Characteristics of Ionic Liquids and Their Application in SemeaTech Electrochemical Gas Sensors

Traditional electrochemical gas sensors usually use aqueous electrolytes, which are prone to issues such as evaporation, drying out, dilution, and freezing at low temperatures during prolonged use—directly limiting the sensor's lifespan, environmental adaptability, and detection stability.

Semeatech has introduced multiple electrochemical gas sensors utilizing ionic liquid-based electrolytes. However, it is crucial to note that using an ionic liquid-based electrolyte does not automatically equate to a long sensor lifespan. Ionic liquids possess a wide range of exceptional properties. Different sensors are engineered to leverage specific traits, resulting in distinct performance advantages—such as an extended lifespan, high temperature and humidity tolerance, high resolution, excellent selectivity, or superior stability. Therefore, a long lifespan is not the core selling point for all ionic liquid-based sensors.

An ionic liquid is a room-temperature molten salt composed entirely of ions, often referred to as a "green solvent." Its inherent low volatility, exceptional thermal stability, and robust chemical stability fundamentally overcome the limitations of traditional aqueous electrolytes. Depending on the design focus, this allows sensors to achieve long-term operation, wide temperature and humidity tolerance, high-resolution detection, or outstanding anti-interference performance under harsh operating conditions.

This article explains the core characteristics of ionic liquids and their direct correlation with the performance advantages of SemeaTech's electrochemical gas sensors.

1. Core Characteristics of Ionic Liquid-Based Electrolytes

The five key characteristics of ionic liquids form the foundational support for high-performance sensor operation:

- **Nearly zero volatility**: No evaporation loss, ensuring no drying out during long-term use.
- **Wide-temperature thermal stability**: Maintains stable liquid state across a broad temperature range, resisting freezing or decomposition.
- **High chemical stability**: Resistant to irreversible reactions with target gases or interfering substances.
- **Stable electrode interface environment**: Suppresses side reactions, enhancing detection selectivity.
- **Poor compatibility with alcohols**: Hinders penetration of ethanol and other organic solvents, effectively reducing cross-interference.

Different sensors focus on one or more of these characteristics to create differentiated performance advantages:

some emphasize long life, others prioritize high resolution, anti-interference capability, or extreme environment tolerance.

2. Application of Ionic Liquids in SemeaTech Electrochemical Gas Sensors

2.1 Hydrogen Sulfide (H_2S) Sensor (4H2S-100HT/ 7H2S-100HT)

Core Advantages: High-temperature resistance (up to 65°C), extended lifespan

- The extremely low volatility of ionic liquids ensures electrolyte stability even at 65°C, preventing the drying-out issue common in traditional aqueous electrolytes.
- High thermal stability and chemical inertness ensure that the sensor does not undergo thermal decomposition or degradation during prolonged operation, guaranteeing long-term reliability.

2.2 Sulfur Dioxide (SO_2) Sensors (e.g., 4SO2-20B/ mini SO2-20B)

Key Advantages: Wide humidity adaptability, stable at 60°C, high resolution, resistance to ethanol interference

- Non-volatile and non-hygroscopic properties ensure immunity to fluctuations in humidity levels, preventing performance drift caused by water absorption or drying out.
- Poor compatibility with ethanol effectively blocks ethanol penetration to the electrode surface, minimizing cross-interference.
- Stable baseline current and low noise characteristics enable high-resolution detection at the 0.01–0.03 ppm level.

2.3 Bromine (Br_2) Sensors (e.g., 4Br2-1/ 4Br2-10)

Key Advantages: High resolution

- The ionic liquid's strong chemical stability resists oxidative degradation from highly corrosive bromine gas, preventing irreversible electrolyte breakdown.
- A stable electrode interface provides a consistent reaction environment with low background noise, enabling high-resolution detection at the 0.01 ppm level.

2.4 Ammonia (NH_3) Sensors (e.g., 4NH3-100L/ mini NH3-100L)

Key Advantages: Long lifespan, resilience in harsh environments, high resolution (mini series)

- Utilizes zero-volatility, highly stable ionic liquid-based electrolyte combined with a loss-free catalytic system, significantly extending operational life.
- Excellent temperature and humidity stability allows adaptation to complex operating conditions; the mini series achieves high-resolution detection at 0.08 ppm.

- Detailed longevity technology is covered in dedicated document AN 260520: Core Technologies and Performance Advantages of SemeaTech Long-Life Ammonia Sensors.

2.5 Hydrogen Cyanide (HCN) Sensors (e.g., 4HCN-10S/ mini HCN-10S)

Key Advantages: Low humidity interference, long lifespan, high resolution

- Non-hygroscopic property ensures electrolyte concentration remains unaffected by ambient humidity, greatly reducing humidity-induced drift.
- Does not react with HCN, so the electrolyte is not consumed, thereby extending sensor lifespan.
- Low noise characteristics support high-resolution detection at the 0.03 ppm level.

2.6 Formaldehyde (CH_2O) Sensors (e.g., 4CH2O-10/ 7CH2O-10)

Key Advantages: Unique electrochemical system, minimal cross-interference

- A stable electrode interface environment provides excellent reaction selectivity for formaldehyde, effectively suppressing side reactions from other gases.
- A controlled reaction environment reduces cross-sensitivity to common interfering gases, enhancing detection accuracy.

2.7 Phosgene ($COCl_2$) and Hydrazine (N_2H_4) Sensors

Core Advantages: Ultra-high resolution (ppb level)

- Extremely low volatility and high chemical inertness ensure long-term baseline stability and minimal background noise, enabling ppb-level detection (10 ppb for $COCl_2$, 0.002 ppm for N_2H_4).
- The electrolyte can stably coexist with highly reactive phosgene and hydrazine without undergoing irreversible reactions, maintaining structural integrity over time.

2.8 Semiconductor Process Monitoring Sensors (4SM Series)

Core Advantages: Resistance to alcohol interference, ultra-high resolution, suitable for semiconductor process gas monitoring

- Poor compatibility with ethanol effectively blocks interference from alcohol vapor during equipment cleaning, ensuring detection accuracy.
- High chemical stability allows resistance to highly corrosive gases such as chlorine, hydrogen chloride, and hydrogen fluoride, preventing electrolyte degradation.
- Ultra-low noise performance enables 0.003 ppm ultra-high resolution, satisfying the stringent requirements of semiconductor process trace leak monitoring.

3. Conclusion

Ionic liquid-based electrolytes are not merely a simple replacement for traditional aqueous electrolytes; their non-volatility, thermal stability, chemical inertness, stable interfaces, and alcohol resistance fundamentally address the limitations of conventional electrochemical sensors in lifespan, environmental adaptability, anti-interference capability, and detection accuracy.

Important instruction: Not all sensors using ionic liquid-based electrolytes are long-life sensors. SemeaTech selectively leverages core characteristics of ionic liquids based on the chemical properties of different gases and specific application needs—some products emphasize longevity, while others focus on ultra-high resolution, anti-interference performance, extreme environment tolerance, or stability, each with distinct performance positioning.

Through precise design, SemeaTech's ionic liquid-based sensors can deliver tailored performance—long-term operation, broad environmental tolerance, high-resolution detection, and excellent anti-interference capability—providing reliable gas monitoring solutions for diverse applications including industrial safety, environmental monitoring, and semiconductor manufacturing.