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Uncovering the Modern Aspects of Chemical Sensors

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Abstract

In every field where volatile material concentrations are measured for analytical and control purposes, chemical sensors are becoming more and more important. They also found a number of applications for electronic tongues and noses, which are sensor systems. This chapter will mostly cover the foundations of sensor science, along with a quick recap of the essential ideas behind several real-world applications, including sensors, transducers, response curves, differential sensitivity, noise, resolution, and drift. The fundamental electronic circuits employed in the sensor sector will be described, with a focus on noise considerations that are crucial for attaining high resolution findings in a setting where minimizing chemical concentration values is the primary goal. High resolution and noise are related since both are necessary for accurate results. The intrinsic working mechanisms, restrictions, and performance of all the most significant transducers—including MOSFET (metal-oxide-semiconductor field-effect transistor), CMOS (complementary metal-oxide-semiconductor), Surface Plasmon Resonance device, Optical Fibre, and ISFET (ion-selective field effect transistor)—will be thoroughly covered. We shall also talk about these transducers' shrinking impacts. The electronic tongue and nose will be covered as instruments that can produce olfactory and chemical pictures for numerous applications in food, medicine, agriculture, and the environment. To ensure that foresee potential significant arising from today's micro and nanoscale achievements, some future trends will be covered in the last section.

Keywords: Sensors; Chemicals, Electronic noses, CMOS, MOSFET

1. Introduction

An electrical signal is produced by a chemical sensor when it receives a signal or stimulus. Chemical sensors are now defined as sensors that receive chemical signals. The output signals are correlated with certain electrical signal kinds, such voltage or current. Depending on the materials used in sensor aspects like cost, accuracy, and range, as well as the purposes, input signal, and conversion mechanism, sensors are classified into many types.

A chemical sensor is a device that creates a signal that can be used analytically from chemical information, such as the concentration of a specific component in a sample or the composition analysis as a whole. The chemical data described above could be the consequence of an analyte's chemical reaction or a physical property of the system being studied. [1]

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It can alternatively be described as an analyzer that, with the sensing material acting as the primary component, must react selectively and reversibly to a particular analyte in order to translate a chemical concentration into an electrical signal.

A novel class of lanthanide-based materials has been developed by Dr. Simon Humphrey, Sam Dunning, and colleagues at the University of Texas at Austin. New rapid chemical sensors that might be used in a variety of applications could be built on a variety of materials. More and more research has been done on molecules containing lanthanide (Ln) ions (charged atoms) as chemical sensors due to their light-emitting, or "photo luminescent," characteristics (Figure 1). [2]

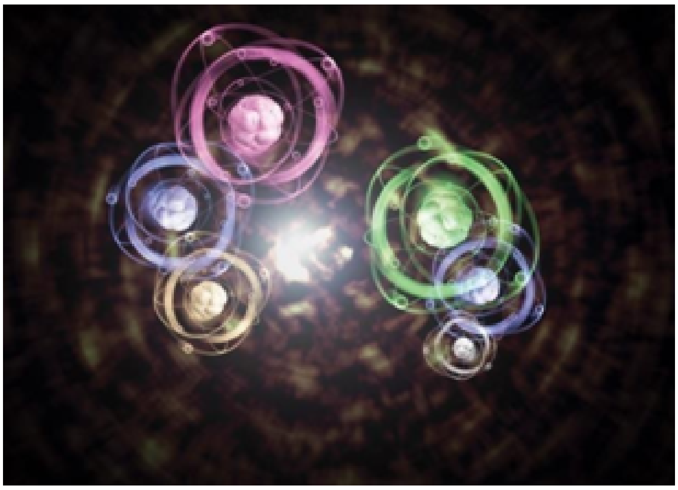


Figure 1: Photoluminescence of Lanthanide ions which have been increasingly explored by chemical sensors

Certain visible and infrared light frequencies are released by lanthanide ions after they have absorbed light. Thus, it follows that, in order to identify chemical impurities in a sample, a solid-state sensor (such a dipstick) can be simply inspected with the unaided eye or a UV reader. Every lanthanide ion, such europium and terbium, has a different light frequency that it emits. This implies that chemical sensors based on lanthanides can be tuned to identify a particular contaminant.

