GENERAL ARTICLES

Ceramic Humidity Sensor

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A new compact, durable, yet highly sensitive and reliable ceramic humidity sensor has been developed as a cooking control device for automatic microwave ovens. The novel ceramic humidity sensor makes use of a new semiconducting porous ceramic material composed of a solid solution $MgCr_2O_4$–TiO_2 having humidity sensitive effects and a rejuvenating response to heat treatment and a new heat-cleaning device to burn off organic contaminants such as oil and dust on the surface of the sensor in order to maintain optimum sensitivity. A new automatic microwave oven using the newly developed sensor has been developed and produced. The sensor controls the heating time by detecting humidity. It is expected that the ceramic humidity sensor will be applied extensively in industrial and medical equipment as well as in household appliances such as microwave ovens and air conditioners.

With the explosive spread of a new automatic control technology consisting of microcomputers and sensors throughout the industrial world, recent automated systems have required various kinds of sensors, including a humidity sensor. The control of humidity is imperative for equipment such as foodstuff ovens, air conditioners, dryers, etc. Conventional humidity sensors which make use of materials such as electrolytes, organic polymers, alumina thin films, and other metal oxides, have limitations in the ambient temperature and humidity range in which they can function accurately. Additionally, their reliability is subject to deterioration due to contamination from oil, dust, and other materials in air. It is because of these shortcomings that humidity sensors have not been extensively used despite a rather large potential demand.

Recently, Nitta et al. (1980a,b) have successfully developed a new compact, durable, yet highly sensitive and reliable ceramic humidity sensor. This humidity sensor has been made possible through the development of a new humidity-sensitive ceramic material and through the adoption of a new heating device to burn off organic contaminants such as oil and dust on the ceramic surface in order to maintain optimum sensitivity (Nitta et al., 1978a,b). Subsequently, an automatic microwave oven using the ceramic humidity sensor has been developed and produced as reported by Nitta and Hayakawa (1980). The sensor controls the heating time by detecting humidity.

This paper is arranged in three parts. The first part outlines the physical and chemical properties of the sensor ceramics. The second part describes the construction, features, and humidity characteristics of the sensor. Finally, as an application of the sensor, we will briefly exemplify a newly developed automatic microwave oven controlled by humidity detection.

Sensor Ceramics

Adsorption of water vapor enhances the surface electrical conductivity of metal oxides. There have been many reports of humidity sensors using this humidity sensitive effect. The humidity sensors normally exposed not only to water vapor but to atmospheres containing various other components tend to lose their inherent humidity-sensitive properties during use due to several complicated physical and chemical processes between these components and the sensor materials. The original surface state of a contaminated metal oxide surface may be recovered by eliminating almost all of the chemisorbed water as well as the poisoning components from the surface through heating at high temperatures. However, the surface structure of metal oxides in powder form is subject to permanent change by repeated heat-cleaning cycles at high temperatures. On the other hand, a ceramic form sintered at high temperatures is essentially more stable physically, chemically, and thermally than the powder form.

Table I. Structural Data of Porous Ceramic

composition, mol %	MgO (39.4), Cr_2O_3 (39.4), TiO_2 (21.2)
phase analysis	spinel type single phase
% theoretical density	60-70
average grain size, μm	1-2
specific surface area, m^2/g	0.2-0.3
% porosity	30-40
average pore size, Å	2500-3000

The most promising approach seems to find a ceramic material with a surface resistivity reversibly responsive to relative humidity, which is not easily changed by repeated heat-cleaning cycles at high temperatures. Of the various metal oxide ceramics investigated, semiconducting porous ceramics composed of the solid solution $MgCr_2O_4$–TiO_2 offer the most promise.

The binary system $MgCr_2O_4$–TiO_2 is very important in refractories because of its good mechanical and thermal properties at high temperature. Since metal oxides with high Cr content are generally difficult to sinter to high densities, the sintered compact tends to exhibit a typical porous structure.

The $MgCr_2O_4$–TiO_2 system containing up to 35 mol % TiO_2 exhibits a single phase solid solution with a pure $MgCr_2O_4$ type spinel structure. Table I gives the structural

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