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Thermal conductivity microsensor for determining the Methane Number of natural gas

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Abstract

As a result of the liberalization of the gas market, more important and frequent fluctuations of the natural gas composition are expected. Owing to this fact, the on-site control of the gas properties will become necessary for end-users. Methane Number (MN) is the parameter used to quantify knocking tendency of a gas, parameter especially relevant when natural gas is used as engines fuel. The present paper describes a measurement method to determine the Methane Number of natural gas as well as the microdevice developed to carry out these measurements. The method is based on the measurement of the gas thermal conductivity and the existing correlation between this parameter and the Methane Number of natural gas. The developed microsensor is ascribed to Microsystems Technology. It integrates two platinum thermoresistors, a sensing one and a reference one, each of them patterned on a microbridge. The latter is defined in turn in the silicon substrate by surface micromachining using porous silicon as sacrificial layer. In the range of natural gas compositions considered (60–100 MN), applying a 50 mA constant current to the sensing thermoresistor, obtained sensitivity has been 0.95 mV/1 MN. Furthermore, the microdevice has been mounted in a gas line in order to test it in field. Additional tests are still required but it can be concluded that the developed microsensor is a valid alternative to measure in situ the Methane Number of natural gas.
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Keywords: Methane Number; Thermal conductivity; Microbridges; Porous silicon

1. Introduction

Natural gas is a gaseous mixture formed of methane, smaller fractions of higher molecular weight hydrocarbons (C_2H_6, C_3H_8, C_4H_{10}, ...) and inert gases (mainly N_2 and CO_2), where the different components ratio depends on the point of origin of the natural gas and on its manipulation during the distribution to end users. The natural gas composition, for its part, determines the chemical and physical properties and, consequently, the quality of the gas. Recent liberalization of natural gas market will give rise to a wider number of natural gas distribution companies making the composition fluctuations observed by end-users to be more frequent and larger. This circumstance will make more and more necessary to measure and control in situ the physical and chemical properties of the natural gas.

Concretely, composition fluctuations have direct repercussions into two problems associated to the natural gas combustion: efficiency and cogeneration engines knocking. Knocking is a serious problem in engines where natural gas is used as fuel. Gas mixture autoignition caused by its high pressure and temperature provokes in turn high pressure waves that impact against piston walls. In addition to decrease engine performance, knocking is extremely damaging for engine lifetime because of the high thermal and mechanical stresses that the latter must withstand under these conditions. Most of the aspects that promote knocking are conditional on engine design and operation conditions, but natural gas composition is also a critical aspect that must be controlled [1].

Methane Number, MN, defined as “methane volume percentage of a mixture with hydrogen that provokes the same knocking intensity than the considered gas”, is the parameter

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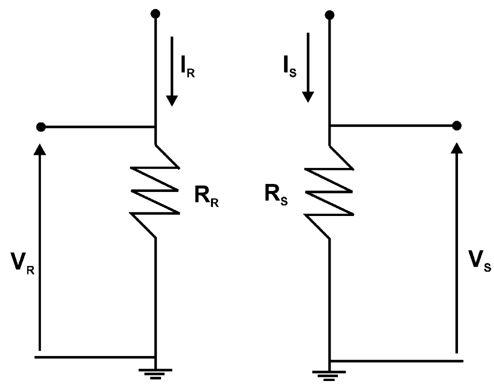

Fig. 1. Microsystem configuration.

