Detective Smart Nose: An Overview on E-Nose

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Abstract— This paper provides an overview for understanding the use of E-Nose as a device that identifies the various components of an odor & also specifies its chemical makeup using various sensors. This device reduces efforts of human experts. One of the major contributions of E-Nose is detection of volatile organic compounds. E-Nose is also a growing research area called BIOMETRICS. Other important application of E-Nose includes agriculture, military, pharmaceutical, cosmetics, and various other research fields.

Keywords - E-Nose, Gas Chromatography, Mass Spectrometry, Acoustic Wave formatting; style;

I. INTRODUCTION

Electronic Nose is an instrument or an artificial olfactory system for detection and characterization for years. It comprises arrays of electrical chemical sensors in which the replacement of olfactory receptors cells is done by electrical chemical sensors array and it also consists of a pattern recognition system for characterizing the specific components of odor [1]. It is even better than the dogs of bomb squad when it comes to smelling. Basically sensors generate a time-dependent electrical signal in response to the interaction of an odor with sensor itself. The sensors technology of artificial olfactory had its very beginning with the invention of the first gas mutli-sensor array in 1982. The development of a device capable of measuring and characterizing various aromas became possible with the advances in odor sensor technology, electronics, biochemistry & artificial intelligence.

Fig.1: E-Nose Systems

The term "E-Nose" was invented in 1988 by Gardner & Barlett [1]. An example of E-Nose is shown in Figure1.The interest or the awareness of extracting pure compound spectra from the complex chromatograph begun with gas chromatography and mass spectrometry by Biller and Biemann in 1974. The use of mass spectrometer as a detector was first introduced by Roland in 1950's. Further Biller biemann came up with GCMS technique which identifies the various components especially the volatile organic compounds in complex mixtures. It comprises of two techniques Gas chromatography and Mass spectrometry. GC separates the components of mixture by fractional distillation and MS characterizes each of components equally by converting them into ions so that they can be moved about and manipulated by electric and magnetic fields. GCMS is widely used in medical, pharmaelogical, environmental and law enforcement fields. For complex odors which comprises of multiple odorant molecules several receptors are activated .The resulting receptor pattern determines the impression of odor.

II. EMULATION OF E-NOSE AS BIOLOGICAL NOSE

Just like Biological Nose an E-Nose can simulate mammalian olfactory responses aromas [6]. The function of inhaling is done by the pump which leads the gas to the sensor whereas this work is done by lungs in biological nose. The gas inhaled by pump filtered by inlet sampling system in Electronic Nose which is done by mucus membrane in Biological Nose. Next comes the sensing of filtered gas which will be done by sensors in E-Nose and by Olfactory Epithelium in Biological Nose. Further in E-Nose the chemical retain occurs which in human body is enzymal reaction. After this the cell membrane gets depolarized which is sending of electrical signals in the E-Nose. At last signals are transferred as nerve impulse through neurons.

III. SYSTEM MODEL

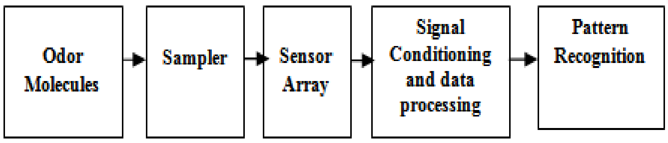

Fig.2: Block Diagram of working of E-Nose

An electronic nose system broadly comprises of a multi-sensor array, a sampling unit such as ANN (Artificial Neural Network) [2]. The system model of E-Nose is defined in figure 2. The various sensors chosen to respond to a wide range of chemical classes and differentiates diverse mixtures of possible analysis. The output from each sensor is collectively assembled and further integrated in order to produce a distinct digital response pattern. This pattern response is identified and classified through recognition of the unique odor signature of collective sensors response. A reference library of known samples signatures is formed prior to analyze which compares the mapped samples with the standard samples values and classify them accordingly. All types of signatures pattern are differentiated by ANN. The process continues until a previously selected level of discrimination is met. The end results are checked and assembled into reference library to be compared.

So an air sample is simply pulled by vacuum pump through a tube (the tube may be of plastic or stainless steel) into a small chamber having an electrical sensor array, which is exposed to the sensors via sample handling unit, sensors produces a transient response as the VOC's (volatile organic compounds) interact with the active material, the signal processing unit receives the recorded sensor response and the odorant mixture is separated from active material by washing gas such as alcohol. Various sensors used in E-Nose are explained as follows:-

A. Various sensors used in E-Nose

a) Optical sensors

These sensors are most commonly used type of sensor in E-Nose. The optical sensors not only detect but also measure the modulation of light properties. The optical sensor is modified so that the quantity to be measured modulates intensity, phase, polarization, wavelength or transient time of light in optical sensor. Special fibers like long-period fiber grating optical fibers can be used for direction recognition. The output can be obtained at sensor spot with REDFLASH dye. An optical sensor is shown in figure 3.

