Introduction

- Why measure CO$_2$?
  - If levels become too high, CO$_2$ begins to act as an asphyxiant.
  - A general indicator of indoor air quality.
  - High levels can enhance plant growth.

- Place that CO$_2$ sensors are used?
  - Confined work spaces.
  - Brewing and carbonated drink industries.
  - Controlled plant growth.
  - Photosynthesis.
  - Fermentation.
  - Aerobic respiration.
Types of CO$_2$ Sensors

- Mass Airflow sensors
  - thermal conductivity
- Solid state electrochemical sensors
- Mixed oxide sensors
- Ion selective membrane sensors
- Optical sensors
Mass Airflow Sensors

- Mass airflow sensors contain a thin-film, thermally isolated bridge structure containing heater and temperature sensing elements. The bridge structure provides a sensitive and fast response to the flow of air or other gas over the chip.
- State-of-the-art chip design and manufacturing techniques allow the micro bridge to be remarkably sensitive, fast, small. Used wherever airflow needs to be measured.
- Typical applications; Air pollution instrumentation, HVAC damper control, Gas analyzers, medical equipment, Process control
Solid state electrochemical sensors

The most popular sensing method for toxic gases and oxygen monitoring. Not used for combustible gas monitoring. This is the best all around sensor for ambient toxic gas monitoring. It is simple, reliable and inexpensive. The disadvantage apply mainly in atypical applications. Solid state sensors can detect most chemicals in the LEL ranges. For toxic gas applications, it is generally favorable to use solid state sensors, especially when the number of sensors is sizable.
Carbon dioxide optical sensor

- Concentration range 0-999 ppm
- Typical sensitivity (-30,+30) ppm
- Temperature up to 300°C
- Response time 10 s

Side view of the CO2 sensor: on the left, the pyroelectric detector with encapsulated porous silicon microcavity centered at 4257 nm, on the right the IR source.
Sensor method

- Single beam absorption infrared

![Diagram of sensor method](image)
Principle of operation

The light intensity which reaches the pyroelectric detector is correlated to the concentration of carbon dioxide. CO2 variation are detected by measuring the voltage between the two armours of the pyroelectric detector which is proportional to the light intensity. Three main components make up the carbon dioxide sensor: a commercial pulsable infrared emitters, a pyroelectric detector and a porous silicon optical filter.

The optical filter consisting of alternating porous silicon layers of different refractive indexes represents the sensing element. The optical filter is projected to selectively allow the propagation of a single wavelength 4257nm, i.e. absorption wavelength of the fundamental vibration of carbon dioxide molecule. The optical filter is allocated on top of the pyroelectric detector.
SEM microphoto of a cross section of the porous silicon optical filter
The graph shows the relationship between output voltage (V) and the concentration of CO\textsubscript{2} in N\textsubscript{2} (ppm). The data points are represented by squares, and the linear fit is indicated by a red line. The table below the graph lists the correlation coefficient (R), standard deviation (SD), number of observations (N), and P-value for the linear fit:

<table>
<thead>
<tr>
<th>R</th>
<th>SD</th>
<th>N</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>-0.99755</td>
<td>0.00458</td>
<td>12</td>
<td>&lt;0.0001</td>
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</table>
Why optical method?

• Inert nature of CO$_2$ makes it difficult to measure with sensors that depend on chemical reactions.
• Optical sensors are not affected by dust, water vapor or most chemicals.
Single Beam NDIR CO$_2$ Sensor

- Narrow bandpass filter is used to select the absorption wavelength of CO$_2$.
- Sensor consists of an IR source, gas sample cell, optical filter, and IR detector.
- CO$_2$ concentration is measured by measuring the amount of IR passing through the sample cell to the detector.
CARBOCAP® CO₂ Sensor

- NDIR Single-Beam Dual-Wavelength.
- Tunable Filter is a Fabry-Perot Interferometer made in silicon.
- Ratio of IR measured in the absorption band and reference band gives CO₂ concentration.
- Eliminates drift, small, cost and effective
CO$_2$ Sensors

- VAISALA GMM220 & GMT220
- Measurement Ranges
  - variable from 0 to 7000 ppm
  - variable from 0 to 20 %
- Sampling Technique
  - diffusion
- GMT 220 is LonWorks compatible.
Future Technology

• In Situ Biosafe Fiber Optic CO$_2$ Sensor for Real-Time Bioreactor Monitoring.

• Intelligent Fiber Optic Systems (IFOS)
  – porous glass optical fiber sensing substrate sections
  – biosafe carbon-dioxide-sensitive fluorescent indicators
  – Superb short-wavelength semiconductor optical sources

• Fluorescence of the indicator in the fiber depends on CO$_2$ concentration.
New Technology Continued

- The proposed sensor system responds to NASA’s need for new techniques for real-time monitoring of bioreactors for biotechnology/medical applications in space/microgravity sciences.

- Potential benefits/advantages
  - high sensitivity, dynamic range, stability, speed, biosafety, and biocompatibility
  - Electrically passive, low-power, low-weight, compact, inline, low-cost and mass-producible
Conclusion

• CO₂ Sensors are used in a wide range of applications and industries.
• NDIR type CO₂ sensors are most common and reliable on the market.
• IFOS type sensors are the future not only CO₂ sensors but all types of biotechnology sensors.
References

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