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A overview of Humidity Sensors

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Abstract:

In this research article, a comprehensive overview of a significance of water content in air and the different techniques utilized to measure it. The review focuses the vital role of humidity in on earth. Various types of humidity sensors such as resistive, optical and ceramic sensors are elaborated. These sensors are vastly utilised in implementations like HVAC systems, weather monitoring, agricultural and industrial processes. A review facilitates understanding of sensors types, operational principles and properties which are crucial for selecting specific sensors for particular parameter and ensuring precise humidity measurements.

Key words: Semiconductor Metal Oxide (SMO), Humidity Sensors.

Introduction:

The sensors detects the stimulus and it responds to that stimulus in the appropriate electrical output. According to the requirement to measure the different physical property the various types of the sensors were designed. The sensor which detects the water vapour present in the atmosphere and gives output into electrical signal such a sensor known as the humidity sensor [1]

Capacitance Based Humidity Sensors:

The humidity measured with the help of sensor which basically operated on the key concept of the capacitances is known as the Capacitance-based humidity sensors. These type of humidity sensors are vastly implemented in the modern day humidity sensing technology due to simplistic procedure for the preparation of these sensors takes one step forward than other type of the humidity sensors. The wide application of these capacitive sensors are due to their broad operating range across the relative humidity RH% [2].

In the capacitive humidity sensors the variation in the value of the capacitance leads to measure the change in the atmospheric humidity.

The trilateral ways to vary the values of the capacitance are,

o The variation in the Dielectric Permittivity in the two plates.
o By changing the area of the overlaps in the twin plates.
o By varying the distance between twin plates.

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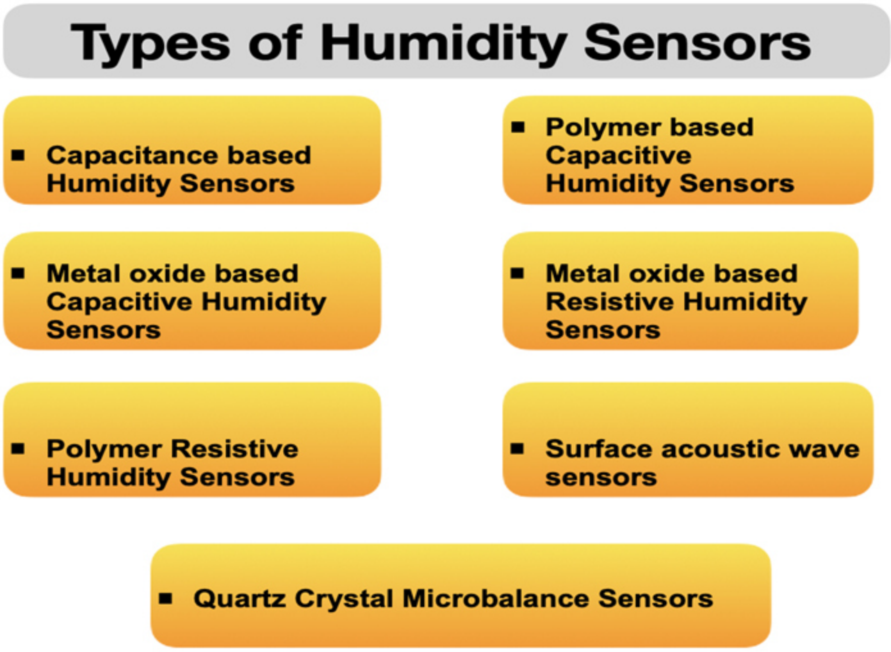

This concludes that only those vapours and gases are capable to vary one of the parameter from above gets detected via capacitive humidity sensors. The H_2O vapours in the atmospheric air impacts in these parameter which results into detection of the water vapours easily observed. The dielectric constant value changes as the variation on the atmospheric humidity occurs, an uncomplicated form of the this kind of the humidity sensor is Gap present between two plates and atmospheric air lies in the gap between twin plates.The increase in the atmospheric humidity results in elevation in the dielectric constant which detected in the humidity measurements of an atmospheric air. The capacitive humidity sensors works well but because of the lower the values of the dielectric permeability of the atmospheric air their sensitivity is very least. The sensor stability improvement make these sensor trustworthy to implement in the variety of the applications. The capacitive-humidity sensors stability enhanced whenever the material utilized for fabrication provides the fabricated material with the properties like the surface of the fabricated material capable to operate with stability even the water vapour condenses.

