Technology

Development of abatement system using no fossil fuels (Combustion Abatement System using H_2: Blisters Burner H_2)

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1. Introduction

Since 1995, the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) has been held annually to discuss climate change and to achieve effective reduction of greenhouse gas emissions in the world. Based on the decision of the Global Warming Prevention Headquarters, Japan announced on April 22, 2021 at the Leader's Summit on Climate, which was hosted by the United State, an ambitious target of a 46% reduction in greenhouse gas emissions by FY2030 compared to that in FY2013, which is consistent with the goal of carbon neutrality by 2050, and a further continued challenge to achieve 50%.

Perfluoro compounds (PFCs) such as C_2F_6 used for cleaning and etching in semiconductor and liquid crystal manufacturing processes have a global warming potential and atmospheric lifetime thousands to tens of thousands of times greater than CO_2, so reducing their emissions is essential. In addition, reduction of energy-derived carbon dioxide emissions is required in all industrial fields.

Japan's basic energy plan states that in addition to the improvement in energy consumption efficiency, the electrification with decarbonized electric power, and the use of hydrogen, synthetic methane, synthetic fuels, etc. or the implementation of innovative technologies for heat demand and manufacturing processes that are difficult to be electrified will be essential. The sixth basic energy plan states that in order to achieve carbon neutrality through the realization of a hydrogen society, it is necessary to reduce the cost of hydrogen supply and create demand in a variety of fields in an integrated manner [1].

In response to the social issues of reducing PFC emissions and utilizing non-fossil energy for taking measures against global warming, it is necessary to provide the market with, not only electification, but also an option for industrial utilization of various non-fossil energy sources.

2. Features and outline of combustion abatement system using H_2

2.1 Abatement system produced by Taiyo Nippon Sanso

Various technologies have been developed for abatement systems, including combustion, catalytic, heater, plasma, and chemical adsorption methods. For a specific application, the most appropriate method among these is chosen in consideration of the target process, process gas flow rate, initial cost, running cost, installation space, and other conditions.

We have been marketing combustion abatement systems since the 1980s, and have delivered numerous large flow rate treatment systems [2] for the production of liquid crystals, which requires a large amount of gas per production unit, and for the batch treatment of waste gas from multiple plasma CVD units. We also provide compact water-cooled combustion abatement systems for small flow rate applications, and launched a new product, Blisters Burner, in July 2022, which is mainly characterized by its cooling structure.

We are also a manufacturer of GaN-MOCVD units, and sell its auxiliary equipment, the Hercules Burner® [3] combustion abatement system. One of the features of this product is that it abates SiH_4 gas, NH_3 gas, etc. by efficiently combusting H_2 gas in the process waste gas, and it has a mechanism to add H_2 gas as a fuel if the process waste gas does not contain H_2 gas. In addition, it is equipped with an ignition burner capable of continuing ignition and combustion only with H_2 gas, and has been sold for more than 10 years as a combustion abatement system that uses only H_2 gas as a heat source. This technology is widely used not only in MOCVD units but also in processes that contain a large amount of H_2 gas in the process waste gas, especially as abatement systems for the EPI process of SiC power devices, which have attracted much attention recently.

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2.2 Features and outline of combustion abatement system using H_2

This product (named Blisters Burner H_2) is a combustion abatement system that uses H_2 gas as a fuel source instead of conventional fossil fuels (city gas 13A or propane gas, etc.) Figure 1 shows a schematic diagram of the combustion abatement system using H_2.

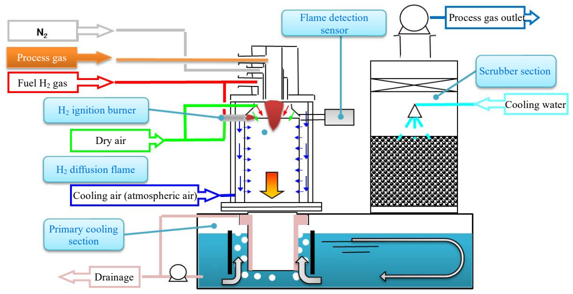

Figure 1 Schematic diagram of combustion abatement system using H_2

The system consists of a burner section, a primary cooling section, and a scrubber section. The process gas discharged from the semiconductor manufacturing equipment is introduced into the burner section, where it is heated and decomposed. The inside of the burner is supplied with guard air to prevent corrosion of the components and adhesion of powder, a secondary product, thereby enhancing the stability of the system during continuous operation. The primary cooling section rapidly cools the high-temperature process gas, and the scrubber section performs final cooling of the process gas and cleaning off the secondary products such as HF, HCl, and other water-soluble gases.

In the case of using conventional fossil fuels, the main flame of the waste gas decomposition burner is formed by premixing combustion. In the case of hydrogen combustion, however, the combustion rate is about 10 times faster than that of natural gas, so there is a high risk of backfiring. Therefore, the hydrogen combustion burner in this system uses a nozzle mixing combustion method, which supplies hydrogen and combustion supporting gas (air or oxygen) separately to the combustion field, and mixes and burns both gases there. In addition, an ignition burner fueled by H_2 gas is used as a constantly igniting ignition source.