2. Components of a chemical sensor

The chemical sensor basically has two basic components in the form of **a chemical resonance system** (Figure 2) known as

- the receptor and
- a physical chemical transducer.[3]

The transducer transmits the electrical signal, and the receptor interacts with analytical chemicals. The receptor is given a test sample to validate the transducer's composition. The transducer gathers information from the receptor and sends it to the signal amplifier. This amplifies the transducer's signal and sends it as outputs.

The figure below provides a clear view of the components of a chemical sensor.

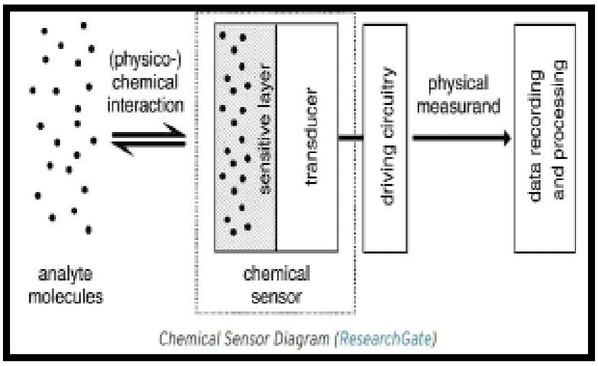
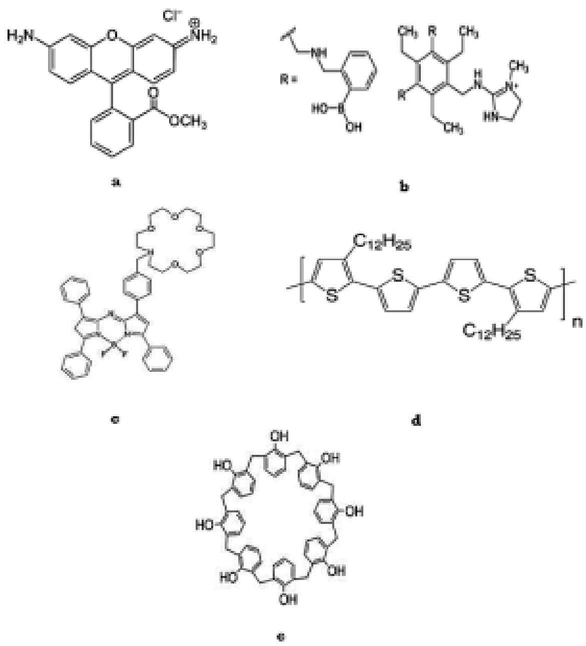


Figure 2: Chemical sensor diagram [4]

Organic chemicals used in sensors

The following are the names of some organic compounds used in chemical sensors: i) Rhodamine dyes (Scheme 1a) were employed to make fluorescent sensors due to their extraordinary spectroscopic properties, including extended absorption and emission wavelengths, high fluorescence quantum yield, large extinction coefficient, and remarkable photo stability. ii) Tannic acid and saxitoxin (Scheme 1b and 1c, respectively) are used in fluorescence-based chemosensors, iii) Poly (3,3′′′-didodecyl [2,2′:5′,2′′:5′′,2′′′-quaterthiophene]- ,5′′′diyl), Poly(4,4′′didodecyl [2,2′:5′,2′′:5′′,2′′′-quaterthiophene]-5,5′′′-diyl) (PQT-12) (Scheme 1d) is employed in high-sensitivity chemical sensors based on organic thin-film transistors. Additionally, it can be used in organic solar cells as donor material. Furthermore, organic solar cells can utilize it as donor material. iv) Calix-8-arene (Scheme 1e) is used in sensor for the direct measurement of high ephedrine content of weight reduction herbal medicines; It can utilize as a donor material in organic solar cells.