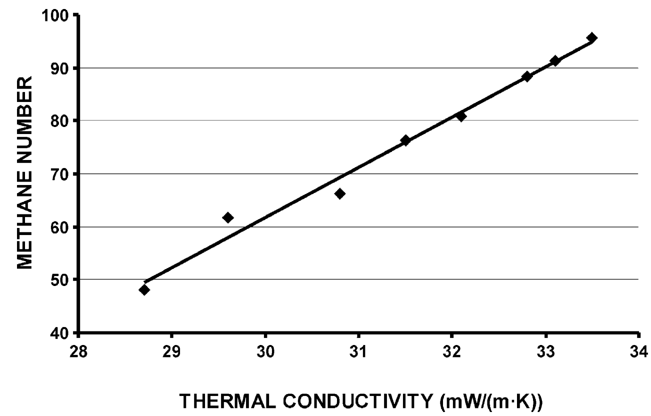

Fig. 2. Methane Number (ISO TC 193) vs. thermal conductivity (NBS 1039).

used to quantify knocking tendency of a gas mixture. Arbitrarily, it has been assigned a value of 100 for pure methane and 0 for pure hydrogen MN. Minimum MN required to keep an engine in good working order depends on the engine characteristics. It is usually admitted that knocking problems are avoided for installations with a MN higher than 75–80. For cogeneration applications, engine characteristics are specified for gases with a MN higher than 65–75. When MN is between 55 and 65, taking measures to prevent engine knocking is recommended. For a Methane Number lower than 55, leaving engine out of service is the best option.

Alternatives to determine natural gas composition and/or quality now in the market, such as gas chromatography, optical measurements or calorimetric measurements, are sophisticated, expensive and big size and weighty alternatives: unacceptable for natural gas end-users. Traditionally, gas chromatography has been the most usual alternative to analyze natural gas but its use has been restricted to laboratory or very specific gas lines nodes because of its high price and its complex operation. Nowadays, portable chromatographs, so-called microchromatographs, have been developed. The traditional injection systems, columns and filament thermal conductivity detectors (TCD) have been substituted by devices based on MEMS technology. These analyzers [2–6] are available for portable, on line and in situ applications. Their price (€18.000–24.000) has been reduced to half of that of a conventional chromatograph. New measurement alternatives based on correlative methods have also been developed [7–9]. They allow the in situ analysis of natural gas composition and properties. Nevertheless they still are too expensive (one-third of a conventional chromatograph price) for the sole determination of the Methane Number.

In this context, a method to determine in situ and on line the Methane Number of natural gas is proposed. The adopted approach, ascribed to the Micro Total Analysis Systems (μTAS) field, consists in measuring the gas thermal conductivity and using the existing correlation between this parameter and the Methane Number of natural gas. Microdevice fabrication process based on Microsystems Technology provides all the advantages related to microelectronics technology, allowing to monitor the gas MN on line at low cost. The present paper describes the measurement principle and the design of the de-

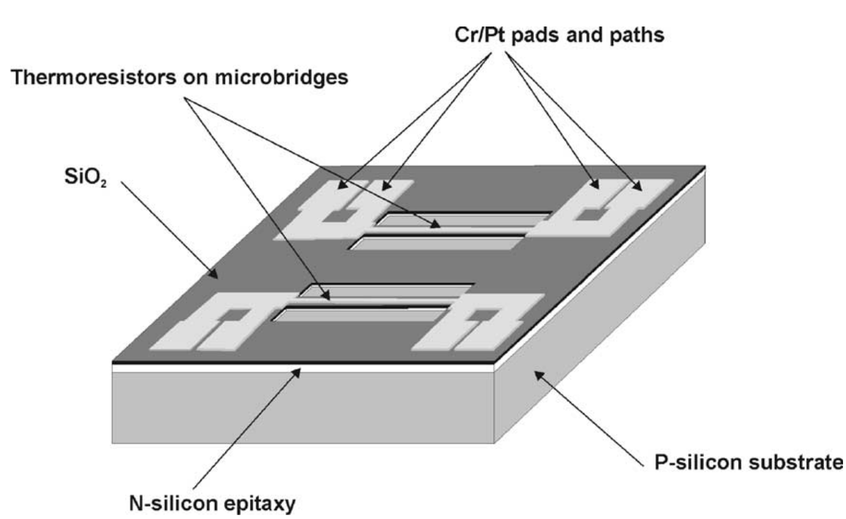

Fig. 3. Microsensor design.

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