Polymer based capacitive humidity sensors:

The Polymer based capacitance humidity sensors [3] are the mostly implemented humidity sensors in the class of the capacitive humidity sensors. Unlike other materials utilized in the capacitive humidity sensors the Polymers are capable for quick reversibility and remeasures the water vapour contains in the air. These sensors fabricated in the both thick and thin films which operates with least of the lag in the humidity measurement the condensation of the water vapours in the surrounding doesn't makes significant affect on its operating capabilities. The change in the capacitance occurred when the interaction between the polymeric thin or thick films occurred. As the water vapour interacts with the polymeric material then the changes in the chemical properties and the physical properties observed. The change occurred in the dielectric constant, swelling in the polymer thin / thick films leads to slightly change in the physical dimensions of the sensor films, influences on the polymer material strength and variation in the conductivity occurred but the most prominent effect were change in the dielectric constant, the change in the dielectric constant allow capacitive humidity sensors to measure the water vapour percentage in the air. The polymer capacitive humidity sensors when interact with water vapours the swelling and change in the physical dimensions make these sensors very short- term reliable because of the surfaces of these sensor films causes creases which the damages sensor. The most of the polymer capacitive humidity sensors fabricated with the cross-linkage hydrophobic polymeric material [4]. These materials have better physical stability and damages due to variation in the physical dimensions also minimised results to long term dependable polymeric capacitive humidity sensors. When the synergy occurs between water vapour in the atmosphere and sensing material, the water vapours gets absorbed on the surface of the sensing material.

Metal Oxide Based Capacitive Humidity Sensors:

The ceramic composites which were the most stable materials at higher temperature environment, the thermally stability allows it to utilized as the sensor in the furnaces and other high temperature industrial area where water vapour prominently maintained along with the these metal oxide sensors have immensely larger surface area to volume ratios which avail the larger surface area for the water molecules in the water vapour which interacts with the sensor and responds to the water vapours percentage via changing in the capacitance.

These metal oxide sensors have an high sensitivity due comparatively larges surfaces in the ratio to volume of the metal oxide material.

The capacitive humidity sensors fabricated with the metal oxides nanostructures. These are of as follows,

o Binary oxides.
o Composites.
o Perovskites.
o Perovskites with the Layers.
o Perovskites consisting Composites.

The capacitance humidity sensor fabricated with the vast range of the metal oxide nanostructures. In the any sensor the physical condition like the temperature, water vapour, gases detect via interaction of these physical conditions with the sensor itself. As the water vapour interacts with the capacitance based sensor, the surface-morphology of the metal oxide material is responsible for the sensitivity. As the porous nature of the metal oxide material increases the sensitivity of the material for measurements of the humidity also increases and least porosity results into the decrease in the sensitivity.

The sensor is not made to take measurements of the humidity only once but the sensor have to operate continuously with repeating the procedure of the measurement.The response rate of the sensor depends on the size of the pores in the metal oxide nanostructures. Larger the pore size quicker the response of the sensors, the pore size exceeds than the 90 nm results in the quicker immediate response in the humidity measurements while the pore size in the metal oxide sensor below the 13nm responds with prolonged response rate.

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The capacitance variation depends on how the pores of the particular size distributed throughout the material. The metal oxides with the dielectric properties were the preferred for the capacitance humidity sensors fabricated by metal oxides. The polymer materials, metal oxide materials, semi-conductor metal oxides utilized in the fabrication of the humidity sensors. An aluminium exploited to electro-chemical itching and the aluminium oxide Al_2O_3 were prepared. The pioneer ceramic the Al_2O_3 material which was the first time utilized in the capacitance based humidity sensors. The surface of the metal anodised to form the Al_2O_3 have the porous surface which makes it compatible for the practical implementation as the humidity sensor [5].

The sensor is reliable and the stable at higher temperatures as well as increased humidity levels.The condensation of the water vapour on the sensor causes the change in the dielectric constant. The Al_2O_3 sensor as the Al surface subjected to the anodised etching further oxidised, which results in the formation of the small pores on the surface these small pores are in the regular arrangement which are formed as the each pore was parallel to each other. These porous structures were highly sensitive to the water vapours as slight change in the humidity results as the condensation occurs in the pores.

The elevation in the humidity results in the increase in the condensation at each pores, the condensation changes the dielectric constant and these pores where align in the parallel pattern which cause sum of the capacitance of the each minute pores results in the total capacitance. The capacitance for the air with water vapours have greater capacitance than the air without the water vapours (dry air). The very fine change in the water vapour content of the also results in the condensation in the minute pores which changes the dielectric constant. The procedure of the anodised itching was better than the sputtering and other expensive techniques. The broad range of the measurement of the humidity give the advantage over other sensors. The linearity in the sensor response with increase or decrease of the humidity content in the air. The frequent calibration for capacitive sensors becomes chief priority for precise measurements.

Metal Oxide Resistive Humidity Sensors:

In this type of the humidity sensors the change in the water vapour in the atmosphere changes the electrical resistance. The resistive humidity sensors detects the change in the electrical conductivity through occurrence of these processes which are chemical- reaction, adsorption, diffusion. These processes carried out on the surface of the sensor.

The variation in the humidity detected as change in the current. The electrode printed or attached on the upper layer of the thick film layer which is the connected to the external circuit.

In the range of 10% to 90% relative humidity variation resistive metal oxide humidity sensors responds in 3 to 4 power to the tenth, which make these sensor quite responsive.