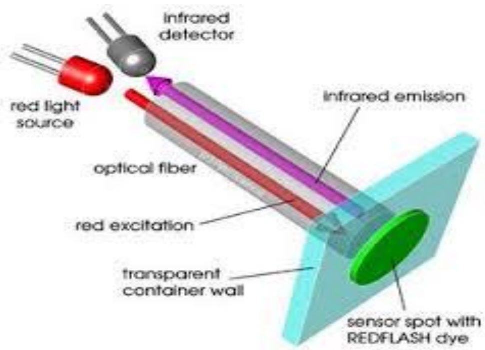

Fig.3: Optical sensor

b) MOSFET type gas sensors

In MOSFET (Metal Oxide Semiconductor Field Effect Transistor) shown in figure 4, gas sensors gate (metal contact mainly made up of polysilicon) is attached to an insulator. The metal absorbs and dissolves hydrogen. So MOSFET sensor works as transducer to convert the chemical signals to electronic signals. This sensor works on principle that threshold voltage of the MOSFET changes when the polysilicon of the gate reacts with certain gases [9]. This happens because of the change in work function and we know change in work function changes drain-source current and gate-voltage current. And hence different electrical signalsare obtain when a chemical is introduced. The entire specification is shown in figure 4.

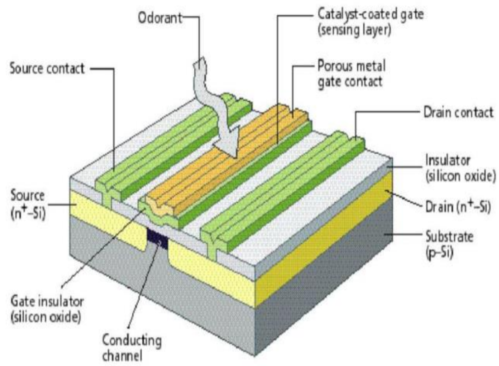

Fig.4: MOSFET Sensor

c) SAW Sensors

Surface Acoustic Waves sensors shown in Fig. 5 are type of micro electromechanical systems (MEMS). SAW sensors are based on principle of piezoelectric effect, it converts electrical energy into acoustic wave (longitudinal waves that has same direction of vibration as their direction of propagation), using an Inter Digitated Transducer (IDT). The acoustic travels across substrate to another IDT which converts it back to electrical signal.

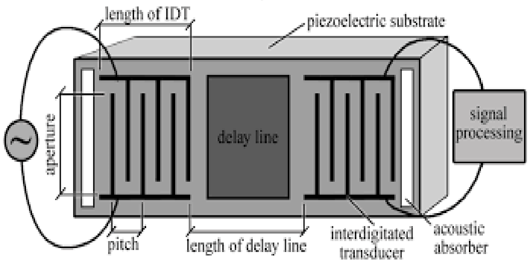

Fig.5: SAW Sensor

d) Quartz Crystal Microbalance sensor

Quartz is a crystal that experiences a piezoelectric effect that is converts the mechanical energy into electrical energy. When alternating current is applied to the quartz crystal sensor as shown in Figure 5 between the electrodes, oscillations will be produced and a shearing wave is generated.

When the sensor is exposed to atmosphere, it absorbs certain gases and the mass of crystal changes leading to change in frequency produced by the crystal, by measuring the change in the frequency atmosphere/gas can be analyzed.

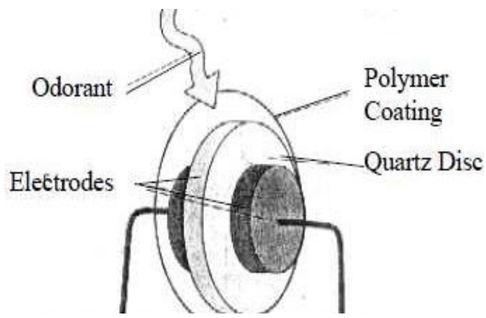

Fig.6: QCM Sensor

e) Conducting Polymer Sensors

A conducting polymer sensor consists of repeating units produced by Polymerisation as shown in figure 7. The conduction of electricity is possible due to presence of alternate single and double bonds in the backbone structure. The sensor adsorbs gas which leads to the change in their conductance and their resistance [12]. Hence this property helps to sense the odour.

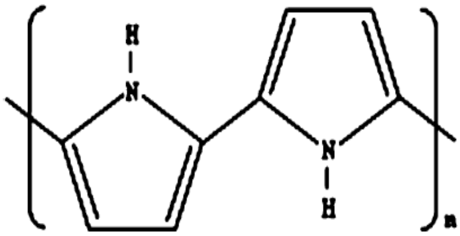

Fig.7: Conducting Polypyrrole Sensor

IV. NEURAL NETWORK AS PATTERN RECOGNISER

After sensing the chemical makeup the signature or pattern is produces by sensor array, so the next important step i.e. the recognition of pattern is done to identify and specify the component of E-Nose is done by Neural Network [3]. The artificial neuron is also known as the brain of every Neural Network takes the input from various neurons at two nodes via sensors and aggregates them with Synaptic weights (amplitude between the two nodes) and passes the result after processing it with suitable transfer function as the output. Hence various aromas can be detected by pattern recognition analysis of responses from various gas sensors that we have used [8].

