October 2008 Volume 7 Issue 9

Trade Science Inc.

Analytical CHEMISTRY
An Indian Journal

Review

ACAIJ, 7(9) 2008 [739-742]

Non-destructive approach in volatile component inspection of food and flavouring materials through electronic nose

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Received: 14th August, 2008 ; Accepted: 19th August, 2008

ABSTRACT

An electronic nose (E-Nose) is a device that uses the pattern of response across an array of gas sensors to evaluate qualitatively as well as quantitatively the volatile components of micro and macro environment subjected thereof. The E-Nose basically mimics the operation of the human nose. The key component in an E-nose is an array of gas sensors. Metal oxide, conducting polymer, quartz crystal microbalance, surface acoustic wave, MOSFETs, and optical sensors are commonly used sensors in E-Nose. The output of the E-Nose can be applied in identifying, quantizing and characterizing especially the volatile food components as perceived by human senses in sniffing process. Present paper elaborates the basics of E-nose functioning as non destructive methods of head space analysis with its application as quality inspection of food and allied materials.

KEYWORDS

E-nose;
Non destructive;
Sensor;
Quality inspection;
Head space analysis.

INTRODUCTION

Electronic nose is regarded as a modular system comprising a set of active materials which detect the odour, associated sensors which transduce the chemical perception into electrical signals, followed by appropriate signal habituation initially and processing later on to train the system to recognize and classify the known odour or distinguish the unknown odour. All the electronic noses developed so far are based on the same working principle as an array of chemical sensors mimicking the olfactory receptors, matched with a suitable data processing method, allows retrieving quantitative and qualitative information on the chemical environment emitted from food or chemicals. A sensor comprises a material whose physical properties vary according to the concentration of some chemical species. These changes are then translated into an electrical or optical signal which is recorded by a device.

The sensors are non-selective. A chemical compound following the steps as given in figure 1 is identified by a pattern of the outputs given by the different sensors utilizing the technique of pattern recognition. Artificial noses, commonly known as "electronic noses,"

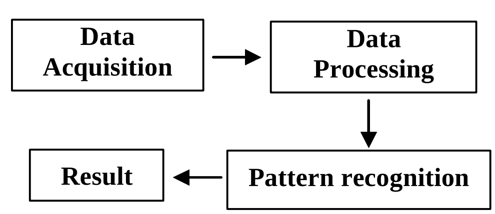

Figure 1: Process steps in the identification of volatile components

have been designed to sense and identify odorants in form of organic compounds in micro or macro environment subjected for analysis. Electronic noses differ from other sensing systems in that they are meant to operate in the noisy sensory atmosphere of open air rather than in the laboratory. Sensing the presence or absence of a particular substance within a controlled sample of air (or liquid) in a laboratory is a much simpler problem than detecting the presence of that substance in ambient air or water. Sensing elements that react to a particular chemical may react, as well, to many other substances with similar chemical structures. Thus, a single sensing element, viewed in isolation, is likely to produce many false positive readings, and may not correctly identify a particular chemical when it is part of a mixture. The sensing system of the natural nose, in contrast is not only sensitive, but is capable also of remarkable discrimination among competing odors. Wine specialist can pick up delicate differences in wines just by smelling them. Thus, the model provided by the natural nose is ideal for creating artificial sensing systems which operate effectively in the noisy natural environmental condition.

The E-Nose consists of three functional components. The key component is an array of gas sensors that respond to volatile organic compounds (VOCs).

Sensor types

1. Electrochemical sensors
2. Conductance-based sensors:
   - Metal-oxide and conducting polymers
3. Potentiometric sensors
   - Chemically sensitive field effect transistors (FETs)
4. Mass-change (Piezoelectric) sensors
   - Quartz crystal microbalance (QCM)
   - Surface acoustic wave (SAW) devices
5. Optical sensors
   - Fluorescent optical fibers
   - Colorimetric

Sample handler is a next unit that transfers the odorant from a sample collection device to the sensor array. Last unit is the signal processing system accepts the sensor array response waveforms for analysis. Signal processing may involve pattern recognition using fuzzy logic, artificial neural networks (ANN), principal component analysis (PCA), genetic algorithms (GA) of soft computing for cluster analysis, and discriminant function analysis (DFA) of multivariate systems. The output of the E-Nose can be the identity of the odorant, an estimate of the concentration of the odorant, or the characteristic properties of the odor as might be perceived by a human sniffing the odorant.

Working principle

A sensor comprises a material whose physical properties vary according to the concentration of some chemical species. These changes are then translated into an electrical or optical signal which is recorded by a device.

E-Nose uses a collection of number of different polymer films. These films are specially designed to conduct electricity. When a substance such as the stray molecules from a glass of soda is absorbed into these films, the films expand slightly, and that changes how much electricity they conduct (Figure 2).

