A COMPARATIVE STUDY OF RESISTIVE AND CAPACITIVE HUMIDITY SENSOR

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ABSTRACT

The measurements of humidity are very important in various fields and are extensively used in many residential and commercial purposes. Since last few decades the humidity sensors are being used to measure humidity. Researches have been conducting to measure humidity in different levels. However achieving high sensitivity is still a big challenge. New fabrication techniques are now being used to develop sensor structure for better sensitivity. Presently the humidity sensors available in the market are fabricated using polymers made up of organic materials, ceramic etc. There are two basic types of humidity sensors used to measure humidity, namely resistive and capacitive humidity sensors. In this paper a comparative study of resistive and capacitive sensors used for measurement of relative humidity are reported. Most of the industries these days require, humidity measurement including laboratories, in the preservation of food and preservation of old and important buildings and in many more areas. The methods used are based on range and advantages, limitations and sensitivity. The humidity sensor must have very high sensitivity, good linearity and response. In addition, the response should be linear and the cost should be low. **Key words:** humidity, sensor, polymer, ceramic

INTRODUCTION

The various methods of detection and measurement of Humidity are available in the literature [7]. Most of the industries these days require, humidity measurement including laboratories, in the preservation of food and preservation of old and important buildings and in many areas [1–6]. The methods used are based on range and advantages, limitations and sensitivity. The humidity sensor must have very high sensitivity, good linearity and response. In addition, the response should be linear and the cost should be low [5]. It is difficult to develop a sensing devices and instruments to fulfill all the parameters with required parameters. Presently the humidity sensors available in market are fabricated using polymers made up of organic materials, ceramic etc. [1, 2].

The ability of ceramic material to sense humidity is based upon ionic conduction; the presence of an adsorbed layer of water at the surface reduces the total sensor impedance due to the increase in the ionic conductivity, as well as capacitance due to the large surface area available for water adsorption. Porous metal oxide (ceramic) based sensors do not change at increased temperatures and high humidity and have high sensitivity. The dielectric constant of air is affected by humidity. As the humidity increases the dielectric also increases. The permittivity of some atmospheric air, of some gases, and many solid materials are functions of moisture content and temperature. Capacitive humidity devices are based on changes in the permittivity of the dielectric material between plates of capacitor. Various types of humidity sensors are based on optical, resistive, capacitive, gravimetric and hygrometric measurement methods. Today most of the techniques used based on capacitive sensing techniques because of less affected by temperature, good sensitivity and easy to fabricate [5].

Resistive sensors work on a similar principle to capacitive sensors, where electrical change is measured to produce a value for relative humidity. However the mechanism in this system is different although resistive sensors use a hygroscopic material similar to the capacitive system. The difference lies in the measurement of the resistance change in the material rather than the capacitance. A capacitive humidity sensor uses capacitive measurement, which depends on electrical capacitance. The capacitive sensor is composed of two metal strips, or electrodes, separated by a thin layer of insulated film. The insulated film absorbs moisture from the air and when the moisture comes in contact with the metallic strips it results in a voltage change. The output voltage measurement is recorded or noted and can be displayed using an analog meter, or converted into a digital reading that indicates the amount of moisture in the air [6-8].

Ceramic humidity sensor suffers low sensitivity over wide humidity ranges and lack of reversibility. Other materials like organic polymer can also be used but are not proved reliable. Ceramic materials possess the properties of chemically inert, robust and give fast response [9-11]. Present work is about the comparison of capacitive humidity sensors with resistive humidity sensors where change in humidity results in change in dielectric of capacitive sensor and resistance or conductance of the resistive humidity sensor. The sensor is placed in a hygrometer to measure relative humidity. The system also contains a probe, cable, electronics, and an output signal along with the sensor. The entire system work to measure the entire humidity range from 0% to 100%.