V. EXERTION OF E-NOSE

E-Nose is designed such that it widely acceptable in various applications in number of industries for production processes. It has vast applications in the fields of automobile, food, drug, packaging, cosmetic, biomedical and many more. It is used in quality assessment of food as it is used in monitoring the freshness and ripeness quality of raw and manufactured products and controlling quality of raw and manufactured products [4]. It is used in premium products authenticity assessments and environmental assessment studies. And E-Noseis also used in detection of volatile organic compounds and microbial pathogen detection [5]. The various applications emerging out of E-Nose system is explained as:

1) Environmental assessment

E-Nose can play a prominent role in the assessment of various problems of environment such as the level of contamination of air by dust or polluting gas, balance in composition of different gases, the harmful gases present in air, greenhouse gases etc [9].

2) Medical

Though E-Nose is not commercialized yet but it has promising results in research field [11]. E-Nose has the applicability as a diagnostic tool to the physician. Various infectious and non-infectious diseases can be detected using E-Nose such as Tuberculosis, Diabetes even hazardous diseases like cancer and haemodialysis.

3) Non-Medical

Various applications such as to monitor quality of goods, sniffer dogs replacement, check on food quality and detection of hazardous gases like Nitrobenzene make use of E-Nose due to advancement in technology. E-Nose thus helps in security and maintenance of quality products and health of human being.

3) Cooking oils

With a surprise E-Nose is not only used in detection of harmful gases but also can be used for the detection of cooking oils [7]. Classification of extra virgin olive oil and normal olive oil or the phenolic compounds for oxidative status can be easily done by using an E-Nose with six metal oxide sensors.

4) Military

E-Nose is of great use in military related works such as it helps to keep a check on Personnel and Population Security, in maintaining and detection of biological and chemical weapons, explosive material detection.

VI. CONCLUSION

Human noses are not appropriate for repetitive task and there is a problem of boredom with human nose but this is not the case with E-Nose. But the selection of electronic nose for certain application is important as the E-Nose applications are highly dependent on required operating conditions such as cycle time, run speed data analysis and data interpretation. An E-Nose has world wide applications and has found its applications in various fields due to presence of arrays of different sensors. So it is appropriate to use E-Nose as a standard tool for detection and analysis.

VII. REFERENCES

[1] Electronic Noses: Principles & Applications, by J.W.Gardner and P.N.Barlett, Oxford University Press, 1999.

[2] B.S.Hoffheins, Using Sensors Arrays and Pattern Recognition to identify Organic Compounds. MS-Thesis, The University of Tennese, Knoxville, TN, 1989.

[3] G.A. Carpenter, S. Grossberg, N.Markuzon, Z.H. Reynolds, and D.B. ZRosen, "Fuzzy ARTMAP: A Neural Network Architecture for Incremental Supervised Learning of Analog Multidimensional Maps," IEEE Transactions on Neural Networks, vol.3, 698-713.

[4] P.E. Keller, R.T. Kouzes, and L.J. Kangas, "Three Neural Network Based Sensor Systems for Environmental Monitoring," IEEE Electro 94 Conference Proceedings, Boston, MA, 1994, pp. 377-382.

[5] H.V. Shurmur, "The fifth sense: on the scent of the electronic nose, "IEEE Review, pp. 95-58, March 1990.
[6] K. Pope, "Technology Improves on the Nose As Science Tries to Imitate Smell." Wall Street Journal,pp. B1-2, 1 March 1995.
[7] A.M. Pisanelli, A.A. Qutob, P.Travers, S. Szysko and K.C.Persaud, "Applications of Multi Array Polymers Sensors to Food Industries, "Life Chemistry Reports, vol.11,pp 303-308, 1994.
[8] J.W. Gardner, E.L.Hines, and M. Wilkinson, Application of Artificial Neural Networks to an Electronic Olfactory System.
[9] Kanan, S.M.; El-Kadri, O.M.; Abu-Yousef, I.A.; Kanan, M.C. Semiconducting metal oxide based sensors for selective gas pollutant detection. *Sensors* **2009**, *9,* 8158-8196.
[10] Smejkalova, D.; Piccolo, A. High-power gradient diffusion NMR spectroscopy for the rapid assessment of extra-virgin olive oil adulteration. Food Chem. **2010**, *118*, 153-158.
[11] Aishima, T. Discrimination of liquor aromas by pattern-recognition analysis of responses from a gas sensor array. Anal. Chim. Acta 1991, *243*, 293-300.
[12] U. Lange, N.V. Roznyatovskaya, and V.M. Mirsky, "Conducting polymers in chemical sensors and arrays," Anal. Chim. Acta, vol.614, 2008, pp. 1-26.