ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

Soil pH Sensing Techniques and Technologies- A Review

Sachin Kumar[1], Babankumar[2], Ritula Thakur[3], Manish kumar[4]

PG Student, Dept. of EEE, NITTTR, Chandigarh, India[1]

Senior Scientist, Dept. of Agrionics, CSIR-CSIO, Chandigarh, India[2]

Assistant Professor Dept. of EEE, NITTTR, Chandigarh, India[3]

Dept. of Agrionics, CSIR-CSIO, Chandigarh, India[4]

ABSTRACT - This paper presents the review on different concepts of soil pH detection techniques and technologies. Soil pH is a key parameter for crop productivity therefore its spatial variation should be adequately addressed to improve precision agriculture management system. Soil pH affects the soil's physical, chemical, and biological properties and processes, and thus plant growth. Soil pH, a measure of hydronium ion (H+) concentration traditionally tested in labs to decide how much fertilizer to apply to a field. Recently, with increased emphasis on precision agriculture, economics, and the environment, soil tests are also a logical tool to determine areas where adequate or excessive fertilization has taken place. In addition, they are used to monitor the impact of past fertility practices on changes in a field's nutrient status. Therefore, developing rapid tools which can detect pH variations on a site-specific basis has become pressing need of the hour because laboratory based methods are inadequate, time consuming, laborious, and expensive. From above perspective, this paper attempts to present review of existing suitable methods, deliberations on pros and cons, and a proposal for pH sensor development which could transmit data wirelessly.

KEYWORDS - Soil pH, acidity, precision agriculture, alkalinity, ISFET detection method.

I. INTRODUCTION

Precision agriculture is a farm management strategy based on sensing position and information technology which may contribute to further optimize soil and crop quality, production levels, sustainability, food safety and farm profitability. Currently, the ability to obtain soil analysis in a rapid and cheap way is a big challenge for precision agriculture. During last two decades micro system technology has been improved to great extent.

Both, the speed or rate of chemical reactions and the solubility of chemicals or biomolecules are dependent on pH [1]. Also, soil pH, has great importance because of its relevance in chemical and biological processes for example, the nutrition growth and yields of most crops decrease where pH is low and increase as pH rises to an optimum level. Many crops grow best if pH is close to neutral (pH 6 to7.5) where as some crops prefer acid or base soils.

Mathematically, soil pH is defined as the negative logarithm (base 10) of the H^+ concentration (moles per liter) in the soil [2]. As the acidity of the H+ in the soil increase the soil pH value decrease. Soil with pH value below 7 are referred to as "acidic" and those with pH values above 7 as "alkaline", soil at pH 7 are referred to as "neutral". In acid soils Ca, and Mg, NO_3-N, P, B, and Mb are deficient whereas, Al and Mn are abundant while in very alkaline soil P, Fe, Cu, Z and B are frequently deficient.(as show in fig.1).

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

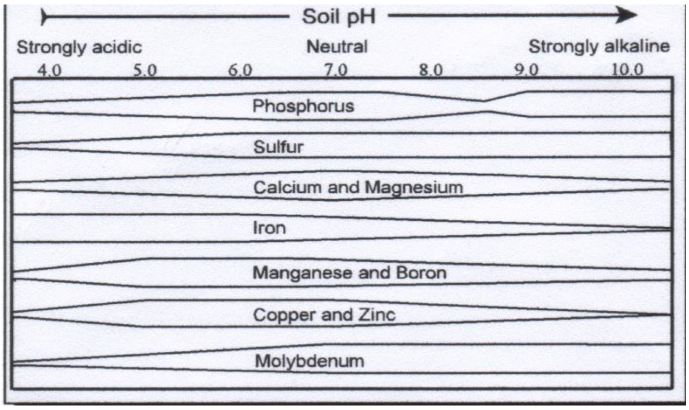

Fig.1 Effect of soil pH on nutrient availability

There are several techniques available for soil sensing. The most common is glass electrode based, discovered by Cremer in 1906 [3], and is still found in many laboratories. The glass electrode produces fast, accurate and reliable readings, however, suffers from a number of drawbacks, such as complexity of construction, fragile materials involved and the need of frequent calibration. Because of these drawbacks, glass electrodes are not ideal candidates for miniaturization. Other approaches have been developed with miniaturization as their main design objective.

The ion sensitive field effect transistor (ISFET), produced by Bergveld in the 1970's, was one such approach based on the design of the standard metal oxide field effect transistor (MOSFET) transistor [4]. In this gate metal was replaced with a reference electrode and the gate oxide material is exposed to the solution under test. Due to chemical reactions between the ions in the solution and the gate oxide material, the drain current through the device will vary. This variation in drain current was shown to be pH sensitive. Numbers of disadvantages were the drift of the device response over time, which also exposed a second drawback of the poor sensitivity of the devices.

