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Ceramic sensors for humidity detection: the state-of-the-art and future developments

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Abstract

The possible applications of humidity sensors in automated systems for environmental control encompass many industrial and domestic fields. Very different operating temperatures and a variety of humidity ranges are needed for these purposes. The different humidity-sensing mechanisms and operating principles identified for ceramics are reviewed. Ceramic humidity sensors are divided into ionic, electronic, solid-electrolyte and rectifying-junction types. Examples of the performance of some ceramic sensors are presented. The correlation between the microstructure of ceramic materials and their humidity-sensitive electrical response is discussed. The improvement of the performance of ionic-type humidity sensors by the addition of alkali ions is explained in terms of influence on the microstructure and on the intrinsic impedance. The recent trend towards the miniaturization and integration of sensors on a single chip requires the production of ceramic films. Ceramic thin films prepared by sol–gel or sputtering processes are investigated. The results obtained on the humidity sensitivity of p–n semiconducting oxide heterocontacts are also reported.

Keywords: Ceramic sensors; Humidity detection

1. Introduction

Monitoring and controlling environmental humidity is receiving ever wider attention, mainly for comfort and for industrial processes [1]. The trend towards using automated control systems has recently gained importance in environmental control because of the falling cost of interface circuits and microprocessors, and their improved reliability and broadening applications [2]. For this purpose, humidity sensors using changes in electrical parameters are needed [3]. Particularly, in recent years the use of humidity control systems has greatly increased in the quality control of production processes and products in a wide range of industries, such as the production of electronic devices, precision instruments, textiles and foodstuffs [4], and also in many domestic applications, such as intelligent control of the living environment in buildings, where humidity sensors are used to maintain a comfortable humidity level and for cooling [5]. Table 1 summarizes the widespread uses and applications of humidity sensors in many different fields. Each field of application requires different operating conditions, and therefore different kinds of humidity sensors have been developed in order to meet the different requirements [6]. Sometimes it is necessary to monitor the absolute humidity, or the dew point, but more often it is important to control the relative humidity (rh).

A wide variety of materials has been studied as sensing elements in humidity sensors and used for commercial devices. The choice of a suitable material is difficult, and should be based on materials that show good sensitivity over the entire range of humidity and temperature, low hysteresis, and properties that are stable over time and thermal cycling, and on exposure to the various chemicals likely to be present in the environment [1].

The materials used in humidity sensors exploiting variations of electrical parameters were roughly classified into three groups: electrolytes, organic polymers and ceramics [6]. The electrolyte humidity sensor using LiCl, developed by Dunmore in 1938 [7], was used for over 40 years, being the only electrical moisture-sensing device available at the time. However, this sensor shows slow response time, and is unable to operate in very humid environments or in the presence of ammonia or organic solvents. Other materials were thus studied to be used in those environments where the LiCl sensor was not suitable. The development of commercial humidity sensors was given great importance in Japan at the end of the 1970s [8–12], and anyone going to Japan in the summer, especially to Kyushu during the *tsuyu*

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