A Review on Classification, Types, and Properties of Humidity Sensors

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Abstract: The development of humidity sensors have been studied due to their significant effects on quality of life, quality of products, safety, cost, and health. This present work had been concerned with humidity sensor, which emphasized on the classifications, types, and properties of the sensor. Humidity sensors are classified into electrolyte humidity sensor, ceramic humidity sensor, semiconductor-type humidity sensor, and polymer film humidity sensor. Two categories of humidity sensors were identified, which were capacitive- and resistive-types. Furthermore, this study focused on the properties of humidity sensors in order to satisfy the widest range of applications, including high sensitivity, high accuracy, good linearity, large operating range of humidity and temperature, short response time, good reproducibility, small hysteresis, good durability and long life, high resistance against contaminants, negligible temperature dependence, and low fabrication cost.

Keywords: Classifications, Humidity sensors, Types of Properties

1. Introduction

Humidity sensors have gained increasing applications in industrial processing and environmental control (Chen and Lu, 2005). There is a continuous need for accurate, reliable, and inexpensive sensing systems in measuring relative humidity (R.H). The term humidity refers to water vapor, which is gas. It is water in gaseous form. While humidity sensors are transducers that convert the amount of water vapor into an electrical or physical parameter, it has been recognized that humidity has a significant effect on the quality of life, quality of products, safety, cost, and health. This has brought about a significant increase in humidity measurement applications, and concurrent with this, an increase in research and development activities have improved measurement techniques, accuracy, and reliability of the instrumentation. There are many kinds of materials, and studies related to sensing, so far, have included ceramics, polymers, semiconductors, electrolytes, and so on. Among of all these, polymers have been favored due to their low cost, easy fabrication, and high sensitivity properties (Sun et al., 2010). Tai and Oh (2002), on the other hand, have reported that ceramic materials are quite interesting due to their chemical and physical stabilities, thus, it can be a promising material to be used in humidity sensor. Therefore, it can be concluded that each type of sensing material has its own merits and specific conditions of application. In this paper, we aimed to present an extensive review of research and development of humidity sensors, which stressed on classification of humidity sensors based on types of sensing materials. In addition, the types of humidity sensors play an important role and are discussed in detail in the next section. Finally, the electrical properties of humidity sensors are described to fit the requirements in the sensor to be better.

2. Classification of Humidity Sensors

Humidity sensors are classified into electrolyte humidity sensor, ceramic humidity sensor, semiconductor-type humidity sensor, and polymer film humidity sensor. Each class has its own merits and specific conditions of application. Electrolyte humidity sensors are widely used for meteorological observations, such as radiosonde because of their reproducibility, long term stability, and low cost. This kind of humidity sensor cannot be used in automatic control systems, which require rapid response. Water evaporates from or condenses into an electrolyte solution, depending on the relative humidity of the surrounding atmosphere. This phenomenon has been applied by electrolyte humidity sensors. For example, the lithium chloride humidity sensor has rather slow responses to humidity compared to other types of humidity sensors.

Besides, ceramic materials have an advantage in terms of mechanical strength, thermal, and chemical stability (Ertug et al., 2012). Ceramic sensors of conductive or capacitive type are based on changes in surface conductivity or dielectric constant upon water vapor adsorption (Su et al., 2006). As for ionic sensing materials, if the humidity increases, the conductivity decreases and the dielectric constant increases as well (Chen and Lu, 2005). Alumina film sensor is an example of this kind of sensor, which has been used in various industries, such as medicine and foodstuffs. This alumina film sensor has fast response times, and even a few ppm of water in the atmosphere can be detected. However, the use of this element is restricted to dry atmospheres due to its hysteresis and the change of sensor characteristics, which occur during its operation. From the viewpoint of mechanical strength, temperature capability and resistance to chemical attack, ceramic materials appear to be the most suitable candidates for chemical sensors.

Furthermore, humidity sensors based on semiconductor materials are able to operate at elevated temperatures, robust, lightweight, long lasting, and benefit from high material sensitivity, and also possess quick response times (George et al., 2010). All these characteristics make them a desirable technology to exploit. When water molecules are adsorbed on semiconducting oxides, the conductivity increases or decreases according to whether the oxides are n-type or p-type. Hence, in order to fulfil the demand for this type of sensor that is able to operate at elevated temperatures, semiconductor humidity sensors using metal oxides have been proposed. Meanwhile, perovskite-type oxide is one of the examples that belong to this group. The changes of the conductivity are obtained when electron donor molecules are adsorbed, in which the changes are larger for n-type semiconducting oxides compared to p-type oxides. Therefore, the n-type oxides as materials for humidity sensing are more favored than p-type oxides (Arai and Seiyama, 2008).