It is evident from literature that the capacitive measurements are extensively used because of their robust and stable with temperature changes and humidity changes as compare to resistive measurements. Although the capacitive sensor and resistive sensor have the similar aim to measure humidity, they differ in their methods. Capacitive sensors are proved to be more accurate and stable while producing repeatable results, making them more suitable for medical type applications where precision is paramount but are bit expensive when compared with resistive sensors. The less expensive resistive sensors are more used in the situations where frequent measurements are done that do not require very precise data.

Sensing Principle

Humidity measurement can be done using dry and wet bulb hygrometers, dew point hygrometers, and electronic hygrometers. There has been a surge in the demand of electronic hygrometers, often called humidity sensors. Electronic type hygrometers or humidity sensors can be broadly divided into two categories: one employs capacitive sensing principle, while other uses resistive effects [12, 13].

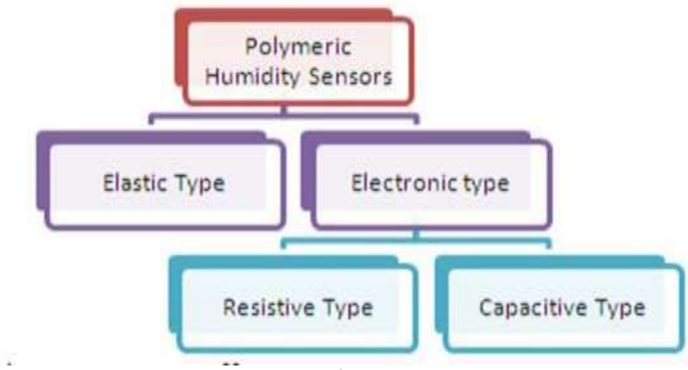

Fig. 1: A Block Diagram Explaining Different Categories of Polymeric Humidity Sensors

Sensors based on capacitive effect

Humidity sensors relying on this principle consists of a hygroscopic dielectric material sandwiched between a pair of electrodes forming a small capacitor. Most capacitive sensors use a plastic or polymer as the dielectric. Humidity and dew sensors, also called hygrometers, are necessary when consistent environmental conditions are required to be maintained. A capacitive humidity sensor is so named because it uses capacitive measurement, which relies on electrical capacitance. These are a common type of humidity sensors.

The capacitive sensor is composed of two metal plates, or electrodes, separated by a thin layer of non-conductive polymer film. The film attracts moisture from the air and when the moisture comes in contact with the metal plates it creates a voltage change. The output voltage measurement is captured and can be displayed via an analog dial, output into another system, or converted into a digital reading that indicates the amount of moisture in the air. The capacitive sensor is contained in a hygrometer to measure relative humidity. The sensor is one part of the system that also contains a probe, cable, electronics, and an output signal. Together they function to accurately measure the entire humidity range from 0% to 100%. The humidity sensor is a small capacitor consisting of a hygroscopic dielectric material placed between a pair of electrodes. Most capacitive sensors use a plastic or polymer as the dielectric material, with a typical dielectric constant ranging from 2 to 15. When no moisture is present in the sensor, both the constant and the sensor geometry determine the value of the capacitance.

At normal room temperature, the dielectric constant of water vapor has a value of about 80, a value much larger than the constant of the sensor dielectric material. Therefore, absorption of moisture by the sensor results in an increase in sensor capacitance. At equilibrium conditions, the amount of moisture present in a hygroscopic material depends on both ambient temperature and ambient water vapor pressure. This is true also for the hygroscopic dielectric material used in the sensor. Relative humidity is a

function of both the ambient temperature and water vapor pressure. There is a direct relationship between relative humidity, the amount of moisture present in the sensor, and sensor capacitance. This relationship is at the base of the operation of a capacitive humidity instrument. In a hygrometer utilizing a capacitive sensor, humidity is measured by a chain process as opposed to being sensed directly. The chain is made up of the components: Capacitive sensor, Probe, Cable, Electronics and Output signal.

