Concept of induction-heating and DBD plasma hybrid reactor

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Abstract: A new concept of chemical reactor powered only by electricity is introduced. The reactor is specially designed to combine two different processes, induction heating and DBD plasma, in a single configuration. The feasibility of the induction-heating and DBD plasma hyrid reactor is tested by removing CF4 chemical which is one of popular perfluorocarbons (PFCs). In the present study, it is trying to verify any synergy effect on the concept of the hybid-type chemical reactor.

Keywords: Induction heating, DBD plasma, CF4 removal.

1. Introduction

Tetrafluoromethane (CF4), one of the popular perfluorocarbons (PFCs), has been widely utilized as a high purity etching gas for use in semiconductor manufacturing. It is well known that CF4 emission causes many serivous issues on climate change. CF4 is an extremely stable gas so that it is one of the longest-lived greenhouse gases known [1]. Combustion is the most common way to remove CF4, there is still room for improvement of CF4 removel process due to the high energy cost ($T \geq 1100$ ℃). Recently, various research groups have been trying to find an efficient way to remove CF4 based on plasma catalysis [2,3]. The chemical processes associated with plasma catalysis can provide different reaction pathways compared to the tranditinal thermo-chemistry. In the plasma catalysis, the combinations of dielectric barrier discharge (DBD) plasma and alumina-based catalysts is applied. However, the removal efficiency ($T \geq 600$ ℃) is still low and relative high temperature is required for the process. In the present study, a new concept of chemical reactor powered only by electricity is introduced to improve the process efficiency of CF4 removal. The reactor is specially designed to combine two different processes, induction heating and DBD plasma, in a single configuration.

2. Reactor concept

Figure 1 shows the conceptual drawing of the induction-DBD hybrid reactor newly introduced in this work. At the middle of the quartz tube, there is a perforated stainless steel cylinder. The process gas containing CF4 is supplied into the cylinder, and the catalyst pellets can physically contact with the process gas inside the cylinder. The copper coil is located outside of the quartz tube in order to inductively heat the cylinder. Once the cylinder is inductively heated, the catalyst pellets inside are activated. The process gas radially flows outside of the cylinder through numerous fine holes. Right after the gas flows out the induction heating zone, the gas enters the DBD plasma treatment zone. When high voltage is applied to the cylinder and the coil is grounded, DBD plasma can be generated at the specific area in-between the cylinder and quartz tube. Herein, the discharge gap is set to 3 mm. The feature of this configuration is that the cooper coil is simultaneously connected with the two different electric circuits, high-voltage plasma power supply and induction power supply.

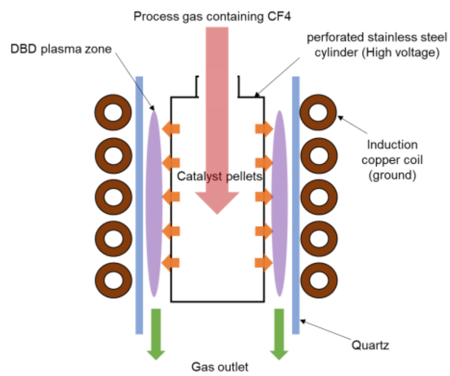

Fig. 1. Conceptual drawing of induction-DBD hybrid reactor.

3. Demonstration

Figure 2 indicates the demonstration of the concept of induction-DBD hybrid reactor. It is clearly found that DBD plasma can discharge on the high-temperature surface of the cylinder inductively heated via the coil. Under the operating conditions we can control, any electrical disturbance is observed. That means the hybrid reactor can stably operate for a long time. As far as we are aware, it is the first attempt to implement the two different phenomena with the single reactor configuration at the same time. In this work, CF4 reduction is selected to verify the characteristic of the hybrid reactor. This is because , according to the previous studies, CF4 can be removed either thermal treatment or plasma treatment. Thus, it is believed that the removal efficiency of CF4 through the hybrid reactor could indirectly provide some synergeic effects of the novel reactor configuration. In addition, it is still mysterious what the magnetic field made by the coil would affect the discharge condition of DBD plasma is. There are many things we have to analyze in order to improve our understanding related to the hybrid reactor.

Fig. 2. Demonstraton of the concept of induction-DBD hybrid reactor.

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4. References

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