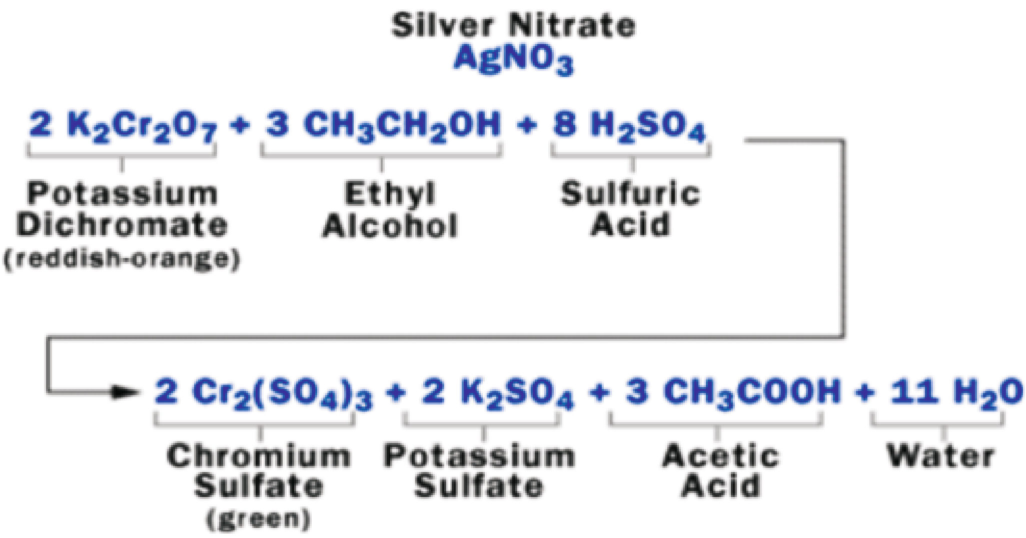
Scheme 1: The structures of Rhodamine dye (a), Tannic acid (b), Saxitoxin (c), PQT-12 (d), Calix-8-arene(e)

3. Applications of chemical sensors

I. Breath Analyzer: Alcohol drinkers exhale a specific number of molecules that corresponds to the amount of alcohol they have drank. A breathalyser is a type of chemical sensor used to determine a person's blood alcohol content (BAC), mainly to determine if the person is fit to drive or not. When the alcohol molecules attach themselves to the receptor, they come into contact with additional substances such as sulfuric acid, potassium dichromate, silver nitrate, and water. This initiates a chemical reaction that results in the generation of an electronic signal that indicates the suspect's blood alcohol concentration (BAC) on a screen or with needles when the chemical difference between the two chambers—one unaffected by the reaction—is detected. Remember this the next time you drive after drinking to avoid getting pulled over by the police for using a breathalyser (Figure 3).

Figure 3: This picture shows a Breathalyzer [5]

The reaction between alcohol and sulfuric acid that turns orange potassium dichromate solution green by converting potassium dichromate to chromium sulphate is catalysed by silver nitrate. The amount of alcohol in the exhaled air can be calculated by the intensity of the green colour.



II. Chemical sensors are employed to identify and quantify nitrogen and phosphorus in air and liquids, as well as to detect toxins. (Scheme 4).

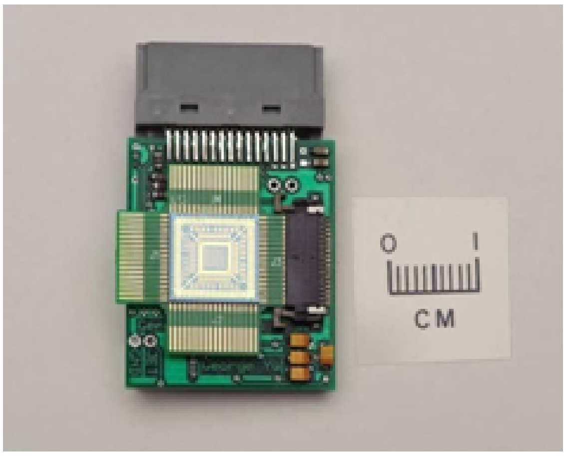


Figure 4: Gas detection sensor [6]

