Introduction to electrochemical sensors xi meng engineering essay

This paper is mainly focused on three parts: introduction to electrochemical sensors Simply describe the working principle, main components breathable film, electrode, electrolyte and filter , influencing factors and selectivity 3)Introduce sensor types (potentiometric sensors, voltammetric sensors and amperometric sensors, review and discuss some examples (Solid-State Reference Electrodes, Ion selective, Carbon Based Materials, Novel Materials/ composites) on the research of electrochemical sensors classified by sensor type for future research.

[Key Words] Electrochemical sensor, electrode, potentiometric, Ion selective

It can be tracked back to the 1950s, when electrochemical sensor was first used to monitor oxygen. To the mid-1980s, small electrochemical sensor began to be devoted into detecting a variety of different toxic gases within PEL range, and showed great sensitivity and selectivity. Currently, various electrochemical sensors are widely used in many static and mobile applications in order to protect the personal safety.

Working principle

Electrochemical sensors work by reacting with the gas to be measured, and showing electrical signals reflecting the gas concentration. Typical electrochemical sensor is made up of the sensing electrode(or working electrode) and the counter electrode, separated by a thin electrolytic layer.

Firstly, gas reacts with the sensor through tiny capillary-type openings, then reaches the hydrophobic barrier, and ultimately reaches the electrode surface. Using this method allows an appropriate amount of gas reacts with

the sensing electrode to form a sufficient electrical signal while preventing electrolyte leaks out the sensor.

Gas spreading through the barrier reacts with the sensing electrode, and the sensing electrode can take the oxidation mechanism or reduction mechanism. These reactions are carried out by the design of the electrode material for the gas to be measured and catalysis.

Electrical current proportional to the measured gas flows between the positive electrode and the negative electrode through a resistor connected between the electrodes. As this process creates electrical current, the electrochemical sensor is always called current gas sensor or micro fuel cells.

In practice, since the electrode surface reacts continuously, the sensing electrode potential cannot be maintained constant, after a longer period of time, it will result in the degradation of sensor performance. In order to improve sensor performance, people introduces reference electrode in the sensor.

The reference electrode is mounted in the electrodes nears the sensing electrodes, The fixed stable potentiostatic acting as the sensor electrode. Reference electrode can be maintained on such a fixed voltage value in the sensor electrode. There is no current flows between the reference electrodes. Gas molecules react with the sensing electrode, at the same time, measure the counter electrode. The measurement result is usually directly related to the gas concentration and the voltage value affects on the sensing electrode can be aimed at the target gas.

Main components

A. Breathable film (also referred as a hydrophobic membrane): breathable membrane is used for covering the sensor (catalytic) electrodes, used in some cases to control the amount of the gas molecular that reaches the surface of electrode. Such barriers are typically made by low-porosity Teflon film and such sensors are called coated sensor. Alternatively, we can also use the high-porosity Teflon membrane covering, using capillary control the amount of the gas molecular reaches the surface of the electrode and such sensors are called capillary type sensor. In addition to providing mechanical protection for the sensor, the film also has the function of filtering out unwanted particles. In order to send the correct amount of the gas molecules, we need to choose the right film and capillary aperture size. Aperture size should be able to allow a sufficient amount of the gas molecules to reach the sensing electrode. The aperture size should also prevent leakage of liquid electrolyte or dry too quickly.

B. Electrode: selecting electrode materials is very important. The electrode material should be a kind of catalytic material, to be able to perform the semi-electrolytic reaction in a long period of time. Typically, the electrode is manufactured by noble metal, such as platinum or gold, reacts with gas molecules after catalysis. Depending on the design of the sensor may be, for the completion of the electrolysis reaction, three kinds of different materials of electrodes may be used.

C. Electrolyte: The electrolyte must have enough promotion to electrolysis reaction, and transfer the ionic charge to the electrode effectively. It also must be able to form stable reference potential with reference electrode and

be suitable to the materials used in the sensor. If the electrolyte evaporates too quickly, the sensor signal will be weakened.

D. Filters: Sometimes the front of the sensor will be installed with the washing filter to filter out unwanted gas. There are limited selections for fileters, different filter has different efficiency degree. Most commonly used filter medium is activated carbon, and activated carbon can filter out most of the chemicals, but cannot filter out carbon monoxide. By selecting the correct medium, electrochemical sensors may have a higher selectivity for its target gas.

The electrochemical sensor manufactured in many ways, ultimately depends on the gases to detect and manufacturers. However, the main characteristics of the sensor is very similar in essence. Here are some of the common characteristics of the electro-chemical sensors:

1. The three-electrode sensors, usually use a jumper to connect the working electrode and reference electrode. If remove it during storage process and it takes a long time for the sensor to maintain stable and ready for use. Some sensors require a bias voltage exists between the electrodes and in this case, the sensor is manufactured with a nine volt battery powered electronic circuit. The sensor stability requires 30minutes to 24 hours, and requires three weeks’ time to continue to remain stable.

2. Most of the toxic gas sensors require a small amount of oxygen to maintain the normal function. The sensor equipped with an air vent on the back in order to achieve this object. Our recommendation is to perform a re-

examination with manufacturers in the use of non-oxygen background gas applications.