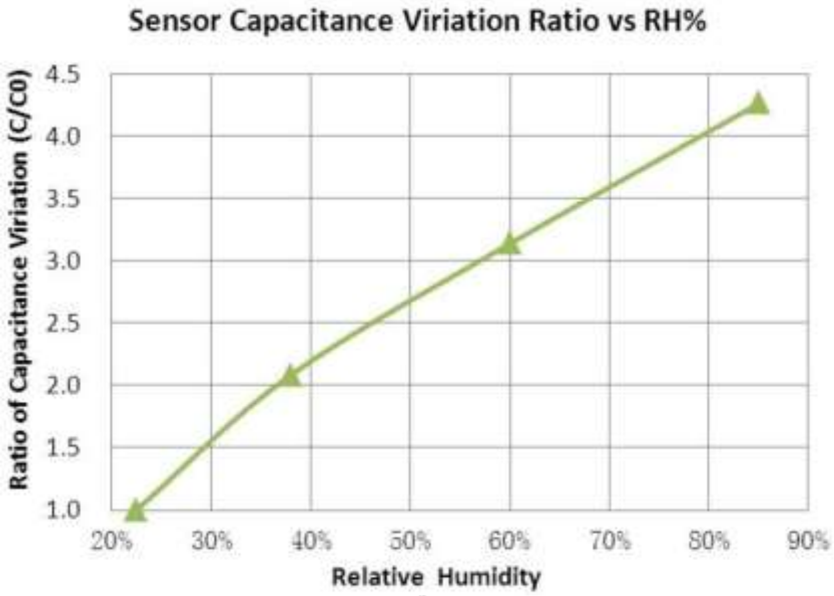

Fig 2: Capacitance variation with the change in %Relative humidity

Sensors based on resistive effect

Resistive sensors work on a similar principle to capacitive sensors, where electrical change is measured to produce a value for relative humidity. However, the mechanism in this system is different. Although resistive sensors use a material that absorbs moisture that is hygroscopic material similar to the capacitive system, the difference is that the measurement is of the resistance change. The principle is based on, the inverse exponential relationship of output voltage with the relative humidity. These sensors use cost-effective, scalable dielectrophoresis, in which a free-standing structure is created to house pre-patterned electrodes that are separated by a single crystalline zinc oxide nanowire. Resistive humidity sensors measure the change in electrical impedance of a hygroscopic medium such as a conductive polymer, salt, or treated substrate. Resistive sensors are based on an interdigitated or bifilar winding. After deposition of a hydroscopic polymer coating, their resistance changes inversely with humidity. The impedance change is typically an inverse exponential relationship to humidity**.** Resistive sensors usually consist of noble metal electrodes either deposited on a substrate by photoresist techniques or wire-wound electrodes on a plastic or glass cylinder. The substrate is coated with a salt or conductive polymer. When it is dissolved or suspended in a liquid binder it functions as a vehicle to evenly coat the sensor. Alternatively, the substrate may be treated with activating chemicals such as acid**.** The sensor absorbs the water vapor and ionic functional groups are dissociated, resulting in an increase in electrical conductivity. The response time for most resistive sensors ranges from 10 to 30 s for a 63% step change. The impedance range of typical resistive elements varies from 1000 ohms to 100,000,000 ohms.

The benefit of a resistive sensor is the high surface-volume ratio, which allows it to measure humidity changes in the environment up to 90% relative humidity at room temperature. These systems do have limitations, and as such are not optimal for measuring values below 5% RH. Applications that favor a resistive sensor include automotive, smart food packaging, and relative humidity sensor networks. For very low RH control function in the 1%-2% RH range, accuracies of 0.1% can be achieved. Resistive sensors are widely used in precision air conditioning controls to maintain the environment of computer rooms and as monitors for pressurized transmission lines, antennas, and waveguides used in telecommunications. The latest development in resistive humidity sensors uses a ceramic coating to overcome limitations in environments where condensation occurs. The sensors consist of a ceramic substrate with noble metal electrodes deposited by a photoresist process. The substrate surface is coated with a conductive polymer/ceramic binder mixture, and the sensor is installed in a protective plastic housing with a dust filter. The material used for binding is a ceramic powder used in liquid form. After the coating the surface and dried it, the sensors are heated. These results in a clear water proof thick film coating that completely recover from exposure to condensation.

