Agricultural Soil Moisture Sensors and Potential Use of Nanomaterials in Fabrication of Soil Moisture Sensors

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Abstract

The soil consists of organic matter, air, mineral matter and water. These components played an important role in the growth and development of plants. The soil has a number of categories. The basis of classification also differs between disciplines. For instance, soil taxonomists and others are completely different from the definition of engineers. Soil can usually be graded on the basis of soil consistency and grain size. The soil has various properties and has an effect on the distribution of the soil moisture. Some of its characteristics are the composition of the soil, thermal conductivity, color, electrical conductivity and soil color. Various soil classification methods are available. This paper provides a study and potential preparation of the sensors for soil moisture from nonmaterial. The soil introduction is discussed, the role of nanotechnology in the agricultural field, the definition of soil moisture, the need to detect soil humidity and the methods of detecting it. Several researchers also address the function of detecting this moisture content of the soil parameter. Ultimately, on the basis of current work, the judgment will be made, specific suggestions and future prospects.

Key words: Agriculture, Nanotechnology, Nanomaterials, Soil Moisture Sensor, Soil Temperature Sensors

Introduction

Depending on the discipline defining, there are several definitions of soil: some are geological, traditional definitions, definitions of the component and definitions of soil taxonomy. For plant growth, the profile of the soil is 100-200 cm in size[1]. Most plants have a maximum length of 100 cm. Many plants are 120 cm long. The soil contains mineral matter, air, organic matter and water. These components played a major role in plant development and growth. There are many classifications in the soil. The classification criteria therefore vary between disciplines[2], [3]. The definition of engineers for instance is totally different from soil taxonomists and others. Soil can usually be categorized on the basis of soil consistency and grain size. Various soil classification schemes are available[4], [5]. The "Unified Soil Classification System" (USCS), "US Department of agriculture" (USDa) and the "American Association of State Highway and Transportation Officials" (AASHTO) system of classification. The soil has various properties which influences the transfer of soil moisture. The soil texture, bulk density, soil structure, soil color, electrical conductivity and thermal conductivity are some of the attributes[5], [6]. Any soil component influenced by plant growth and growth is measured or detected. Some of them include nutrients, pollutants, water/moisture, ph, temperatures, electrical conductivity, structure, color, and bulk densities.

1. Nanotechnology Role in Agriculture:

Agriculture is the use of biological processes in agriculture for food production and other goods that are valuable and important for humans. The top ten application fields of nanotechnology have been listed and clustered in developing countries. Agricultural development in the developing country was focused on their classification of regions[7], [8]. They found that nanotechnology should be used to promote agricultural production in order to reduce and eliminate extreme poverty in developing countries. As a result, nanotechnology has put agricultural enhancement in the second place. In all phases of production, storage, processing, packaging and transport of agricultural products nanotechnology has many applications. Nanotechnology, by new techniques such as precise agricultural techniques, managed environmental agriculture, the capacity for plants to consume nutrient resources, the more efficient and focused input use, disease control and disease identification, effective treatment and environmental pressure, storage and distribution systems will be revolutionized by nanotechnology. By using nanoparticles in the animal sciences, the effectiveness of medication improves[9], [10]. In the treatment and disinfection of animal and poultry, nanoparticles are in use with silver and iron. Nano smart dust and gas sensors can quickly assess environmental pollution levels. The use of sensors based on nanomaterials allows for soil parameters such as moisture, the temperature, pHS, and nutrients to be identified and possible correcting.

2. Soil Moisture Sensors:

2.1. Soil Moisture:

- **Soil Moisture Content:**

Soil moisture content was defined as a quantity of soil water and soil water capacity in two different terms. Soil water content is the amount of water which can be evaporated by heating from the soil to about 100-110ºC, normally to 105ºC, before any further weight loss occurs. Soil water capacity defines the soil water's energy state and is used to measure water flow, to quantify the stored water and to relate soil and plant to water. A water potential difference between two soil positions is representative of a water flow pattern from high to low. In fact, the soil water content is usually changed over time (for example, seasonally shifting field conditions or changing in response to irrigation). Additionally, the amount of water between different levels (i.e. between limits of plastic and liquid, or between capacity of ‘‘wilting point’’ and ‘‘field capacity'') can be needed. Once humidity falls below the wilting level (wilting point), the minimum point of soil humidity that the plant does not need to wilt or any plant with a lower point is specified and cannot decompress its turgidity any more when put in the saturated atmosphere for 12 hours. The moisture content of the soil is 0-100%.

