporous layer made of a dye containing sol-gel material (Figure 1). This dual hierarchical porosity is essential to improve the response of the sensing layer in the life sciences, both in terms of selectivity and sensitivity. The stability of the sensor is also drastically improved.

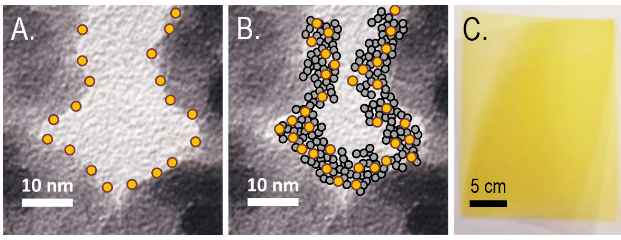

Figure 1: SEM micrograph of the sensing layer based on silica nanoparticles showing the difference between the incorporation of dyes either in a single level (A) or dual level (B) of porosity. The yellow dots represent the dyes encapsulated in the nanoporous structure of the sol-gel matrix (grey dots). The sensing layer is deposited on A4 sheets (C).

The methods of production of these hierarchical sensing layers vary in function of the size and location of the oxygen sensors. The slot die coating is used for large areas (A4 sheet) whereas printing techniques such as aerosol jet printing is required for patterns with high resolution.

Typical sensor performances in temperature of 37°C with relative humidity of 90% are the following:

- Working range 0.1% - 21% O_2
- Accuracy 0.1% at 2% O_2
- Precision ±0.3%
- Shelf life 12 months

An extra compact system has been designed and produced in a format very similar to a microscope objective (Figure 2). The reader can be directly mounted on microscopes used routinely in the life sciences. The oxygen sensor are biocompatible, can be sterilized and disposable, and placed to the inner surfaces of any transparent plastics, glassware or bioreactor. The microscope facilitates alignment between sensor and reader while ensuring a stable and constant optical environment for reliability.

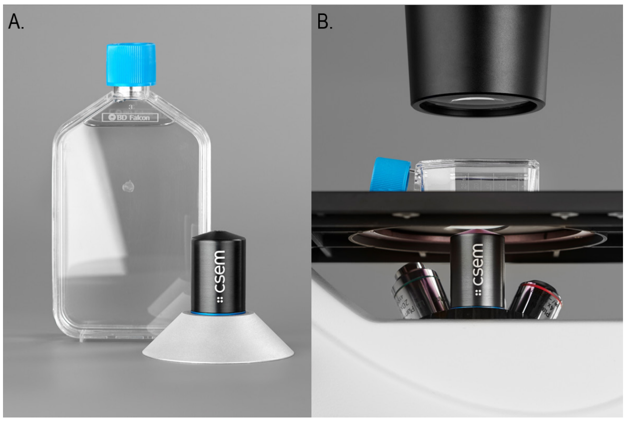

Figure 2: Contactless sensing system for microscopes showing the sensor placed in a disposable plastics (A), and the reader installed on an inverted microscope (B).

A fiber-based system was developed to monitor oxygen in incubation chambers (Figure 3). This innovation allows on-site gas monitoring with minimal invasiveness thanks to an optical fiber that is simply connected to the desired environment to be controlled.

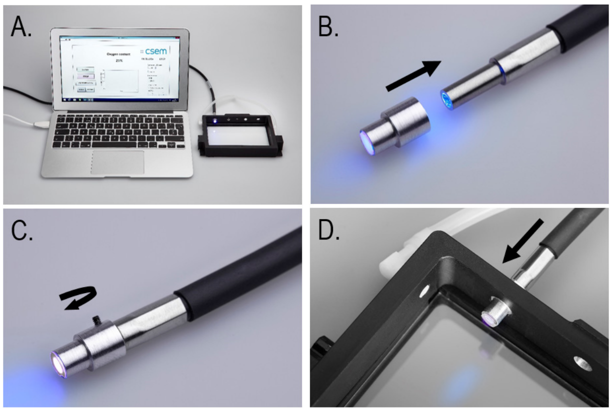

Figure 3: Overview of a gas sensing system for incubation chambers (A). The oxygen sensor on its support is inserted on the optical fiber (B), screwed (C) and pushed in the incubation chamber with gas control (D).

The oxygen sensing solution is highly customizable. Power supply on battery, wireless communication or e-reading on mobile devices are also available on these systems.

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[1] E. Scolan, B. Wenger, R. Pugin, "Optical sensor for detecting a chemical species", EP3184994A1, 2015.