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A carbon dioxide gas sensor based on solid electrolyte for air quality control

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Abstract

A practical CO_2 gas sensor for air quality control is developed by using a combination of a $Na_3Zr_2Si_2PO_{12}$ (NASICON) as a solid electrolyte and Li_2CO_3 as a carbonate phase. The sensor's electromotive force (emf) shows a linear relationship with the logarithm of CO_2 concentration. Zeolite is chosen as a filter material in order to minimize the effect of interfering gases on the sensor's emf and shows very little sensor response deterioration to CO_2. Under continuous energizing, both the emf and a change in the emf (defined as Δemf) are stable over a period of 2 years. However, after the sensor is exposed to a high humidity atmosphere in an unpowered state, the emf decreases, but Δemf stays constant. A new data selection method for renewing the standard of the emf is investigated in order to monitor CO_2 concentration using Δemf. The output of the CO_2 monitor corresponds to a conventional non-dispersive infrared (NDIR) analyzer.

Keywords: Gas sensor; Solid electrolyte; Carbon dioxide; Air quality control

1. Introduction

Recently, accurate measurement of CO_2 concentration in offices and houses has become widespread, as CO_2 is a good indicator of air quality pollution. Although infrared spectroscopic analyzers are commonly used in this field, they have several disadvantages such as their large size and high cost, so there is a need to develop inexpensive and maintenance-free CO_2 sensors. To provide these needs, solid-electrolyte type CO_2 sensors composed of a solid electrolyte and a carbonate phase have been developed [1–3]. In this study, we have produced a practical CO_2 gas sensor with a platinum heater and a new zeolite filter. A CO_2 monitor utilizing this sensor was developed and tested in an office.

2. Experimental

The construction of the CO_2 sensor element is shown in Fig. 1. A solid electrolyte sinter of $Na_3Zr_2Si_2PO_{12}$ (NASICON) — Na^+ conductor, about 4 mm in diameter and about 0.7 mm in thickness — was used. A pair of gold electrodes was attached to both surfaces of the solid electrolyte by screen printing. A working electrode was pasted with lithium carbonate on one side of the electrode

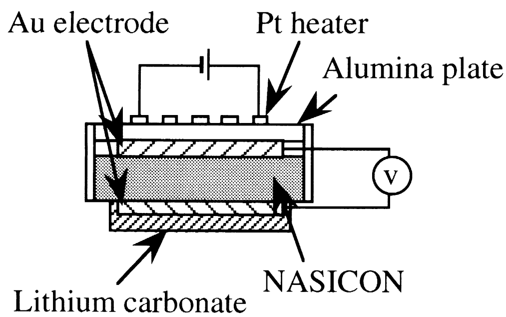

Fig. 1. Construction of the sensor element.

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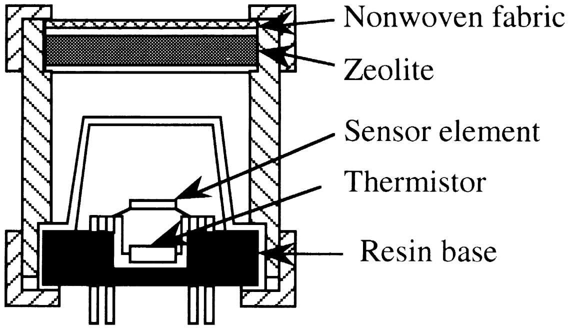

Fig. 2. Construction of the CO_2 sensor.

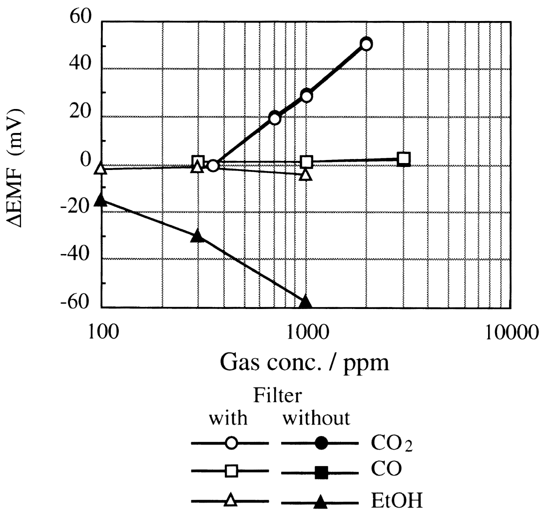

Fig. 3. Sensitivity of various gases.

by screen printing and baked at 600°C. A built-in Pt heater screen printed on an alumina plate was laminated on a reference electrode and sealed with glass. The sensor element was heated at 450°C and the electromotive force (emf) was measured by a high-impedance voltage meter.

The construction of the CO_2 sensor is shown in Fig. 2. The sensor element was mounted on a resin base and the gas entrance was covered with a filter consisting of zeolite powder (Na/Y type, about 1 g) sandwiched between two non-woven fabrics. The size of the sensor was 24 mm in diameter and 31 mm in height.

3. Results and discussion

3.1. Basic properties

The sensitivity of various gases is shown in Fig. 3. In this figure, change in emf (Δemf) is calculated according to expression (1).

$$\Delta\text{emf} = \text{emf}\,(CO_2 = 350\,\text{ppm}) - \text{emf}\,(\text{measuring atmosphere})\,. \quad (1)$$

The Δemf of the sensor showed a linear relationship with the logarithm of CO_2 concentration and was slightly effected by interfering gases, such as carbon monoxide and ethyl alcohol, because of the zeolite filter. The emf response time reached 90% of the saturated value in about 123 s when CO_2 concentration was changed from 350 to 1000 ppm. The emf of the sensor increased as the surrounding temperature rose, necessitating a correction in the temperature dependence using a thermistor. On the contrary, the emf was scarcely affected by absolute humidity in the surrounding atmosphere.

3.2. Long-term stability

The heating condition stability of the emf and Δemf in indoor atmospheres is shown in Fig. 4. Both the emf and Δemf indicated excellent stability over 2 years. On the other hand, when the sensor was exposed to a high humidity atmosphere, the emf decreased but Δemf stayed fairly stable. It is therefore possible to measure CO_2 concentration by calculating Δemf.

3.3. Practical properties

A CO_2 monitor, capable of measuring the proportional output to CO_2 concentration, was produced. New data

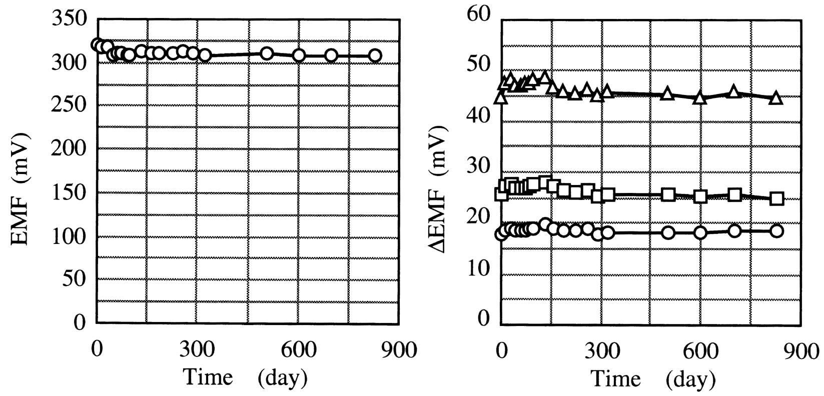

Fig. 4. Heating condition stability of the emf and Δemf in indoor atmospheres.