# Biosensors & Applications

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Advances in low power computing and chemical technology have paved way to development of biosensors for various applications such as process monitoring, patient monitoring, re-breathers used by divers, to name a few. Most of the sensors are based on optical methods as explained in below sections.

## Optical Process Monitoring

Optical process monitors may utilize ratio-metric fluorescence analysis (CO2) or fluorescence lifetime (O2) or other characteristics of the sensing film's response to incident light to measure the parameter of interest. In order to support measurements over large dynamic range and under varying operating conditions, optical process monitors include automatic gain control and automatic temperature and pressure compensation. Optical process monitors find use in a range of environments, including laboratories, pilot and production plants, as well as outdoors. Applications enabled by the robust, non-electrode design include the following: pharmaceutical and bioprocessing; regenerative medicine; food, beverage, and brewing; and environmental monitoring.

Figure 1: Optical Process Monitoring System Courtesy: Polestar Technologies, Inc.

## Transcutaneous $O_2$ and $CO_2$ Sensors

Defence personnel from combat zones or other people who have met with accidents often suffer head injuries and brain injuries in particular. Their treatment (such as non-invasive ventilation, long-term oxygen therapy etc) requires accurate and reliable monitoring of arterial $O_2$ and $CO_2$ levels. Transcutaneous sensors are non-invasive sensors specifically developed for this application. These sensors use polarographic methods to measure transcutaneous $O_2$ and thus arterial $O_2$ (as both arterial and transcutaneous $O_2$ values are correlated when the blood flow is normal). A temperature controlled heating element elevates the skin temperature (to a few degrees above normal body temperature) to maximize capillary blood flow and to increase gas diffusion from capillaries to the skin surface. Similar methods are used in measurement of arterial $CO_2$ as well.

## $CO_2$ Sensors for Re-breathers

Deep sea divers need equipment such as rebreathers that recirculate the air already used by the diver by removing $CO_2$ metabolic product and replacing oxygen used by the diver. As excessive level of $CO_2$ are harmful to the diver, it needs to be monitored continuously and warn the diver in case of an alarm condition so that a corrective action (e.g. going back to the surface) can be taken as early as possible. Sensors use special polymer films to detect the level of $CO_2$. Measurements of the sensing film are controlled by the on-board microcontroller that also collects digital reading from the system's miniature digital temperature and pressure

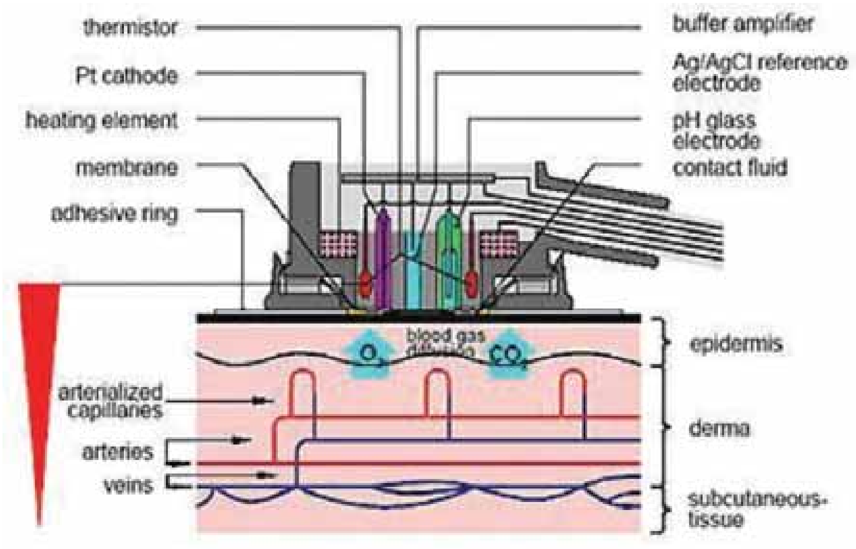


Figure 2: Transcutaneous Sensing Mechanism Courtesy: R. Carter, Royal Infirmary, Glasgow.

sensor. The microcontroller will use the temperature and color sensor readings to calculate the level of $CO_2$ within the sensing film which it will then compare with a preprogrammed temperature and pressure dependent trip point value. Optically connected status indicators notify the diver the sensor's condition and $CO_2$ hazard level.

## Typical Architecture of a Bio-sensor

As outlined above, most sensors use optical means to measure levels of $O_2$, $CO_2$ etc. A general architectural block diagram is shown below. Every sensor need not have not have all the blocks shown below and the actual construction (and packaging) may vary based on the application.

A controlled light source (invariably an LED, sometimes extended by a fiber optic cable) illuminates the sensing polymer with the required frequency of excitation. Sensed signal(s) from single or multiple photo-detectors are amplified (sometimes using automatic gain control) to the input level of the digitizer (usually an on-chip analog-to-digital converter). The digitized signal is then processed by a microcontroller, to compute the fluorescence life time or ratio-metric fluorescence based on the gas or parameter being measured. These intermediate values are plugged in the equations that relate them to the desired parameter of interest (concentration of $O_2$ or $CO_2$). In order to compensate for various influencing factors, measurements from on board ambient temperature and pressure sensors are used while computing the final result. Due to manufacturing tolerances there can be variations from one sensor film to another. Pre-shipment calibration is performed under standard conditions in the lab and results are stored in non-volatile memory (some vendors allow download of these values from their websites). Therefore, in addition to the compensation due to influencing factors, calibration factors are also applied in real time to produce an accurate measurement. The final results are then output on a local display (for e.g. in handheld monitors) or used to turn on indicator LEDs (as in the case of sensors used in rebreathers) or communicated via industrial process control buses for monitoring, analysis and data logging at a central computer.

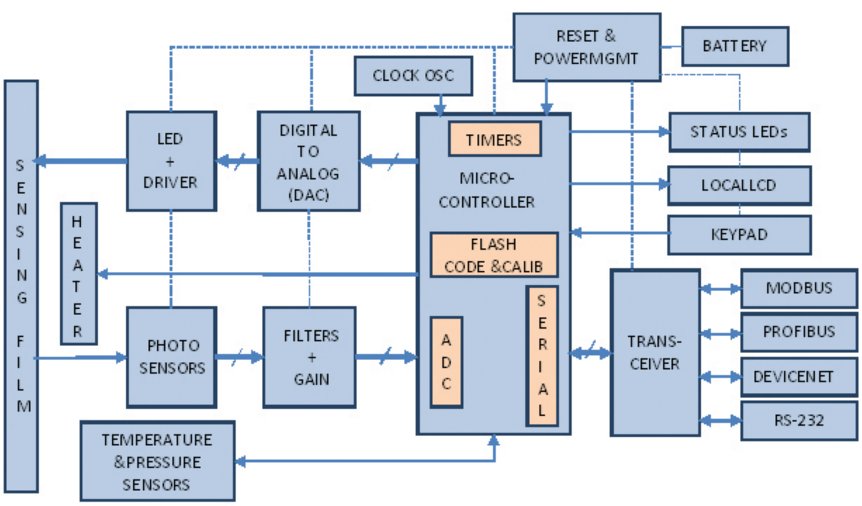


Figure 3: Architecture of a Bio-Sensor or Optical Process Monitor

## Conclusions

Apart from the small sample of current applications of biosensors outlined above, one can foresee their integration into food processing plants, public water distribution systems, online patient monitoring systems to name a few. In terms of physical construction, miniaturization makes board level sensors as chip level sensors thus enabling wearable sensors (powered by harvested energy from vibrations/human body motion/passive human power), disposable sensors or even tiny sensors that one can swallow.

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