In addition, the utilization of polymers as materials for humidity sensor membrane presents many advantages, such as low cost, flexibility, and easy processability (Su et al., 2006). The water content of the polymer is directly related to relative humidity at a particular temperature. Hence, a direct indication of the relative humidity for the detected property at particular temperature is provided. Despite the tremendous development of humidity sensor based polymer, they still suffer from a variety of disadvantages, including hysteresis, non-linearity, instability and short life, swelling, and oxidation. These disadvantages become more significant at elevated temperatures and high relative humidity. The sensors in this category can be classified into impedance and capacitance types, whereby the impedance type consists of ionic and electronic conduction types (Yamazoe and Shimizu, 1986; Sakai et al., 1996).

3. Types of Humidity Sensors

Generally there are two types of humidity sensors, which are the capacitive type and the resistive type (Rubinger et al., 2007). These two sensors depend on whether the sensor is designed for changes of capacitance measurements or resistance measurements. Besides, each type of humidity sensor can be differentiated in terms of the sensing materials used, the manufacturing techniques, and the sensors have somewhat different characteristics, with advantages and limitations for both.

The capacitive-type humidity sensors are widely used in weather-monitoring applications. These sensors consist of a substrate, in which a thin film of sensing material is deposited between the electrodes. Su et al., (2006) reported that capacitive-type humidity sensor is fabricated with hydrophobic polymers. The change in dielectric constant of this type of sensor is almost directly proportional to relative humidity. The dielectric constant changes occur due to water vapors, which means, the dielectric constant of the film changes as it absorbs water vapor, varying the capacitance of the sensors in proportion to the changes in relative humidity (Ahmad et al., 2008; Yang et al., 2006). In addition, these sensors provide a wide relative humidity range and condensation tolerance. The characteristics of capacitance-humidity show a linear relation from 0 to 100% R.H, and this sensor has the advantages of good accuracy, low hysteresis, and fast response time.

On the other hand, the resistive-type humidity sensors measure the change in electrical resistance of a sensing element. Commonly, the resistive-type humidity sensor is fabricated using polymer electrolytes or polymer-salt complexes (Su et. al., 2006). In this type of sensor, the change in resistance is inversely proportional to relative humidity because the water vapors dissociate the ionic functional groups, resulting in a decrease in electrical resistance. Specifically, the resistive sensors have a slower response; although generally, they are fast enough for most applications. Besides, resistive polymer sensors are generally suitable for a narrower ambient temperature range, typically from 0°C to 80°C. The main advantages of the resistive-type humidity sensors are their wide operating range for both humidity and temperature, the ease to calibrate them accurately, and the fact that they can be easily exchanged. The impedance is further subdivided into ionic and electronic conduction types.

4. Properties of Humidity Sensors

Generally, a humidity sensor has to fulfil the following requirements to satisfy the widest range of applications; (1) a high sensitivity, (2) high accuracy, (3) good linearity, (4) large operating range of humidity and temperature, (5) short response time, (6) good reproducibility, (7) small hysteresis, (8) good durability and long life, (9) high resistance against contaminants, (10) negligible temperature dependence, and (11) low fabrication cost. Table 1 depicts the most important requirements for sensors to function. Although many humidity sensors have been developed based on various principles to satisfy the different applications, no one solution can satisfy all the requirements in all times and in all applications.

Table 1. Glossary of the Most Relevant Properties of Humidity Sensors (Dickey et al., 2006)

Parameter	Description
Sensitivity	The ratio of the change in output signal to the change in input signal
Accuracy	Conformity to a standardized reference signal
Response time	The time required to reach 63% (or 93%) of the final (stable) sensor output after stepwise ramping the humidity
Drift	Change of the sensor output signal with time at constant input signal
Repeatability	The distribution of sensor outputs after when performing consecutive readings under similar conditions
Reproducibility	The distribution of sensor outputs when measuring the same under different conditions
Hysteresis	The difference in output signal when measured for an up-trace and down-trace of the input signal
Temperature dependence	The variation of the sensor output with temperature at constant humidity

5. Conclusion

The construction of a good sensor for humidity is a complex matter. The materials that have been reviewed in this work include electrolyte, ceramic, semiconductor-type, and polymer film, which possess their own merits and specific conditions of application. The differences between these two types of humidity sensor, resistive-type and capacitive-type, have been described. The advantages of the capacitive-type humidity sensor over the resistive-type sensor are that it uses less power and has better linearity. However, resistance measurements are simpler and more straightforward than capacitance measurements. The humidity sensor is featured with high sensitivity, accurate, quick response and small hysteresis, good reproducibility and repeatability, large operating range of humidity, and temperature can be a good candidate for a high performing humidity sensor.

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