III. Liquid electrolytes are used by amperometric sensors to measure air quality. (Figure 5a and 5b).

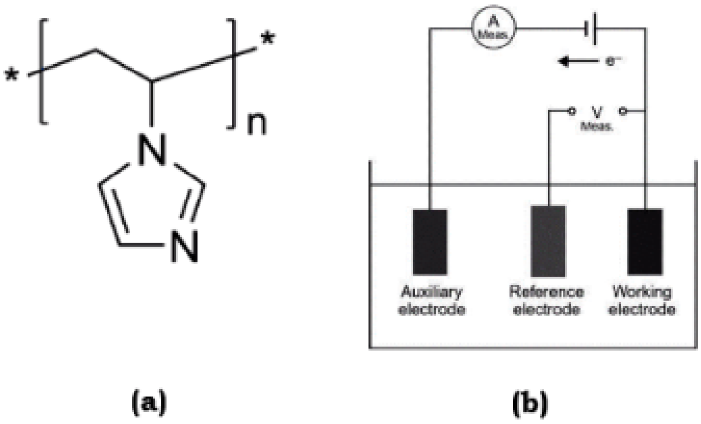
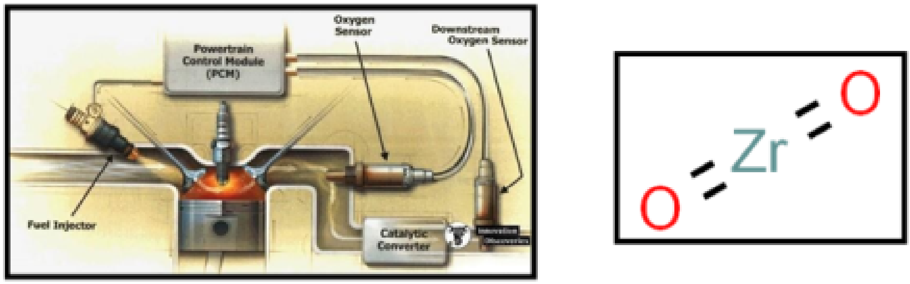


Figure 5: (a) Polyvinyl imidazole: A chemical applied in Amperometric sensor [6], (b) Amperometric sensor [6]

IV. The LAMBDA sensor, also known as an oxygen sensor (Figure 6a), is a small probe that is installed between the catalytic converter and the exhaust manifold of an automobile. Volvo developed it throughout the 1970s. A more recent model of automobile will have two lambda sensors installed. The second sensor will thus be directly behind the catalytic converter in such scenario. By maximising the air and fuel mixture, the lambda probe will modify the amount of fuel supplied to the engine cylinders, hence ensuring optimal engine operation. By guaranteeing that the catalytic converter is operating properly, this will also have an impact on the rate of emissions of dangerous gases. The lambda sensor can measure the amount of fuel and air in the unburned hydrocarbons following combustion since it is positioned ahead of the catalytic converter. In this manner, the Electronic Control Unit (ECU) of the car, which controls certain engine functions, will receive accurate information about emissions and be able to release the precise amount of gas required. Reducing polluting emissions requires this. Zirconia applications are typically built using lambda sensors (Figure 6b). [7]



(a) (b)

Figure 6: (a)TheFigure beside shows the setup of oxygen sensor (b) Zirconia: Used in Lambda sensors