- **The Requirement for Soil Moisture Measurement Content:**

A significant part of the soil is the volumetric water content, affecting various microbial, chemical and physical processes. In the growing of plants three of the main considerations are the nutrients of the soil and the properties of the soil; secondly, the soil moisture is the property of the soil. Agricultural soil moisture measures have the following objectives: Water saving, automatic irrigation, product or output increases, soil salinity control and control of soil erosion.

2.2. Moisture Content Factors Affecting Soil:

Factors influencing soil moisture content include structure, texture, organic matter, soil density, temperature, depth of soil, salt content, etc.

2.3. Soil Moisture Content Measurement:

The diagram below shows the general classification of soil measurement methods available (Figure 1). The advantages and disadvantages of each method have their own.

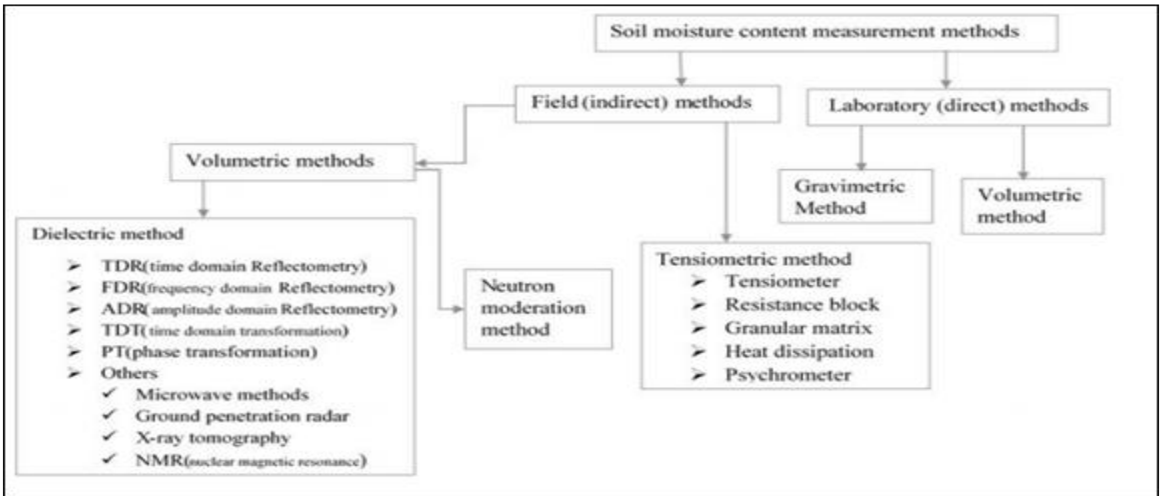

Figure 1:- Soil Moisture Content Measurement

2.4. Gravimetric Measurement Method:

It is a method based on the mass of components and defined as shown in Equation 1, of direct laboratory soil humidity assessment. The basic technique of soil water measurement is used by people. This approach is the standard by the other methods, because it is based on direct measurements. Gravimetric samples, however, are destructive and measurements of the same soil sample cannot be rendered and destructive.

$$\text{Gravimetric soil moisture content } (\theta g) = \frac{mass of water}{mass of dry soil or mass of sample soil} = \frac{mass of sample soil - mass of dry soil}{mass of dry soil or mass of sample soil} = \frac{Mwater}{Msoil} \quad \text{.......... (1)}$$

2.5. Moisture Content Measurement Method of Volumetric Soil:

Due to the level of evapotranspiration, flux expression of precipitation and liquid transfer, water content volumetric expressions are more efficient. The volumetric soil humidity value of the laboratory may be measured as follows:

Volumetric soil moisture content (θv) = volume of water content/volume of samples soil = (Mwater/ρwater)/ (Msample/ρb) = (θg$*\rho$b) /ρwater……………………………….. (2)

Here ρb is the dry soil bulk density.

