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FOOD SAFETY

In controlled atmosphere (CA) and the World's First Oxygen Sensor on a Chip

Food safety is a critical aspect of ensuring public health, focusing on the handling, preparation, and storage of food to prevent contamination and foodborne illnesses. Proper food safety practices help maintain food quality, extend shelf life, and safeguard consumer well-being.

Controlled atmosphere (CA) is a technology that plays a vital role in food preservation. It involves adjusting and maintaining specific levels of gases, such as oxygen, carbon dioxide, and nitrogen, in storage environments to slow down respiration and spoilage in perishable products like fruits, vegetables, and meats. By combining CA with stringent food safety protocols, businesses can ensure that food remains fresh, nutritious, and safe for consumption throughout the supply chain.

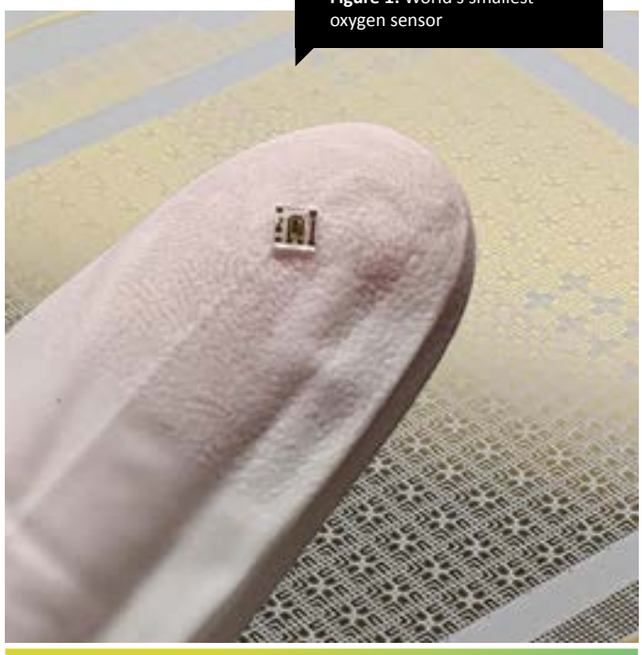

Figure 1: World's smallest oxygen sensor

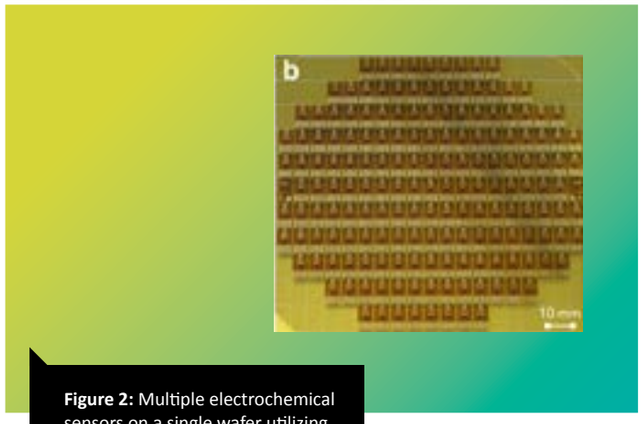

Figure 2: Multiple electrochemical sensors on a single wafer utilizing MECS-Technology®

Controlled atmosphere (CA) in food packaging provides a range of advantages that enhance food quality, shelf life, and safety. The primary benefits are:

- **Extended Shelf Life:** Adjusting the levels of oxygen, carbon dioxide, and nitrogen slows down the growth of spoilage microorganisms and delays oxidation, helping perishable foods like fruits, vegetables, and meats last longer.
- **Preservation of Quality:** CA packaging helps retain freshness, color, texture, and nutritional value by reducing degradation caused by environmental factors such as air and moisture.
- **Reduction in Chemical Preservatives:** By controlling the atmosphere inside the packaging, the need for artificial preservatives can be minimized, making products more appealing to health-conscious consumers.
- **Prevention of Oxidation:** By reducing oxygen levels, CA packaging prevents oxidative reactions that can cause rancidity in fats and spoilage of foods like oils, nuts, and snack items.
- **Control of Ripening:** For fresh produce, controlled levels of gases such as ethylene can slow or regulate the ripening process, allowing fruits and vegetables to reach consumers in optimal condition.
- **Reduction of Microbial Growth:** CA packaging creates an environment unsuitable for the growth of certain bacteria, molds, and yeast, thus improving food safety and reducing spoilage.
- **Improved Transport and Storage:** Foods in CA packaging are more stable during long-distance transport and storage, enabling wider distribution of perishable goods.
- **Customization for Specific Products:** CA can be tailored to meet the unique requirements of different foods (e.g., low oxygen for meat, high carbon dioxide for bakery products), enhancing product-specific preservation.
- **Reduced Food Waste:** By maintaining freshness and quality over a longer period, CA packaging reduces spoilage, helping both producers and consumers minimize food waste.
- **Consumer Appeal:** Foods packaged in a controlled atmosphere often appear fresher and more appealing, which can enhance consumer satisfaction and sales.

