NO and H_2 production from water and nitrogen using arc plasma for synthesizing ammonia

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Abstract: In this contribution, we report NO and H_2 production from water and nitrogen to generate ammonia which is carbon-free and has high energy density. We have varied some parameters including reactor configuration, reaction time, and arc length. From the experiments, it is confirmed that NO and H_2 can be produced simultaneously from water and nitrogen using arc plasma.

1. Introduction

Ammonia (NH_3) is an important industrial chemical with a wide range of applications including use as fertilizer, refrigerant, hydrogen carrier, and a precursor for many other nitrogen containing compounds. Traditionally, ammonia has been produced through the Haber-Bosch process, which combines nitrogen gas with hydrogen gas over an iron catalyst at high temperature and pressure [1]. Therefore, this process requires a lot of energy and money. In addition, Haber-Bosch process has problems such as its significant carbon footprint and greenhouse gas emissions.

2. Methods

20 LPM nitrogen was supplied and water was injected from 4 to 16 ml/min into plasma reactor using syringe pump. After plasma reactor, the products were partially pumped out and passed through liquid trap. Then, gas products were analyzed by FTIR and GC. We utilized AC power supply with 20 kHz and maximum 6 kW. Plasma waveform was observed by oscilloscope and plasma power was calculated based on this.

3. Results and Discussion

In this study, firstly we have tried two types of plasma reactor. One is cone type and the other is hollow type. Main difference between the two reactors was the shape of high voltage electrode. Cone type reactor had literally cone shaped high voltage electrode and hollow type reactor had cylinder shaped high voltage electrode. As a result, hollow type reactor showed better NO production than cone type reactor. This difference might be attributed to direct arc plasma contact with water. Water just flowed down along the reactor wall in cone type reactor though water can meet one side of the arc. On the other hand, water passes through the whole arc plasma discharge region in hollow type reactor.

In hollow type reactor, we investigated several parameters. First, lower nitrogen feed, water injection rate, and plasma power were varied while total nitrogen flow rate was fixed. In general, high power and high water injection rate led to high NO production because those conditions could provide more active oxygen species. And, higher lower nitrogen flow rate revealed higher NO production. High lower nitrogen flow rate can make longer arc since it comes out from discharge gap. This means that the chance of contact between plasma and reactant, and possibility of reactive species generation by arc plasma discharge increases.

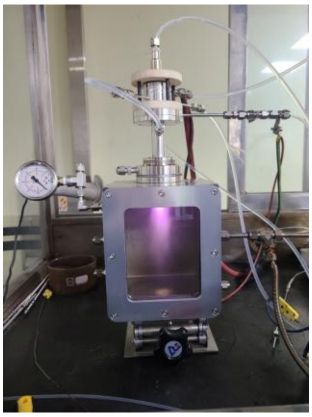

Fig. 1. Picture of arc plasma while injecting nitrogen and water

4. Conclusion

In summary, we investigated NO and H_2 production from water and nitrogen using arc plasma to synthesize ammonia. Assuming that there is enough hydrogen, our research showed relatively low energy requirement and significantly high ammonia production rate than other nitrogen reduction reactions [2]. We also confirmed that NO and H_2 concentration can be increased while using same plasma power by modifying reactor configuration, reaction time, and arc length.

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References

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