NOVEL MICRO GAS GENERATOR
OF CARBON DIOXIDE
FOR ACTUATION AND GAS SOURCE

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Abstract

This paper presents a novel microgenerator of CO₂ (carbon dioxide) gas. Chemical reactions result in the production of CO₂ gas, which is used as actuation in addition to gas supplier.

Keywords: Micropump, Carbon dioxide, Sodium bicarbonate

1. Introduction

The use of gas as pumping source was previously reported [1, 2] in which they electrically hydrolyzed water for the production of gases. Another group recently reported the production of N₂ (nitrogen) gas for the generation of pumping power [3]. We also simultaneously reported a novel micropump which is actuated through the production of O₂ (oxygen) gas [4]. We now report another type of gas generator which is more versatile than the previous ones.

2. Theory

It is well known that NaHCO₃ (sodium bicarbonate) can easily be decomposed into water and gaseous CO₂ by heating as the following chemical equation:

\[ 2 \text{NaHCO}_3 (s) \rightarrow \text{Na}_2\text{CO}_3 (s) + \text{H}_2\text{O} (l) + \text{CO}_2 (g) \]  \hspace{1cm} (1)

CO₂ can also be produced from NaHCO₃ after reaction with mild acid such as HOC(COOH)(CH₂COOH)₂ (citric acid):

\[ 3 \text{NaHCO}_3 (s) + \text{HOC(COOH)(CH}_2\text{COOH)}_2 (s) \rightarrow \text{HOC(COOH)(CH}_2\text{COONa)}_2 (s) + 3 \text{H}_2\text{O} (l) + 3 \text{CO}_2 (g) \]  \hspace{1cm} (2)
Fig. 1 Schematic diagrams of the two types of CO₂ generators. Pyrolysis of NaHCO₃ produces CO₂ gas (a). Otherwise, CO₂ is produced after the reaction of NaHCO₃ with citric acid (b). The reaction is started by addition of water to melt citric acid. Parafilm which is used as a barrier is melted by underlaid microheater.

The reaction of NaHCO₃ can be applied to CO₂ supplier as well as micropumps. Fig.1 shows the constitution and action mechanism of CO₂ generator. NaHCO₃ in a chamber is decomposed by the underlaid microheater (Fig. 1a). Alternatively, water droplet is caged by paraffin layer and released by heating. The released water dissolve HO(COOH)(CH₂COOH)₂ powder and then, NaHCO₃ reacts with HO(COOH)(CH₂COOH)₂ and CO₂ is produced (Fig. 1b).

3. Fabrication

Two types of CO₂ generator were fabricated based on equation (1) and (2), respectively, and fabrication process is illustrated in Fig. 2. Aluminum was thermally evaporated (Fig. 2a) and microheater was patterned on a glass plate (Fig. 2b). Punctured PDMS (polydimethyl siloxane) was layered on the glass for a chamber of NaHCO₃ or NaHCO₃/HO(COOH)(CH₂COOH)₂ mixture (Fig. 2c). Pattern of microchannel and chambers was made by SU-8 (a negative photoresist) and used as mold for PDMS upper sheet. CO₂ generator was completed by being covered with this upper PDMS sheet just after pouring NaHCO₃ or NaHCO₃/HO(COOH)(CH₂COOH)₂.
(COOH) (CH₂COOH)₂ mixture (Fig. 2d and 2e).

4. Results

CO₂ generator was activated by electrical input, which resulted in the pyrolysis of NaHCO₃ or the melting of paraffin layers. Sample in chamber was pushed through a microchannel by the produced CO₂. The movement of sample through a microchannel is shown in Fig. 3. Fig. 4 shows the reaction chamber in which NaHCO₃ reacts with HOC(COOH) (CH₂COOH)₂ producing CO₂ bubbles. Theoretically, more than 1.3 ml of CO₂ gas is produced from 5 mg of NaHCO₃, the actually used quantity.

5. Discussion

 Constituents of CO₂ generators described in this paper is simple, easy to be controlled and integrated, and totally bio-compatible. In addition, CO₂ gas is known as an essential component in the culture of animal...
Fig. 4 Production of CO₂ bubbles through the reaction of NaHCO₃ with citric acid. Ballooning of CO₂ bubbles is indicated by arrows. Each time interval is one second.

cells. Because pH of culture media is controlled through the interaction between NaHCO₃ within culture media and CO₂ gas, gaseous CO₂ must be continuously supplied for the survival and growth of cells. We are now fabricating portable cell chips of which the pH is controlled by the integrated CO₂ generator.

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References