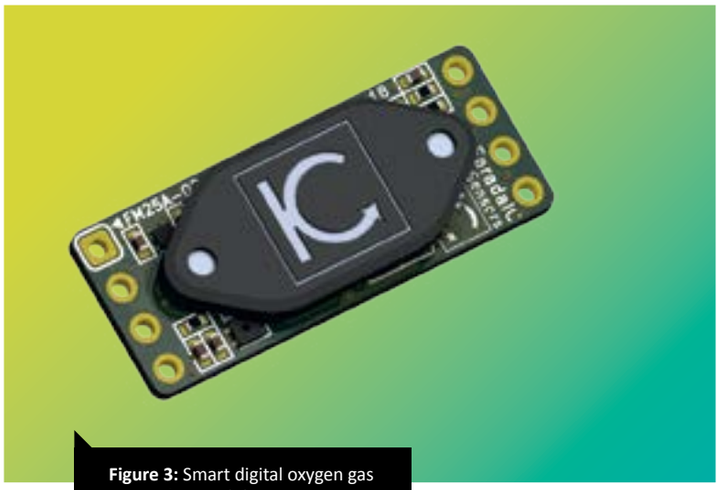

Figure 3: Smart digital oxygen gas measuring module

- Controlled atmosphere packaging is widely used in the food industry for products like fresh produce, meats, dairy, and bakery items, offering a cost-effective solution to modern food preservation challenges.

The MECS-Technology® from FaradaIC and especially, Oxygen sensors play a crucial role in enhancing food safety in controlled atmosphere (CA) or modified atmosphere (MA) packaging by ensuring the appropriate oxygen levels are maintained throughout the packaging process and storage. Here's how they contribute:

1. PREVENTING MICROBIAL GROWTH

- Oxygen sensors monitor and maintain low oxygen levels in CA packaging to inhibit the growth of aerobic microorganisms (e.g., molds, bacteria).
- **Impact on Food Safety:** Reducing oxygen minimizes spoilage and microbial contamination, ensuring safer food products.

2. ENSURING PROPER GAS COMPOSITION

- Sensors verify that oxygen levels match the specified parameters for the food being packaged (e.g., very low oxygen for meats, moderate oxygen for fresh produce).
- **Impact on Food Safety:** Maintaining the correct atmosphere prevents oxidation, off-flavors, and spoilage.

3. EARLY DETECTION OF PACKAGING LEAKS

- Continuous monitoring can identify leaks in packaging that allow oxygen to enter and disrupt the controlled atmosphere.
- **Impact on Food Safety:** Early detection helps prevent contamination or degradation, reducing the risk of unsafe food reaching consumers.

4. PREVENTING OXIDATION

- Sensors help maintain low oxygen levels to prevent oxidative reactions that can degrade fats, oils, and vitamins in foods.
- **Impact on Food Safety:** By reducing oxidation, sensors help preserve the nutritional and sensory quality of foods, ensuring they remain safe to consume.

5. SUPPORTING COMPLIANCE WITH STANDARDS

- They ensure that CA packaging meets regulatory and industry standards for oxygen levels in food packaging.
- Impact on Food Safety: Consistent compliance reduces risks of recalls and enhances consumer trust in food safety measures.

6. ENHANCING SHELF-LIFE PREDICTABILITY

- By maintaining precise oxygen control, sensors help predict and extend shelf life accurately.
- Impact on Food Safety: Proper shelf-life management reduces the likelihood of food spoilage or waste, ensuring that products are safe to consume within their expiration dates.

7. REAL-TIME MONITORING AND AUTOMATION

- Sensors enable real-time monitoring of oxygen levels and automated adjustments in CA packaging systems.
- Impact on Food Safety: Continuous monitoring prevents errors in the packaging process, reducing the risk of unsafe packaging conditions.

8. COMPATIBILITY WITH DIFFERENT FOODS

- Oxygen Sensors adapt to the unique oxygen requirements of various food types (e.g., low oxygen for red meat to maintain color and safety, or balanced oxygen for fresh-cut produce).
- Impact on Food Safety: Optimized oxygen levels improve the preservation of each food's specific safety and quality needs.

Our Faraday-Ox® (Figure 3) is the first oxygen measuring module of its kind, fully digital and factory calibrated for easy integration into IoT devices (Figuers 4 and 5).