The issues with the accurate measurement of soil and water quantities typically do not directly determine the volumetric water contents. This approach is therefore used to measure indirectly the soil moisture content. Since indirect use of the measurement system of volumetric soil moisture content is equivalent to a direct process. Thermal soil conductivity estimation may be designed as either a separate distance heater or sensor with no porous block or contact temperature sensor and porous block heater. The investigator has designed a new sensor for soil heat dissipation with only one bipolar transistor acting as an aspect for the sensing of heat and temperature. The block used was porous. As a temperature detector or sensor, the input power was (VCE*IC) and (VBE α T). Some of the advantages of the proposed sensor were low power usage, small size, and minimal heater, and high efficiency, low cost and high efficiency. The sensor is almost ten times higher than that used in traditional sensors with different heating and sensing components. The suggested sensor has a temperature increase of around 7.5°C -9.1°C for the applied energy (80 MW in a period of 45 s), while the traditional porous block test shows an improvement of only 0.8 oC-1.5 °C for the temperature. The sensor may not function for a long time and takes a while before the moisture is distributed within the porous block. Researchers proposed the soil humidity meter design using the soil thermal conductivity properties. Here a certain distance was distributed between the heater and the heat sensors. The voltage of the IC sensor output is mostly linear to the moisture content. With the rise in temperature and soil moisture, the voltage production is increased. This is because the moisture content in the soil decreases and the space overflows and the thermal conductivity increases. The system comprised a pipe consisting of a hollow pipe made of PVC, an emitter-based transistor as a heater, an AD590 temperature sensor, an IV converter and an enhancer for the biasing of transistors. The power output of the amplifier system is measured in such a way that 1mV is equal to 1 ° C. Low cost, higher accuracy and linearity were the key benefits of the proposed sensor. Researcher simulates, Modeled and checks a silicone-based heat pulse moisture sensor. The measurement sensor mounted at a certain distance from the heater source monitored the maximum temperature change (TM). It was dependent on the application of a heat pulse at a specified interval of time. A small CMOS transistor temperature sensor, high cost and high performance has been designed and manufactured to insert into the 0,912 mm inner and 20 mm long test sample. If the water content spectrum is known, the water mass ratio of dry soil mass was approximately 1.96 ° C ($m3\ m{-}3$) per unit change in the average agricultural soil, in water contents q= 400 Jm−1. A capacitive soil moisture sensor was prepared by the researcher. The quantity of measurement at the frequency 32 MHz was a complex permittivity. It was extracted by a capacitive sensor impedance calculation of a fork-like configuration considered to the right geometry for field application. The impedance can be measured using a twin T-bridge optimized for the wide range of natural soils permittivity. A study of soil permeability measured showed a prevailing effect on dielectric permittivity of the liquid water material. For soil moisture tests, the investigator has designed a multi-chip module micro device. In order to assess the volumetric heats potential and thus the quality of water of soil, a dual-speed heat pulse technique (measurement of maximum temperature rise some distance from the heater, and application of a heat pulse for a short period of time) was implemented. High accuracy CMOS intelligent temperature sensors were the temperature sensors (reference and probe). The researcher built a system to measure the level of soil moisture utilizing dual heat pulse sensors. T-type Thermocouples were used for the temperature sensor and the heater was used with a Cu coil. The heater and sensor were separated with a distance of 0.5 cm during installation and 2 cm long. DC was supplied for 120 seconds on the heater 1.5V. The machine consisted of the amplifier, ATMEGA 16 Microcontroller, built-in ADC, LCD displays, and RF XBee Pro modules for the transfer to a far apart computer of analog values from the microcontroller. System data processing in MATHLAB was completed. The machine has been tested for different containers of volumetric soil humidity on white clay soil. The results showed that the temperature increase was inversely proportional to the soil moisture content increase. The thermocouple's outgoing voltage at the two poles increased by 85 µV at 2.2% soil moisture, while at 80% soil moisture it changed to about 49 µV. The heater can be made from the semiconductor metal oxides for the sensor of soil moisture. For example, through home-made pyrolysis technology, researchers have produced micro heaters from the SnO_2 film on aluminum substrate. During coating, the substrate temperature was maintained at 450 ° C. For some time, the deposited substrate was annealed to the air at 700 ° C. Transparent heaters were sprayed on a glass substrate directly. The coating procedure was produced without the use of the clean room or high-temperature manufacturing in normal production conditions. The spray paints included a mixture of multi-walled carbon nanotubes and graphic platelets, which are applied to the optical and electrical properties as a functional process. The color rheology has been changed to suit spray process standards. Layer morphology was studied using electron and profilometer scanning microscopy. The experiment was exterminated in order to achieve a consistent heat distribution and was further tested for accelerated aging. The result has been shown to be an effective and promising process for the manufacturing of large areas of heated glass. A new type of capacitive sensor coated with the polymer material, known as "DQN 70," has been employed to determine the moisture content of the soil. The latest kind has been designed and developed for the sensor detection. As the coating material and its impedance performance were tested for the correct coating material three separate BPDA-mPD, PMMA andDQN-70 polymers were taken. DQN-70 demonstrates the repeatable and consistent efficiency of these three components. The power shift of the sample was measured and converted to a voltage signal at a different moisture level. To calibrate the sensor performance, the thermo gravimetric approach was added. The study was more than three months inside the soil and provided a consistent output.

