SENSING OXYGEN INSIDE SEALED PACKAGES  
- A NON-INVASIVE OPTICAL TECHNIQUE -

SUMMARY

Photonic BioSystems has technology for measuring oxygen non-invasively inside sealed packages for the food, beverage, medical, pharmaceutical and electronics industries. Using optical interrogation, it eliminates destructive package testing and enables non-contact, rapid, real-time O₂ measures. The sensory approach is versatile. It can measure O₂ either in the gas phase environment of a dry package, in the headspace of a liquid package, or of dissolved-oxygen in fluids and beverages.

It addresses two QA/QC problems faced in the sealed-package field: inspecting package integrity; and determining the O₂ environment inside Modified Atmosphere Packaged (MAP) products. Its utilization broadly encompasses packages having O₂ content different than ambient air – either packages under vacuum, or of positive-pressure, or that are made via MAP-gas flushing. The oxygen sensing range is 0.05% to over 70%.

Our innovative approach makes “smart packages” by incorporating a small amount of an oxygen-sensitive luminescent dye inside the package. Sensor capability can be engineered into diverse package materials from which packages are made, such as flexible films, rigid trays, or closures. Alternatively, sensors can be made singly as small discrete labels or tags that are put in packages.

Our optical instrument remotely interrogates the sensory dye with light to derive the O₂ measure. If the O₂ level does not comply with a predefined package specification, it indicates the package was either improperly prepared or used flawed materials. Alternatively, it indicates that package integrity has been breached, post-packaging, causing it to fall out of spec.

The technique is valuable for a range of applications. It uniquely provides packagers the opportunity for 100% inspection, to QC every item and keep defects out of distribution. In the packaging plant, it can enable on-line product monitoring for better process-control management, as well as identification of flawed package. For package-R&D, it will improve efficiency and lower development-test costs.
Since the instrument is small, practical for use as a portable O2-scanner, it is deployable as a hand-held inspection tool to monitor product in the distribution path. Product inspection could be performed anywhere in the supply chain, up to the point of sale or use, to ensure storage, shipping or handling abuse or other manner of breach has not compromised package integrity and quality.

The technology will raise the standard for package quality, efficiency, and safety of delivered goods.

**Expected packager benefits include:** (i) more efficient and lower plant operating costs, (ii) earlier identification of packaging equipment malfunction, (iii) reduced losses from out-of-spec packaging, (iv) elimination of product loss to sacrificial sampling of goods for test purposes, (v) lower liability risks, (vi) higher customer acceptance and the opportunity for premium pricing commensurate with higher quality, and (vii) reduced losses from flawed product in the field.

**Customer benefits include:** (i) reduced losses from dealing with inferior or unusable product, (ii) greater confidence in their supplier, and (iii) lower liabilities for resellers to end consumers, e.g. retail grocer or food-service facility.

*In the context of Homeland Security and verification of package integrity, this technology also has significant value for protection against terrorism-threats, counterfeiting, and adulteration, such as a violation of package integrity via needle injections. Even minor deviations to the expected package oxygen content can be measured and flag a product as suspect.*

**PRODUCT DESIGN FEATURES**

The optical sensing technique employed is specifically designed to enable:

- Highly sensitive oxygen measurements, to low oxygen levels
- Tailoring of the sensor to the oxygen range of interest
- Use of low-concentrations of the sensing dye, to be economical
- Measurement of irregularly shaped materials – i.e. bottles and flexible packages
- Measuring packages with contents or labeling of highly variable contrast backgrounds
PRODUCT SPECIFICATIONS

The product meets performance specifications that satisfy needs for inspection of low O₂ content in the food packaging industry. These include:

- **O₂ Range**: 0.05 % - 70% O₂
- **O₂ Precision**: 0.02% (in the O₂ range of 0 – 5%)
  
  1% of reading (in the O₂ range of 5 – 70%)
- **O₂ Sensor Response time (T90%)**: 10 seconds
- **Measurement time/package**: < 1 second

UTILIZATION ASPECTS

O₂-sensing polymer films can be made from nearly any grade of packaging plastic designed for food, pharmaceutical or electronics packaging. Multilayer barrier packaging films have been fabricated with oxygen-sensing layers that demonstrated functionality for O₂ measurements with no harmful effect on the film’s other properties. The sensory dye is based on natural organic substances proven to be safe in extensive biocompatibility testing.

Through our patented technology, sensing films can be produced economically allowing use even in relatively cost-sensitive packaging operations. The dye can be at concentrations so low that it cannot be seen by eye.

The optical measurement process and either the O₂ sensory films, or the labels, can be implemented to a wide variety of package types satisfying diverse applications:

(i) Incorporated into a layer of multi-laminate flexible films used in pouches, bags, and blister packages for solutions, powders, or devices.

(ii) In a coating on the inner face of lidding material used typically to heat-seal closures on containers and trays. Lidding materials are often multi-layered films.

(iii) For bottles, vials, or rigid containers, in the cap or closure or in the internal wall of the vessel (many plastic containers are thermo-formed from multi-laminates with barrier properties).

(iv) In metalized packaging laminates, provided with a “window” for optically interrogating the oxygen sensing dye from outside the package.
INSTRUMENTATION

A bench-top optical instrument for remotely measuring oxygen sensors is shown below. This rendition of a lab instrument is comprised of a sensor-signal analyzer box and an optical head for interrogating the oxygen-sensor samples with light. A portable computer (not shown) communicating with the analyzer displays O₂ measures to the user and stores data. The PC can be utilized to present results for groups of packages in graphical format (e.g. control charts) and store relevant sample data such as sample ID and the reading time/date along with O₂ values.

- The technique is applicable to very small packages, even individual pills. Only a small sensor area needs to be “visible” to conduct the optical interrogation, e.g. ¼” diameter region.

- The sensor is highly specific for O₂ and immune to packaging gases (N₂ or CO₂). Volatiles or constituents of most packaged products will not interfere with its performance.

- Sensors allow in-package O₂ monitoring even when there is little or no “headspace” gas volume, such as in vacuum packages (impossible for conventional invasive needle-sampling methods, which require a sample of headspace-gas to be withdrawn from the package).