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Carbon dioxide/methane gas sensor based on the permselectivity of polymeric membranes for biogas monitoring

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Abstract

Membrane based-sensors have been used for determining the composition of bi-component mixtures in the 0–100% range, such as oxygen/nitrogen, carbon dioxide/helium, carbon dioxide/methane, hydrogen/nitrogen, and hydrogen/methane. These sensors are suited for the low cost and low/medium precision market.

The present study describes a carbon dioxide/methane sensor suitable for biogas composition monitoring. The membrane used is poly(dimethylsiloxane) (PDMS) hollow fiber. The calibration curves were obtained at three different temperatures. The results clearly show that the permeate pressure of the sensor is related to the gas mixture composition at a given temperature. The sensor enables quantitative carbon dioxide analysis in binary mixtures of carbon dioxide/methane with fast, continuous, reproducible, and long-term stable response.

Keywords: Membrane-based sensor; Permselectivity; Binary gas concentration sensor; Carbon dioxide/methane mixture

1. Introduction

Low cost concentration sensors for monitoring processes would have a great impact on environmental preservation, for safety and in energy saving [1]. There is a growing market for such sensors and in particular for a cheap and reliable carbon dioxide/methane sensor of medium precision for biogas monitoring. Biogas is composed of almost equal parts methane and carbon dioxide. It therefore, is combustible and potentially dangerous [2]. The utilization of this gas as fuel for electrical and thermal energy production could avert this danger, reduce the impact on the environment and could provide a renewable energy source [2,3].

The biogas composition has been measured with biogas analysers such as those produced by http://www.ados.de, http://www.kelma.com, http://www.enviroequip.com, and http://www.omniinstruments.co.uk [4–7]. However, the cost of these apparatus is high (about €2500) and it is difficult to install them at each biogas emitting site. The currently proposed carbon dioxide/methane sensor could be used to control the biogas emissions and to optimise the operating conditions of methane recovery units.

Recently, the use of a membrane-based sensor was proposed for determining the composition of binary mixtures, such as oxygen/nitrogen, for medical applications [8]. The sensor is based on the permselective effect of membranes. A small stream of the binary gas mixture, whose concentration is to be read, is supplied to the feed side of the sensor. Assuming that the membrane is selectively more permeable to one of the components in the feed gas then, if the feed pressure is kept constant, the permeate flow is related to the gas mixture concentration. A non-selective barrier such as a needle valve causes a pressure drop on the permeate outlet which is related to the permeate flow rate and, therefore, to the feed concentration. The pressure in the permeate side can be measured by means of a cheap pressure transducer [8–10].

This paper describes a permselective gas sensor for determining the composition of carbon dioxide/methane mixtures in the 0–100% range. A polymeric membrane is used: poly(dimethylsiloxane) (PDMS) hollow fibers (supplied by GKSS, Germany). For a PDMS membrane, calibration curves were obtained at three different temperatures. Reproducibility, sensitivity, response time, and reversibility, long-term stability and temperature dependence of this sensor are discussed.

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