CHANGE IN ELECTRICAL RESISTANCE AND VOLTAGE WITH %RH

Most resistive sensors use symmetrical AC excitation voltage with no DC bias to prevent polarization of the sensor. The resulting current flow is converted and rectified to a DC voltage signal for additional scaling, amplification, linearization, or A/D conversion as shown in fig 3.

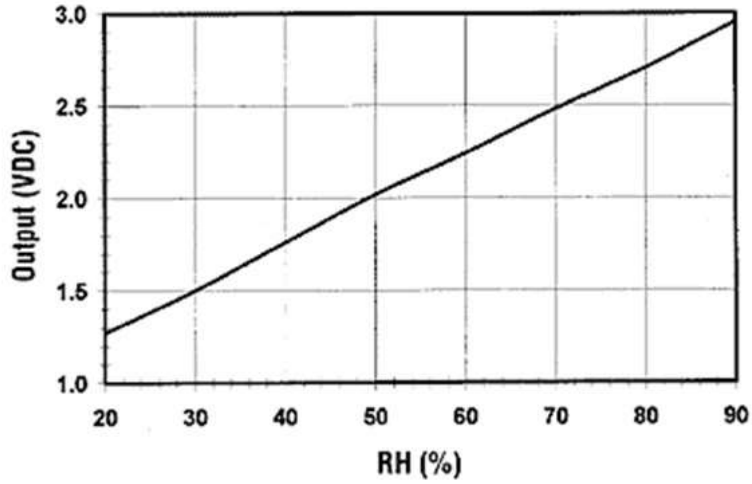

Fig 3: DC voltage versus %RH

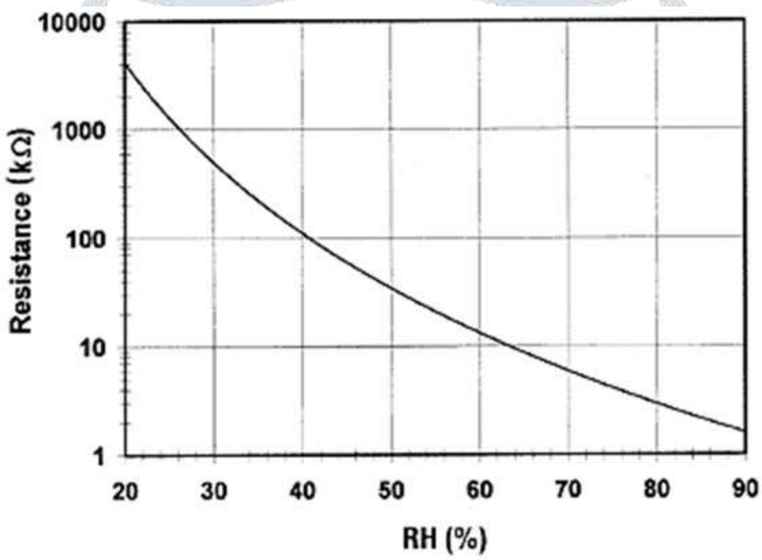

Fig 4: Curve showing the change in resistance with change in relative humidity

It is seen from figure; resistive sensors exhibit a nonlinear response to changes in humidity. This response may be linearized by analog or digital methods. Typical variable resistance extends from a few kilohms to 100 MV. Nominal excitation frequency is from 30 Hz to 10 kHz.