The researcher developed a Soil Moisture Sensing System for the implementation of Smart Irrigation dependent on resistance differences of the soil among the samples. The experimental results showed that the resistance changes and the soil water content were related to each other, i.e., soil resistance decreased with increasing water content. The water has been built with two metal bars, which have been bound together using an insulation tape, since water is a strong conductor of electricity in the face of ions. A low cost soil moisture sensor was manufactured by the researchers using a 2 cm diameter transparent tube made of plastic which was cut into small, 2 inches high tubes. Growing tube with a knife was slanting cut lengthwise and then connected to a tape to allow removal. This used to be the mold. A 1:1 ratio mixture of Paris Plaster and water was formed and poured without bubbles into tubes. In the mold galvanized 1.5-inch nails were carefully placed, and no touch was projected outside between the nails, with a fourth of each tooth. It was used as an electrode. The whole configuration had to be set for 24 hours after removing the plastic tube. It was a soil moisture sensor resistance type. Researchers have used a modified nanomaterial probe and have conducted a Soil Moisture Sensing project using Arduino Uno and GSM Sim900 Interfacing. They used two electrodes, one being Al and one being the polyaniline electrode plated in the nanoparticle. The goal of the nanoparticles was to increase the conductivity of the probe. Some of the disadvantages of a soil-based resistance-based measuring device are the distance-dependent separation, soil-dependent, and low resolution of the sensor. The investigator made a low-cost soil moisture sample probe with a capacitive touch sensor and thin film condensers. The amount of soil moisture was related to capability of the condenser. As an electrode plate the condenser was constructed from the electrode samples. The condenser was developed with low cost soil moisture sensors using a film substrate condenser and an integrated capacitive touch circuit. With a depth of 20, 10 and 30 cm, the produced recorded dynamic changes in the soil's moisture and the sensor had to be mounted between the condensers and the soil for between 10 and 14 days after deployment. Researcher reported that $BaTiO_3$ nanosized may be used as a constant heater for estimation of soil moisture content based on thermal conductivity. The DPHP (dual-probe heat pulse) system used a heater (Peltier effect) and a temperature sample to measure the volumetric heat capacity of soil and consequently the water content (V). On-Chip Included Silicon Bulk-Micro machined soil moisture sensors have been developed. This is the first time a micro device uses the DPHP system and the first embedded soil moisture monitor. This micro device is best suited for non-destructive and automatic analysis at different soil depths.

Conclusion

The soil is the main resource on the surface of the Earth. It's sometimes known as the life of all living creatures on earth. Soil will comfortably support living and non-living things if they are optimal. Optimal soil includes its materials in an acceptable structure, both in nature and in quantity for living and non-living things. The main component of the soil, especially the soil moisture content, affects living things on the ground. The amount of moisture in soil determines a country's agricultural productivity. Plants need maximum moisture or water to grow and perform properly. The benefits of measuring soil moisture are water quality, weather forecasting, soil erosion prevention and increased productivity. Some of the disadvantages of inappropriate plant watering include soil erosion, loss of water, plant wilting and reduced production of plant. Therefore, it is somewhat convenient to quantify and calculate the soil moisture. In this respect, work has in the past been done with certain methods. The approaches are in particular gravimetric, volumetric and tensiometric techniques. Dielectric methods and neutron reduction approaches are the volumetric processes. The volumetric approach includes time domain reflectometry, the reflectometric method for Frequency domain, amplitude domain reflectometry method, the transition of time domain, phase and non-reflective techniques such as microwave systems, radar and nuclear magnet resonances. The methods for tensiometric therapies include the tensiometer, the granular matrix, the resistance block method, the heat dissipation method and the psychrometer. Nevertheless, these approaches still have their own drawbacks, such as high cost, low accuracy, temperature dependent, low resolution, calibration depending on the surface, slow response time, poor deployment, small area coverage for one sensor, operational complexity etc... Improving is therefore necessary. For example, the performance of soil moisture measurement devices can be improved using advanced materials.

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