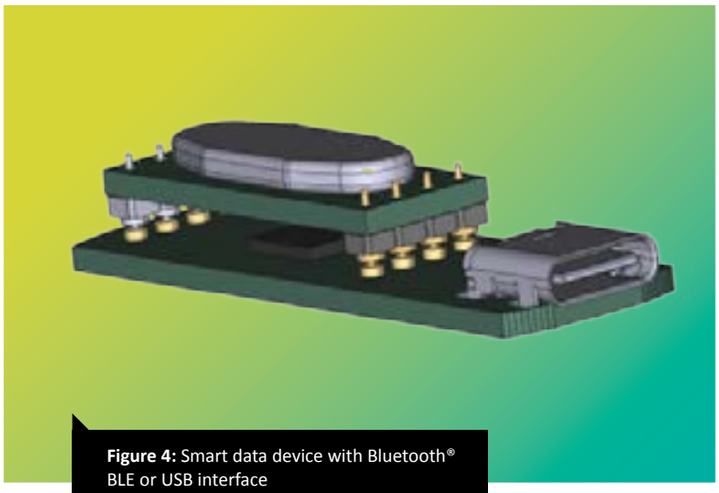

Figure 4: Smart data device with Bluetooth® BLE or USB interface from x-log Elektronik GmbH

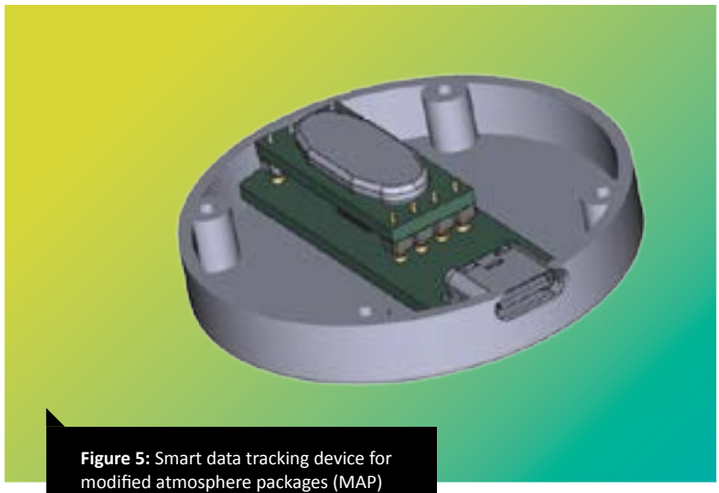

Figure 5: Smart data tracking device for modified atmosphere packages (MAP) from x-log Elektronik GmbH

By enabling precise control and monitoring of oxygen levels, oxygen sensors significantly reduce the risks of spoilage, contamination, and degradation, making them indispensable in CA packaging for food safety.

Micro electrochemical sensors from FaradaIC are sensors with MECS-Technology® and complex systems that utilise chemical reactions to detect and quantify gas concentrations. These sensors work on the principle of measuring electrical currents generated by reactions related to gas concentration, providing accurate and fast measurement of gas concentration. Due to their novel chemical structure, they do not dry out like other electrochemical sensors and can therefore also be used in dry environments with 0% relative humidity and industrial temperature ranges of up to 85 °C. The structure is similar to that of MEMS (Figure 1) and is optimized for use in high-volume applications.

For high-volume production, MECS-Technology based sensors can leverage from existing MEMS fabs and porcesses. This enables a fast ramp-up into high volume applications and designs, that have not been possible with conventional electrochemical sensors before. (Figure 2)

Our sensors can be integrated into bags and packages, enabling users to track and monitor the food condition inside during transportation and storage in real time.

The differences between FaradaIC's MECS-Technology® and other gas sensing technologies can be seen in Figure 7. Miniaturizing the electrochemical gas sensor onto a chip, the most desired features can be combined onto a single platform.

By incorporating our sensors into bags and packages which are stored in a warehouse, our customers can set new standards for freshness monitoring in controlled and modified atmospheres. Additionally, our MECS-Technology® can easily be integrated into BLE (Bluetooth® Low-Energy) based real-time location systems (RTLS), locating each and every sensor together with the freshness status of the packaged food. (Figure 6)
With the latest improvements in BLE technologies and data transfer into cloud systems, freshness monitoring with location tracking becomes the perfect combination to transfer sensor data together with their location to the cloud via mesh networks. There, the data is analysed and forwarders can determine the best time of sales for each individual packages and bringing them to the point of sales.

Asset tracking is already a requirement in warehouse systems, and the new BLE technologies enable simultaneous data transmission from inside bags and even through food and packaging, providing many real-time benefits such as:

Detailed condition monitoring with real-time localisation.
General gas monitoring in bags and packages.
Shelf life prediction for each single package.
Finding the bags with best time of sale.

- Detailed condition monitoring with real-time localisation
- General gas monitoring in bags and packages
- Shelf life prediction for each single package
- Finding the bags with best time of sale
- Licensing complete packaging system
- Recalibration of sensors via the network

Figure 6: Storage of MAP bags with best-in-and-best-out system

Technology	MECS-Technology® Micro Electro Chemical Systems	MOX Metal- Oxide	Infrared NDIR for non dispersive gases	Electrochemical	Photoacoustic
Miniaturized	✓	✓	⊗	⊗	⊗
Cost-effective	✓	✓	⊗	⊗	⊗
Selective	✓	⊗	✓	✓	✓
Ultra-low power	✓	⊗	⊗	✓	✓
High volume manufacturing	✓	✓	⊗	⊗	✓

Figure 7: Gas sensors: Technology comparison