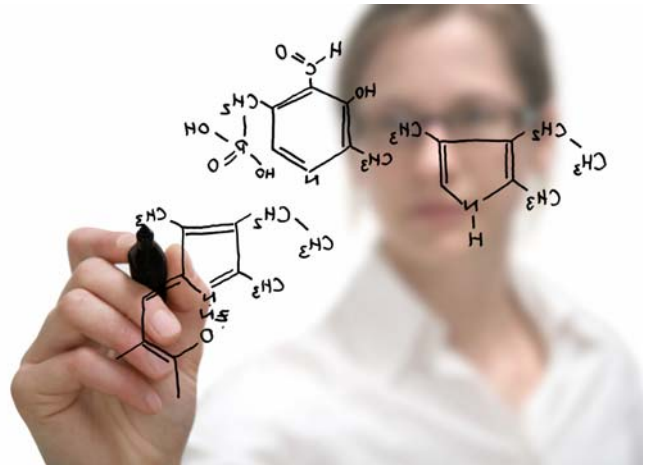
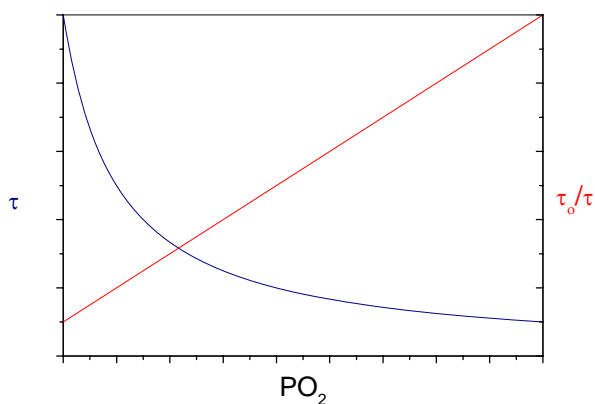


Oxygen

Polestar's optical oxygen sensors operate on the principle of fluorescence quenching wherein oxygen deactivates the fluorescent excited state of a molecule reducing both the intensity (I) and lifetime (τ) of the observable fluorescence signal. The oxygen sensors incorporate various fluorescent organo-metallic indicator compounds within a hydrophobic gas-permeable polymer film. Oxygen in the environment of interest equilibrates with that within the sensing membrane in agreement with Henry's Law.



When oxygen molecules within the sensing membrane collide with molecules of the fluorescent indicator in the emissive excited state, the energy of the fluorescent excited state can be transferred to the oxygen molecule yielding a molecule of singlet oxygen while returning the fluorescent indicator to its more stable electronic ground state. The singlet oxygen generated in the fluorescence quenching encounter eventually undergoes vibrational relaxation to its triplet ground state releasing the acquired energy in the form of heat. Unlike the detection mechanism used in polarographic oxygen electrodes, oxygen is not consumed in the fluorescence quenching detection process making the sensors immune to the affects of low flow conditions or fouling that are known to affect the calibration of oxygen electrodes.



The degree of fluorescence quenching observed with fluorescent oxygen sensors is fully reversible and predictable. Oxygen quenching in response to the partial pressure of oxygen obeys standard Stern-Volmer kinetics (see Equation 1) which describe the affect of quenching on both the fluorescent intensity and lifetime as function of oxygen content.

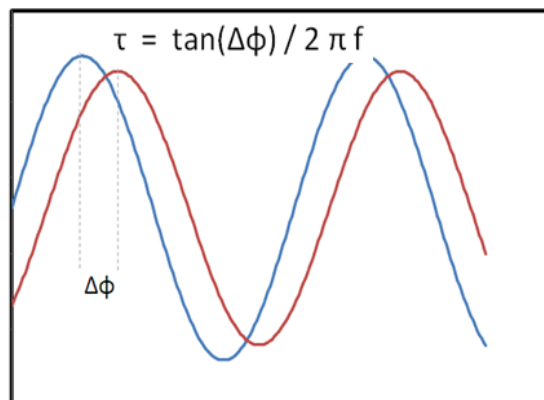
$$I_0 / I = \tau_0 / \tau = 1 + K_{SV} [O_2] \quad \text{Eq. 1}$$

I_0 and τ_0 - intensity and lifetime in the absence of oxygen

K_{SV} - Stern-Volmer constant

Polestar’s DSP series Optical Process Monitors can be used to continuously measure the oxygen dependent fluorescent lifetime of Polestar’s oxygen sensing membranes in any of Polestar’s various probe configurations. Sinusoidally modulated Light Emitting Diodes (LEDs) provide the light energy used to excite the fluorescent sensing membrane which then emits a sinusoidally modulated fluorescence signal of the same frequency but phase shifted relative to that of the LED. The fluorescence lifetime (average time the fluorescent indicator resides in the excited state) is calculated from the measured phase shift ($\Delta\phi$) using the expression shown in Figure 2 wherein f is the modulation frequency of the LED. Calibration factors convert the measured value of lifetime to units of oxygen partial pressure which can then be displayed in other user-specified units based on the temperature-dependent values of water vapor pressure and the known relationship between oxygen partial pressure and concentration.

Because it is inherently self-referencing, the phase shift detection approach eliminates the potential for measurement error arising from changes in sample turbidity, refractive index, viscosity, or color. This ensures stable, drift-free calibration and hence reliable measurements throughout the lifespan of a sensing element. The inverse relationship between oxygen content and fluorescence quenching also makes this method extremely sensitive at low pO_2 , in stark contrast to traditional electrode-based methods.



An established high technology company, Polestar Technologies is a recognized leader in the development and manufacture of optical sensors for monitoring oxygen, pH, and carbon dioxide in many different applications, such as biopharmaceutical, food, beverage, brewing, processing, packaging, and water quality.

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