The "resistive" sensor is not purely resistive in that capacitive effects make the response an impedance measurement. A distinct advantage of resistive RH sensors is their interchangeability, usually within plus-minus 2% RH, which allows the electronic signal conditioning circuitry to be calibrated by a resistor at a fixed RH point. This eliminates the need for humidity calibration standards, so resistive humidity sensors are generally field replaceable. The accuracy of individual resistive humidity sensors may be confirmed by testing in an RH calibration chamber or by a computer-based DA system referenced to standardized humiditycontrolled environment. Nominal operating temperature of resistive sensors ranges from -40° C to 100°C.

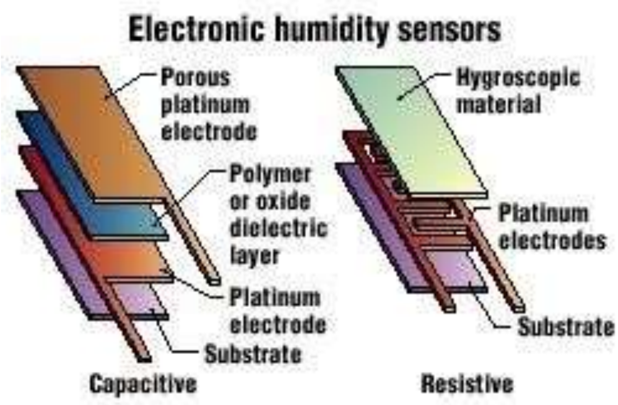

Fig 5: Fabrication of capacitive and resistive humidity sensor

COMPARISON OF BOTH HUMIDITY SENSORS

According to the measurement units, humidity sensors are divided into two types, that is, Relative humidity (RH) sensors and absolute humidity (moisture) sensors. Most humidity sensors are relative humidity sensors and use **different sensing principles.**

Active Material	Thermo-set Polymer	Thermoplastic Polymer	Thermoplastic Polymer	Bulk Thermoplastic	Bulk Al_2O_3	Lithium Chloride Film
Substrate	Ceramic or Silicon	Ceramic or Silicon	Polyester or mylar film	N/A	N/A	Ceramic
Sensed Parameter	Capacitance	Capacitance	Capacitance	Resistance	Resistance	Conductivity
Measured Parameter	% Relative humidity	% Relative humidity	% Relative humidity	% Relative humidity	% Relative humidity	% Relative humidity
RH Change	0% to 100%	0% to 100%	0% to 100%	20% to 100%	2% to 90%	15% to <100%
RH Accuracy	±1% to ±5%	±3% to ±5%	±3% to ±5%	±3% to ±10%	±1% to ±5%	±5%
Interchangeability	±2% to ±10% RH	±3% to ±20% RH	±3% to ±20% RH	±5% to ±25% RH	poor	±3% to ±10% RH
Hysteresis	<1% to 3% RH	2% to 5% RH	2% to 5% RH	3% to 6% RH	<2% RH	very poor
Linearity	±1% RH	±1% RH	±2% RH	poor	poor	Very poor
Rise time	15 s to 60 s	15 s to 90 s	15 s to 90 s	2 min to 5 min	3 min to 5 min	3 min to 5 min
Temperature Range	-40 °C to 185 °C	-30 °C to 190 °C	-25°C to 100 °C	10 °C to 40 °C	-10 °C to 75 °C	–
Long Term Stability	±1%RH/5 yr	±1%RH/yr	±1%RH/yr	±3%RH/yr	±3% RH/yr	>1% RH/°C
Substrate	Ceramic or Silicon	Ceramic or silicon	Polyester or mylar film	N/A	N/A	Ceramic

CONCLUSION

A comparative study between resistive and capacitive sensors has been done. The methods which are reported here are very common to use commercially. These methods are very popular and cost effective. The methods used are based on range and advantages, limitations and sensitivity. The humidity sensor must have very high sensitivity, good linearity and response. In addition, the response should be linear and the cost should be low. It is difficult to develop a sensing devices and instruments to fulfill all the parameters. Different humidity sensors are fabricated and designed for different ranges and parameter.

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