The potentiometeric approach also shows promise in the area of pH sensing and has been regularly exploited [5]. This sensor type uses two electrodes, one coated with a pH-sensitive material, while the other is fabricated from an inert material (Ag/AgCl), which acts as a reference electrode. The sensor functions by measuring the open circuit potential between the two electrodes when the senor is in contact with a solution. The resulting potential is pH-dependent. This is a successful approach in terms of functionality and repeatability. The inter-digitated electrode (IDE) structure is required to increase the sensing area of the devices upon miniaturization.

Another work investigates another sensing approach for pH measurement i.e. conductimetric sensors. It has been exploited as gas sensors, and can also be used for pH sensing. A standard conductimetric sensor consists of two identical electrodes, between which a sensing layer is deposited.
There are various techniques for soil pH sensing but the present paper discusses only two techniques which are most efficient and recent techniques for soil pH sensing.

II. SOIL pH SENSING TECHNIQUES

A. Ion selective field effect transistor -An ISFET is an alteration of the typical field impact transistor utilized as a part of numerous speaker circuits. In the ISFET, the metal door, which is ordinarily utilized as data, is supplanted by a particle touchy film, the deliberate arrangement, and a reference terminal (as indicated in Fig. 2). In this manner, an ISFET joins in one gadget the sensing surface and a sign enhancer which delivers a high current, low impedance yield and permits the utilization of associating links without exorbitant protecting [6-7].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

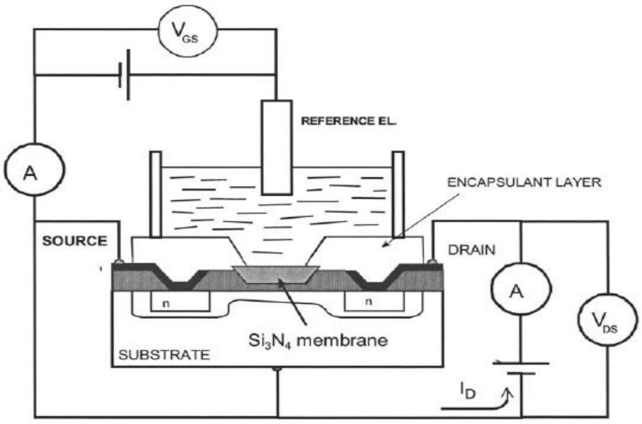

Fig. 2 Scheme of the ISFET mechanism of response and the electronic circuit associated with it.

Dissimilar to glass electrodes, where the pH-sensitive knob must be loaded with a support arrangement, the ISFET semiconductor innovation brings about a genuine strong state pH sensor. The entire microchip is implanted in plastic in such a route, to the point that just the gate surface is left open to be in contact with the sample. By supplanting the delicate glass globule with the implanted microchip, a powerful and without glass pH measuring gadget can be outlined. The last anode consolidates in one plastic lodging, the pH-sensitive ISFET device, reference terminal and a temperature sensor [8].

The ISFET uses a different mechanism for measuring pH from that of traditional glass electrodes. The measurement principle is based on the control of the current flowing between two semiconductor electrodes. These two electrodes are called drain and source electrodes and placed in a silicon chip together with a third electrode (gate) between them. The gate is in direct contact with the solution to be measured. The gate electrode consists of a special chemical layer, which is sensitive to hydrogen ions.

Materials like silicon oxide (SiO2), silicon nitride (Si_3N_4) and aluminum oxide are used in the pH sensing layer. Hydrogen ions will reside at the surface of the chemical layer in proportion to the pH. The positive charge of the hydrogen ions produces an electric field that influences the current between the source and drain. Therefore if the pH value changes, the current through the transistor will change accordingly. To maintain the drain–source current at a constant value a control voltage has to be applied through the reference electrode. The change in the control voltage is a measure of the pH value of the sample.

B. Conductimetric pH sensor -A polymer is a chemical compound constituting repeated structural units formed by the process of reacting monomer molecules to form polymer chains. This process is called polymerization. The main advantage of using polymers for sensor applications is their relative low cost and ease of fabrication. Most of sensing applications use polymers. This is because their physical properties (e.g. volume) or chemical properties (e.g. ion concentration and hence conductivity) will change when they react with external materials (e.g. nutrients, pH, temperature, humidity and soil moisture) [9].The high application potential of conducting polymers (CP) in chemical and biological sensors is one of the main reasons for the intensive investigation and development of these materials. A standard conductimetric sensor consists of two identical electrodes, between which a sensing layer is deposited (as shown in Fig.3).

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

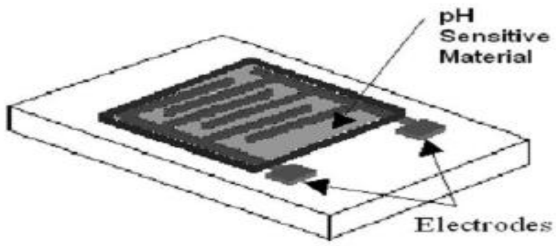

Fig.3 Conductimetric pH sensor

In conductimetric pH sensor poly-aniline (PANI) is chosen as the pH sensitive material to be deposited over the inter-digitated electrode (IDE) structure. PANI is a conducting polymer and has shown its suitability as a pH sensing material in many applications [2]. The conductive material used was Ag thick film conductive paste (Heraeus Materials).