As in the conventional system, this system adopts a method of introducing fuel gas and combustion supporting gas into the process gas flowing in the center of the combustion field (combustion cylinder) from the surrounding area. By effectively contacting and mixing the formed hydrogen flame with the process gas, the abatement performance is improved. We drew out the potential of H_2 gas combustion by developing a structure that mixes the process gas and the combustion flame appropriately by optimizing the injection rate and angle of the fuel H_2 gas and the combustion supporting gas. We measured the concentration of H_2 gas at the burner outlet and confirmed that it was 1000 ppm or less, which means that unburned H_2 gas is almost zero.

At the beginning of the development, the decomposition efficiency of PFC gas (CF_4) was about 25% under the constant flow rate conditions of fuel H_2 gas, combustion supporting gas, and process gas. However, by optimizing the burner structure and each gas flow velocity, we were able to raise the decomposition efficiency to 95%.

3. System performance

We conducted evaluation tests of the H_2-fueled burner of this system and a conventional burner fueled by fossil fuel (city gas 13A) for the CF_4 and SF_6, typical PFC gases abatement performance. The decomposition rate of each PFC was calculated by measuring the concentration of PFC waste gas by FT-IR. The decomposition rate data of the target gases were obtained by changing the heat input to the burner under fixed conditions of the target CF_4 gas flow rate of 3 L/min with dilution N_2 gas flow rate of 100 L/min and the target SF_6 gas flow rate of 2 L/min with dilution N_2 gas flow rate of 150 L/min. Figure 2 and Figure 3 show the relationship between the fuel gas heat input (compared to city gas 13A calorific value) and the decomposition rate of CF_4 and SF_6.

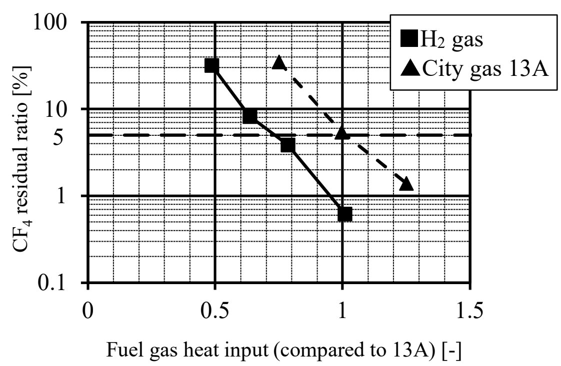

Figure 2 Comparison of CF_4 decomposition performance by fuel type

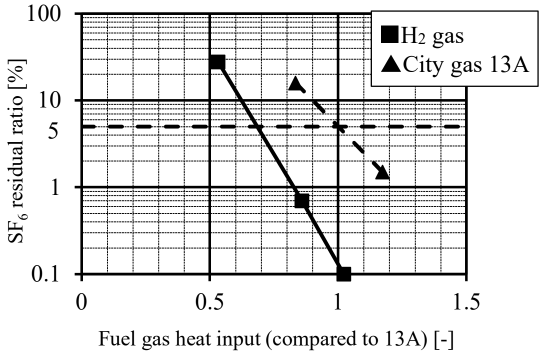

Figure 3 Comparison of SF_4 decomposition performance by fuel type

The results of the performance evaluation tests showed that the heat input to achieve a CF_4 and SF_6 decomposition efficiency of 95% or higher can be reduced by about 30% on a calorific value basis by using H_2 gas fuel compared to using fossil fuel.

In addition, it was also confirmed for other PFCs that the same abatement performance as that of the conventional fossil fuel burner could be achieved by the H_2 gas combustion burner even when the heat input was reduced by approximately 30-50%.

Based on these results, we determined that the performance of this system has certain advantages in PFC decomposition efficiency on a calorific value basis over conventional systems using fossil fuels, and brought the system to product commercialization.

4. Conclusion

We have achieved product development of a combustion abatement system using H_2 with the following features through the evaluation of its gas decomposition performance to treat PFCs discharged from oxide film etching and plasma CVD cleaning, and to cope with CVD processes etc.

- By using H_2 fuel, the heat input for PFC gas decomposition can be reduced by 30-50% compared to conventional fossil fuel burners under the same conditions.
- Due to the reduction in heat input, the amount of feed water and wastewater for cooling the abatement system can be reduced as well.
- By using this system, the direct emissions of CO_2, a greenhouse gas, generated from the combustion of fuels in conventional abatement systems fueled by fossil fuel can be reduced to zero.
- The system can be converted from a fossil fuel type to a hydrogen type by replacing only the burner. By preparing hydrogen fuel supply lines in the system at the time of the system installation, the fuel type can be easily changed after delivery.

We have developed a combustion abatement system using H_2, which will be launched in April 2024. This product uses H_2 gas as a fuel in order to contributes to carbon neutrality and respond to the coming hydrogen society. In this report, it was clarified that the amount of heat input to this system is less than that in the case of using fossil fuel. Therefore, this system can achieve not only a simple fuel conversion from fossil fuel to hydrogen gas, but also downsizing of facilities, water saving, and wastewater reducing.

By launching this product, we are now able to propose optimal abatement systems that meet the various needs of the times, such as our customers' desire for carbon neutrality.

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