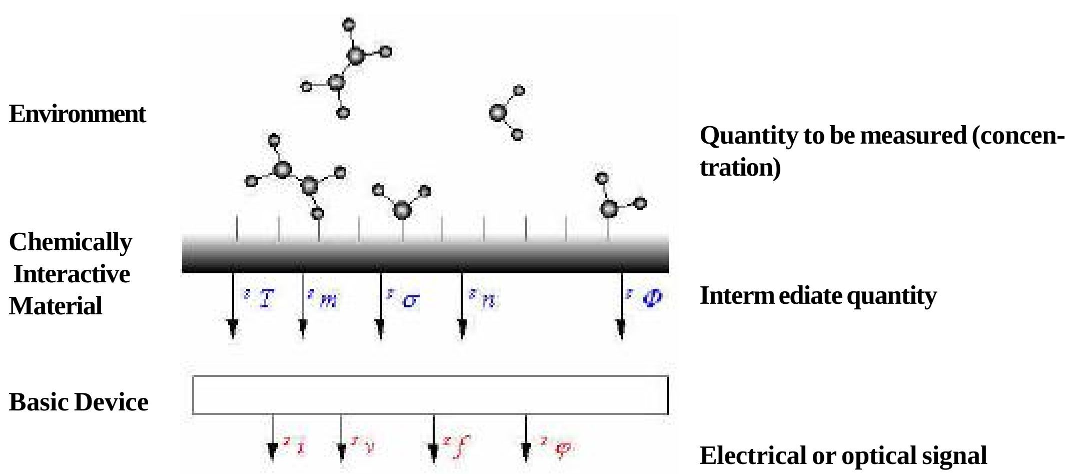

Figure 2: Structure of a typical generic chemical sensor

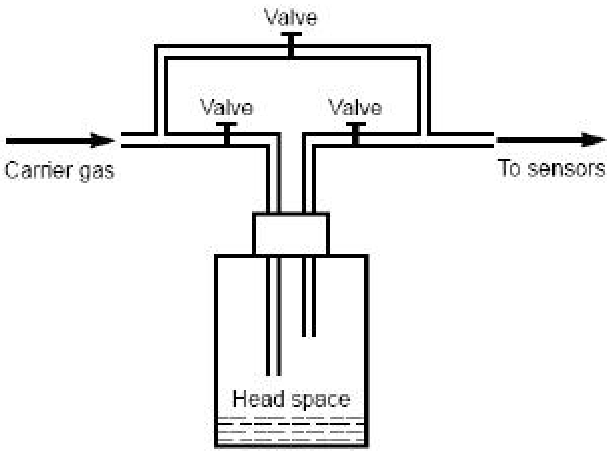

Figure 3: E-nose typical setup showing headspace sampling system for volatile component analysis

Technology and engineering

Many industries rely on sensory panel and Gas chromatography (GC) sometimes as head space analysis to assess the quality of a flavoured food products (Figure 3). Their advantage over existing traditional technologies is that they are capable of monitoring broad or narrow spectra of analytes continuously in real time, at the point of need (Figure 4). Both techniques have major drawbacks. Sensory panels can be subjective and GC is not fast and needs skilled people for the interpretation of the data. That is why there is a need for a fast, simple and objective technique. Two technologies are used to create a fingerprint of a smell as sensor array (in most cases using metal oxide sensors) or mass spectrometry (without GC column). Sensors are more sensitive and can be used for quality inspection of raw materials in food or allied fields, and mass spectrometry is more selective can avoid the individual effect (ethanol) in finished products (beer). Thus, chemical sensing represents the fast growing area of analytical instrumentation, in all areas of food and allied industries. Availability of dedicated, inexpensive computational capacity and by the need to obtain rapid and precise information about detection and monitoring of gases and vapors occupies a prominent position among chemical sensors.

Industrial applications

- Industrial process control and automation of food processes
- Food product development
- Quality inspection of food and other chemical compounds

Destructive and nondestructive approach

Electronic nose technology is developing currently at a fast pace. New systems are characterized by enhanced performance, increased reliability and reduced cost. The focus on recent developments in the field of chemical sensor technology, sensor systems and application specific instrumentation are need of hour. New concepts include advanced user friendly algorithms, improvements on cross interference reduction, reproducibility and database transferability between systems. Successful development of an electronic nose requires a development of an array of sensors that are specific to the compounds of interest.

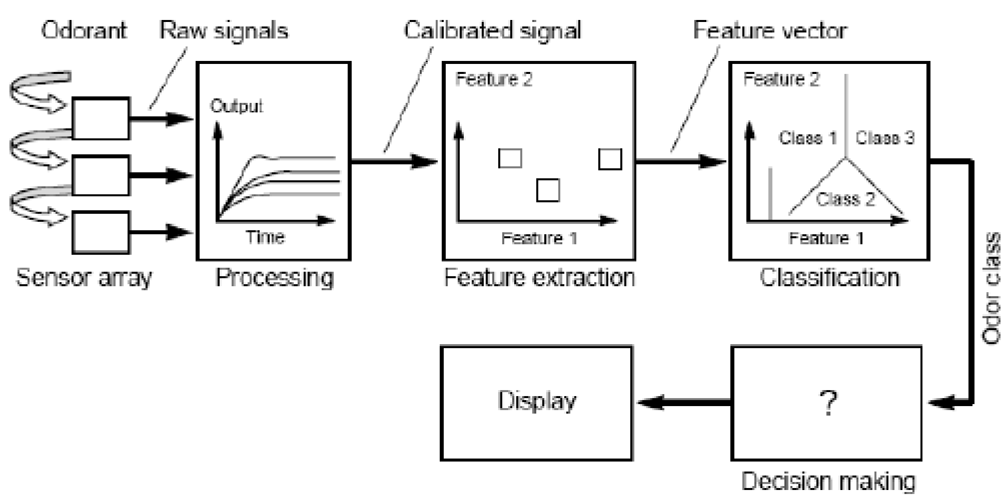

Figure 4: Block diagram for various stages of sensing system

CONCLUSION

Electronic nose is now becoming available as a commercial product. Sensation into an objective numerical output of the E-Nose and human panel give results which are qualitatively similar but electronic nose shows a better defined class separation. Electronic nose technology is developing currently at a fast pace. New systems are characterized by enhanced performance, increased reliability and reduced cost. The reliability of this new concept depends on the uses of advanced user friendly algorithms, improvements on cross interference reduction and database transferability between systems.

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