3. The electrolyte of the battery in the sensor is an aqueous solvent to be isolated, the hydrophobic barrier prevents leakage from the aqueous solvent. However, like other gas molecules, water vapor can pass through the hydrophobic barrier. In high humidity conditions, the prolonged exposure may result in the accumulation of excess moisture and cause leaks. Under low humidity conditions, the sensor may dry. Designed for monitoring a high gas concentration sensor having a lower porosity barrier to limit the gas molecules passing through, so that it does not affect by humidity, and like those monitoring low concentration gas, such sensors have a higher porosity barrier and allows gas molecules to flow freely.

Pressure and temperature

The electrochemical sensor pressure changes with impact minimally. However, due to the differential pressure may damage the sensor, so the entire sensor must maintain the same pressure. Electrochemical sensor is also very sensitive to temperature, and usually takes the internal temperature compensation. So it is best to try to keep the standard temperature.

In general, when the temperature is above 25 ° C, the sensor readings are higher; below 25 ° C, lower readings. The error by temperature effect is usually from 0. 5 to 1. 0% per degree Celsius, depending on the manufacturer and the sensor type.

Selectivity

The electrochemical sensor usually has a high selectivity to its objectives. The degree of selectivity is dependent on the sensor type, objective gas, concentration of the target gas to be detected. The best electrochemical sensor is a sensor of the detection of oxygen, it has a good selectivity, reliability and a longer life expectancy. Other electrochemical sensors are susceptible to interference from other gases. Interference data can be drawn by a relatively low concentration of the gas calculated. In practical applications, the interference concentrations may be high to mislead signal make false readings or false alarms.

Reference Electrodes

Typically, use of reference electrode is to remain at a constant potential, thus behaving independently from the properties of the working electrode and those of the solution being measured. This separation method between reference electrodes and working electrodes is the basis of accurate electrochemical measurements for a great amount of

applications,

Example: Solid-State Reference Electrodes

Reference electrodes have been put in use in a variety of industries, but usually traditional reference electrode composition is not adequately effective and fails to work properly when subjected to harsh industrial processes. Traditional reference electrodes depend upon a liquid solution for appropriate potential measurements. Liquid solution-based reference electrodes are in widespread use; however, successful miniaturization and

mass production is severely limited by continual maintenance as well as contamination control. The alternative is a solid-state reference electrode (SSRE), but typically these devices cannot compete adequately with the reproducibility of liquid-based reference electrodes or be mass-produced consistently. Recently, a novel SSRE was developed using a polyelectrolyte junction and was able to fabricate a SSRE and a pH-sensing chip that displayed excellent reproducibility between synthetic batches, instant stabilization time, and superior sensing characteristics and can be readily miniaturized for affordable mass-production.

By using a solid KCl melt in conjunction with an Ag/AgCl component, in order to use in beverage industry applications. This SSRE has a wide range of pH use, stable potentials, and small drift potentials. The reported stability and life time of this reference electrode make it particularly applicable for the food industry. In addition to food industry, engine diagnostics are utilizing SSRE to assess efficiency.

Potentiometric sensors

Potentiometric sensors have usually been defined as a zero-current technique to measure the potential across an interface, oftentimes a membrane. As now, research has been focused on highlighting the significance of membrane composition using carbon pastes and polyvinyl chloride as well as unique ionophores specifically designed for targeted species.

Example: Ion selective

Scientists in this field are facing a challenge ranging from medicinal chemistry to environmental toxicity is that novel ion selective electrodes (ISEs). ISEs typically use an ionophore as the sensing platform to ensure selectivity to a specific ion of target. The increasing use of heavy metal and ion in industrial processes makes ion selective sensors important for the appropriate sensing and quantification of potential pollutants. Use and research were divided into cations, anions, and neutral species and got great achievements.

Voltammetric sensors

Voltammetry provides an electroanalytical method for deriving information about one or more analytes by measuring the current as a function of the potential. Several types of experiments may be performed to gather information from voltammetry including cyclic voltammetry, squarewave voltammetry, and stripping voltammetry to name a few common techniques.

Example: Carbon Based Materials

Carbon based electrodes have been widely used in voltammetric research because of low cost, availability, stability, and the ability to easily modify the morphology of carbon. There are a number of carbon-based electrodes including glassy carbon. Polycrystalline boron doped diamond, carbon nanotubes, and most recently grapheme. Through the detection of the neurotransmitter serotonin, they found that “ pristine” carbon nanotubes networks exhibited background current densities that were 2 orders of magnitude lower than glassy carbon and 20 times lower than polycrystalline

boron doped diamond. Numerous advantages of using carbon as an electrode tip including mechanical strength and inhibition of water electrolysis.

Amperometric sensors

During an amperometric measurement, the working electrode, or sensor , is held at a constant potential while the current is monitored. The current is then related to the concentration of the analyte present.

Example: Novel materials/ composites

Use of new materials, especially manomaterials, has become an increase of research in electrochemical sensors. The incorporation of these manomaterials in conjunction with one another to form novel composites is particularly interesting, as many of these materials have been found to have synergistic effects.

Electrospun carbon nanofibers provide more edge sites on the outer wall than carbon nanotubes, which may lead to more facile electron transfer, better dispersion, and better wettability. And the low cost, facile construction, high sensitivity, and lack of pretreatment make it appealing for future electrochemical sensing application.