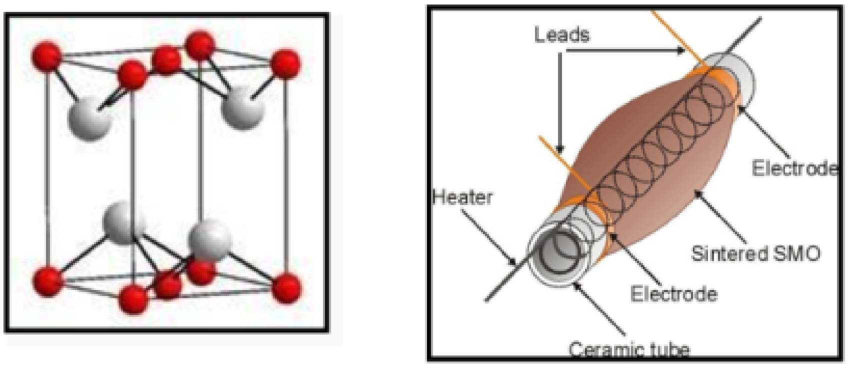
V. High-tech sensor for blood glucose measurement

For diabetics who need insulin, the new blood glucose measurement with the sophisticated Free Style Libre sensor is designed to make life much easier. A discrete scan can be used to test blood glucose thanks to the sensor, which is fastened to the upper arm (Figure 7). The sensor delivers much more information about the glucose course than previously possible and renders the conventional stinging unnecessary. [8]

Figure 7: A glucose sensor [9]

VI. TAGUCHI SnO Sensor

As a result of electronic interactions between the semiconductor sensor materials and the target gas, this type of gas sensor uses varying resistance or conductance to identify the gas. Following numerous attempts to enhance gas-sensing performance, SnO-based (Figure 8a) semiconductor gas sensors were introduced to the market in 1968 as town gas and liquid petroleum gas leakage monitors (Figure 8b). SnO has been the most appealing semiconductor gas sensor material among the different kinds of semiconductor metal oxides that have been researched and/or demonstrated as sensor materials thus far.



(a) (b)

Figure 8: (a) Structure of SnO [10], (b) A Taguchi-type sensor where the heater is embedded in a ceramic tube and semiconductor material is mounted on the tube with two pre-printed electrodes. [11]

VII. TITRATION is a traditional analytical chemistry procedure.The titrant, a precisely known concentration reagent solution (a standard solution), is gradually added to the sample solution while being stirred continuously. This process continues until equivalency is reached, or when the reaction between the reagent and the sample is roughly 100%. This point is reached in an acid-base titration (Figure 9) if the sample, which was before either acidic or alkaline, reacts neutrally, or if it is neutralised. This status is indicated by the indication. The burette's scale can be used to determine how much titrant has been used up to this point. The volume consumed is used to compute the outcome. Titrations were carried out long before sensors were widely available. Typically, indicator substances—dissolved dyes that exhibit a noticeable colour shift in the area of the equivalency point—have been used. The use of electrochemical probes for experimental signals gained increasing traction starting in the 1930s. [12]

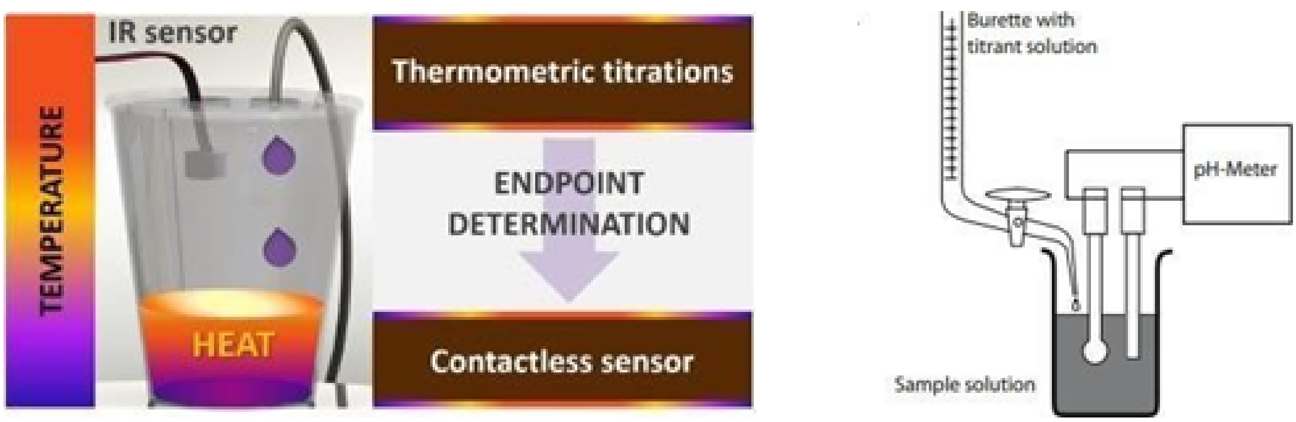


Figure 9: Low-cost device for thermometric titration

Chemical sensors also find their used in:

For chemical sensors, the following detectors can be found:

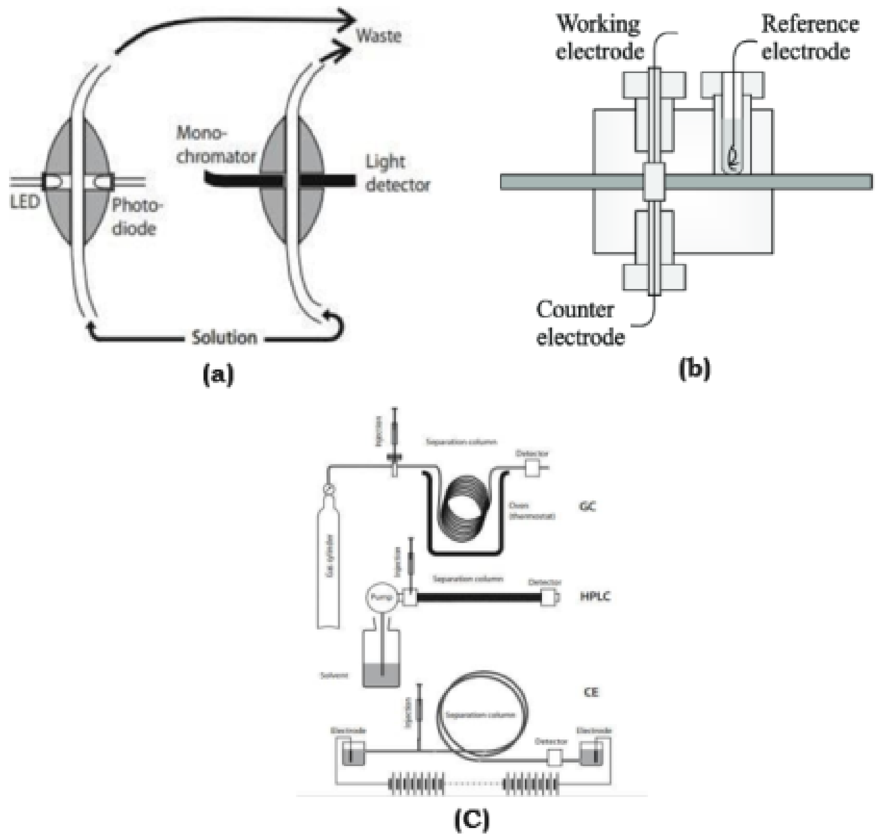


Figure 10: (a) Photometric detectors for flow injection analysis [13], (b) Electrochemical flow-through detectors [13], (c) Chromatography [13]

4. Conclusion

The use of chemical sensors is quickly growing as nanomaterials enter the market. Chemical businesses are becoming more reliant on chemical sensors due to their detection capabilities. The rising levels of pollution have fueled the demand for chemical sensors. The increasing need for accuracy and precision in sensors will drive their improvement in the future. Additionally, the biological area is opening up new fields related to nano-biosensor fabrication, so it is imperative to use relevant sensor keywords like response curve, sensitivity, noise, drift, resolution, and selectivity. For the scientific and industrial communities involved in sensor science advancements, an accurate understanding of these sentences and their implications is essential since it facilitates the appropriate communication of experimental and theoretical results. While noise comments are crucial in defining resolution, some basic transducers have also been examined to show intrinsic sensing and sensitivity mechanisms.

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