III. FUTURE WORK

Author proposes to develop an in-situ soil pH sensor with nano-particles of antimony and zinc which will overcome the existing drawbacks and requires no power source for its operation. The design of proposed soil pH sensor is shown as fig.4.

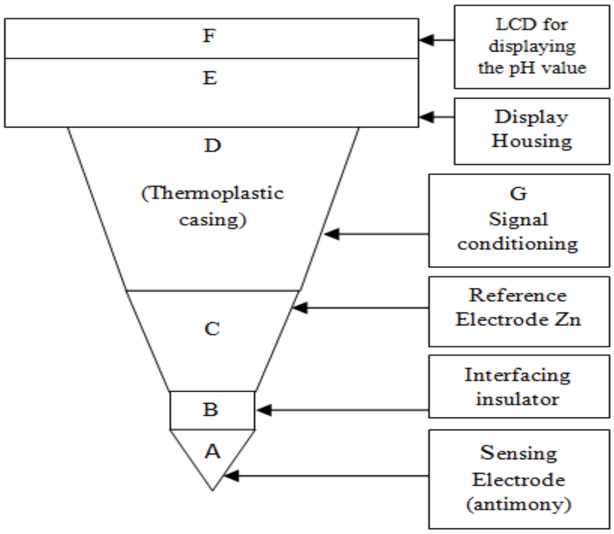

Fig.4 In situ soil pH meter with metallic nano-particle sensor

A conical shaped sensing electrode (A) interface with a reference electrode (C) through the interfacing insulator (B). The electrodes (A&C mention in fig.4) connected to a signal conditioning network (G).The signal conditioning network being enclosed in a thermoplastic casing (D) and being connected to a LCD (F) for display of pH value. The proposed device will be portable, simple and easy to use in-situ pH meter for direct measurement of soil pH. The use of nano-particle in the formation of reference electrode will increase the sensing efficiency of the sensor.

IV. CONCLUSION

The presented work, reviews the soil pH sensing techniques based on ISFET and Conductimetric technology, and since both of the technologies have some drawbacks, a new way is proposed. Hence this paper proposes the implementation

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

of an efficient and improved in-situ soil pH sensing approach based on nanotechnology, in which nano-particles of ZnO will be used to increase the sensing efficiency of the electrodes.

ACKNOWLEDGEMENT

The Authors are grateful to director CSIO for his kind support, guidance and the permission to carry out above research work.

REFERENCES

[1] Arousian Arshak', Edric Gill, Khalil Arshak, Olga Korostynska and Colm Cunniffe" Drop-Coated Polyaniline Composite Conductimetric pH Sensors" ISSE2007
[2] Muhammad Imran Khan1, Abdul Mannan Khan2, Ahmed Nouman3, Muhammad Irfan Azhar4,Muhammad Khurram Saleem5" pH Sensing Materials for MEMS Sensors and Detection Techniques", *International Conference on Solid-State and Integrated Circuit vol. 32 (ICSIC 2012)p.p18-22*
[3] J. D. R. Thomas, "Devices for Ion Sensing and pH Measurements", *Pure AppliedChemistry,Vol.Vol73,No1,2001,pp.31-38*.
[4]P. Bergveld, "Development of an Ion-Sensitive Solid- State Device for Neurophysiological Measurements", Ieee Transactions on Biomedical Engineering, Vol. BM17, No. 1, 1970, pp. 70
[5] A. Eftekhari, "pH sensor based on deposited film of lead oxide on aluminium substrate electrode", *Sensors and Actuators B: Chemical, Vol. 88, No.3,2003,pp.234-238.*
[6] Ph Duroux, C Emde, P Bauerfeind, C Francis, A Grisel, L Thybaud, D Armstrong, C Depeursinge, A L Blum "The ion sensitive field effect transistor (ISFET) pH electrode: a new sensor for long term ambulatory pH monitoring", *Accepted for publication 23 April 1990*
[7]. J. Artigas, A. Beltran , C. Jime´nez ,*, A. Baldi , R. Mas , C. Domı´nguez , J. Alonso "Application of ion sensitive field effect transistor based sensors to soil analysis" *J. Artigas et al. : Computers and Electronics in Agriculture 31 (2001) 281–293*
[8] I. Schaepman" pH measurement using ISFET technology", published in LabPlus international - October 2005
[9**].** Vinay S. Palaparthy,Maryam S. Baghini,Devendra N. Singh"Review of polymer-based sensors for agriculture-related applications**",***Emerging Materials Research Volume 2 Issue EMR4, Published online 23/07/2013*
[10].Ulrich Lange, Nataliya V. Roznyatovskaya1, Vladimir M. Mirsky"Conducting polymers in chemical sensors and arrays",*analytica chimica acta 6 1 4 (2008) 1–26*