A very wide energy band gap semiconductors from group III-V as boron and gallium achieves advantage of high stability. The stability promotes these material in efficient operation with steady physical and chemical stability while sensors are operational.

GaN material have precision and exactness in atmospheric humidity detection, the robust nature kept operational even exposure to harsh chemicals remains unaffected.

BN nanostructure thin films operates at higher temperature surrounding above 500°C .

Polymer Resistive Humidity Sensors:

The Polymer Based Resistive Humidity Sensor there is standards for the sensors calibration is not fixed which allows to calibrate the sensor according to the sensor operational field and circumstances. The response and reproducibility makes the sensor seamless operational [6]. The surface impurity does not makes response lag but the accuracy remains as before works. The chemical have harsh and damaging effect on the sensor which makes the sensor non-operational. The sensor in which at the lower relative humidity below 10 %, very low conductivity observed that means the very resistivity.

At the relative humidity greater than 95 %, the conductivity also very high but that much high relative humidity will obstruct the sensing capabilities because the high water condensation not suitable for the sensors.The resistive humidity sensor have depend on the temperature parameter as the semiconducting metal oxide materials utilized in the sensors these material conduction varies. The Gravimetric Humidity Sensor [7] have classified in the various types which are mentioned as,

Quartz Crystal Microbalance Sensor:

Humidity is crucial factor, have effect on most of important processes in surrounding. Sensors which operates at variation in capacitance or resistance composed of the metal oxide, composites, ceramic materials have certain lacunas which affects the continuous working of the sensor. Few times sensitivity and response time delays at higher humidity. QCM type of sensors operates quite different, sensor measurements were precise but frequent fluctuations in the atmosphere induces the hysteresis.

Zero gas means least amount of wetness in small portion of gas that require for calibration of the sensor results to minimisation in inability of the quartz in tracing exact amount of humidity in around.

The piezoelectric electric crystals have small size, highly chemically stable and very responsive which utilized in as micro-balances. These crystals capable to transform the mechanical strain to the electric field as output.

The different types of gravimetric sensors fabrication varied from other but the all humidity sensation mechanism remains unchanged. Mass sensitive sensors actually depend on the vibrations generated by thin crystal layer the frequencies of vibrations are in in MHz.

As humidity in the atmosphere interacts with piezoelectric sensor, change in the vibrational frequency of the thin crystal layer acts as the measure for the humidity [8].

Surface Acoustic Wave (SAW) Sensor :

A colossal responsive to surface effects, minute variation on surface detected and extent of water vapour in air is observed. Alternation in water vapour content affect as condensation or evaporation on the surface that changes the resonance frequency sensor.

Sensor surface exploited to condensation and evaporation simultaneously, equilibrium exists in them and Dew Point is measured. Multiple stage thermoelectric components work to regulate temperature on sensors, Pt. resistors detectors monitors temperature.Condensation-evaporation detected by feedback controls temperature sustains the equilibrium [9-10].

The distinctive water vapour monitoring capability within wide temperature variation -20°C to near about 62°C with least delay in responsiveness.

Advantages:

• Highly Sensitive
• Sustainable in adverse parameters
• Reliable for over long life.
• Proficiency of sensor wide implementations.
• Extensive operational humidity range.
• Quick response

Disadvantages:

• High Signal disturbances
• Convoluted Circuits.
• Difficult for technical maintanance.

References:

[1] Lee, C.Y., & Lee, G.B. (2005). Humidity sensors: A review. Sensor Letters, 3, 1-15.
[2] Ishihara, T., & Matsubara, S. (1998). Capacitive type gas sensors. Journal of Electroceramics, 2(4), 215–228.
[3] Ingram, J. M., Greb, M., Nicholson, J. A., & Fountain, A. W. (2003). Polymeric humidity sensor based on laser carbonized polyimide substrate. Sensors and Actuators B: Chemical, 96, 283–289.
[4] Sadaoka, Y. (2009). Capacitive-type relative humidity sensor with hydrophobic polymer films. In E. Comini, G. Gaglia, & G. Sberveglieri (Eds.), Solid State Gas Sensing (pp. 109–151). Springer.
[5] Chen, Z., & Lu, C. (2005). Humidity sensors: A review of materials and mechanisms. Sens. Lett., 3, 274–295.
[6] Wu, T.F., & Hong, J.D. (2016). Humidity sensing properties of transferable polyaniline thin films formed at the air–water interface. RSC Advances, 6, 96935–96941.
[7] Radeva, E., Georgiev, V., Spassov, L., Koprinarov, N., & Kanev, St. (1997). Sens. Actuators B, 42(1), 11.
[8] Vetelino, K. A., Story, P. R., Mileham, R. D., & Galipeau, D. W. (1996). Sens.Actuators B, 35, 91.
[9] Glück, A., Halder, W., Lindner, G., Müller, H., & Weindler, P. (1994). Sens. Actuators B, 19, 554.
[10] Wohltjen, H. (1984). Sens. Actuators, 5, 307.