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Review

Micro gas analyzers for environmental and medical applications

Shin-Ichi Ohira^a, Kei Toda^{b,*}

^a Department of Chemistry and Biochemistry, University of Texas at Arlington, Arlington, TX 76019-0065, USA

^b Department of Chemistry, Kumamoto University, Kurokami, Kumamoto 860-8555, Japan

ARTICLE INFO

Article history:

Received 8 February 2008

Received in revised form 4 May 2008

Accepted 6 May 2008

Published on line 14 May 2008

Keywords:

Micro gas analyzers

Environmental and medical applications

Atmospheric analysis

Breath and skin gas

Microchannel scrubbers

Micro gas chromatograph

Microfluidic devices

ABSTRACT

In this review, novel microsystems and microdevices to measure gaseous species for environmental analysis and medical diagnostics are described. Miniaturization of analyzers makes field measurements affordable. As well, high sensitivity and good time resolution can be achieved by miniaturization. Some such devices have already been successfully applied to real environmental analyses. Mobile monitoring is available with the use of micro gas analyzers to investigate the natural environment, air pollution and to detect nerve or explosive gases released accidentally or through terrorist activities. Miniature devices are also attractive for medical analyses. Gases produced from the human body reflect gases contained in the blood and certain metabolic conditions. Noninvasive monitoring using miniature devices is available in hospitals and in a patient's home. Many investigations have been conducted using wet and dry chemistry methods for both applications. Instruments employing wet chemistries, which comprise liquid droplets, liquid film, miniature diffusion scrubbers, and microfluidic devices have been studied. Among the instruments using dry methods, miniature samplers, portable gas chromatographs, and microfabricated gas chromatographs have all been investigated. These instruments are expected to usher in a new era of environmental monitoring and will find uses in many medical applications.

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* Corresponding author. Tel.: +81 96 342 3389; fax: +81 96 342 3389.

E-mail address: todakei@sci.kumamoto-u.ac.jp (K. Toda).

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doi:10.1016/j.aca.2008.05.010

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1. Introduction

Gas analysis is more challenging for analytical chemists than water analysis because of the difficulty of handling and sampling air. Many recent efforts in this area have, however, resulted in attractive and practical methods now being available for many uses. Miniaturization of gas analysis systems is an especially attractive approach [1,2]. Air analysis must be performed on-site in environmental/atmospheric analysis and medical diagnostics. There are several reasons why on-site measurements are needed in gas analysis.

- Gas analytes may be lost during sampling and subsequent transport to the laboratory because of reactions and adsorptions.
- Time variation data is important in atmospheric analysis. Therefore, continuous or near real time measurements are required in the field.
- Mapping of gas concentrations is available by mobile monitoring around a pollutant source with a portable device.
- More effective data can be obtained by changing the sampling point with feedback of real time data. This is useful in identification of pollutant sources and to assess a polluted area.
- To prevent significant damage in a civic area from an accident or an act of terrorism, miniature instruments are needed to be placed in airports, railway stations and stadiums to monitor levels of potential nerve or explosive gases.
- Analysis of gases emitted from the human body can be used as a noninvasive diagnostic.
- Small instruments can be placed in a hospital room, not only in an intensive care unit (ICU), but also next to a patient in a normal hospital room or even in a patient's home.
- Medical test data can be made available in a short time and treatment can be decided upon immediately.

Miniaturization is the key to establishing instrumentation for on-site analysis. By employing miniaturization, sophisticated instruments can be readily used in the field as sensors. Inorganic gases and water-soluble gases are measured by wet chemistry after collection into an aqueous phase. On the other hand, organic gases are mainly measured by dry methods

and mostly dry preconcentration process is incorporated into the analysis. There are merits to miniaturization and use of microdevices in the gas collection and measurement process.

- Microdevices achieve high-speed analyses due to fast reactions in a microfluidic channel.
- In the collection of gas samples, a high enrichment factor is easily available because of a high surface to volume ratio of microdevice. Therefore, high sensitivity and good time resolution are available with a microsystem if the system and procedure are appropriately designed.
- In some gas analyses, trapped gases are desorbed by heating and chromatographic separation is performed using changing column temperatures. Very fast heating/cooling is available, because of the ultra small heat capacity of a microdevice, to dramatically shorten measurement times.
- Power consumption is small, especially in heating devices. Hence, an entire system can be driven by a battery to use in the field.
- Microdevices are environmentally friendly because of their small consumption of chemicals. These devices are thus available as environmentally friendly instruments for environmental analysis [3].

In this paper, we present the recent progress that has been made in miniaturization and developing microdevices for gas analysis from practical miniature systems to advanced microchannel devices. We also describe successful applications of these devices in environmental analysis and medical diagnostics.

2. Miniature gas analysis system with wet chemistry

Wet chemistry is classically used for gas analysis where gases are collected in a suitable device (the use of an impinger is the most popular conventional method) and are subsequently determined by colorimetry or fluorometry. Micro gas collectors have recently been investigated and integrated with reaction/detection systems. Representative works are summarized in Table 1.

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