An indirect ammonia synthesis system by using dielectric barrier discharge

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Summary

An Indirect Ammonia synthesis from nitrogen and water through plasma processing is proposed and demonstrated. NH_3 is a promising hydrogen storage material because of its high hydrogen storage density. Magnesium nitride (Mg_3N_2) is a key material for the indirect NH_3 synthesis because reaction of Mg_3N_2 with water easily generates NH_3 at room temperature. Therefore, in this study, we focused on generation of Mg_3N_2 by nitridation of Magnesium oxide (MgO) with a non-thermal atmospheric-pressure dielectric barrier discharge (DBD) plasma under a N_2 atmosphere. Since NH_3 is generated through a simple chemical reaction, our scheme does not cause NH_3 decomposition by plasma, which is one of the greatest concerns associated with plasma synthesis. Unlike the conventional NH_3 generation process which emits CO_2 and require high temperature and pressure, our scheme enables NH_3 synthesis from N_2 and H_2O without CO_2 emission. This leads to achievement of an on-site small scale NH_3 synthesis system under mild conditions, which is necessary for a future low-carbon society.

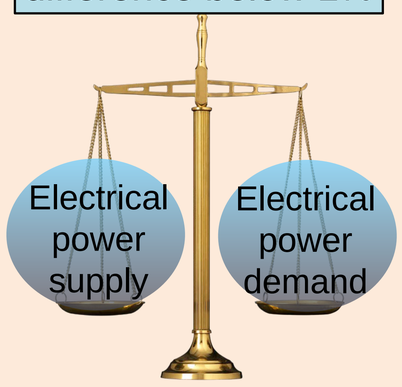
Back ground and Purpose

Low-carbon society

unstable renewable energy will increase greatly (~20%)

It is difficult to balance power supply and demand

Suppress the difference below 1%



A new technology for energy storage system is required.

Energy storage materials

NH_3 — Promising hydrogen storage material

- High Weight density of Hydrogen (17.8 mass%)
- Easy to make the liquefaction fuel (<1MPa)
- High energy Volume density
- Mass production

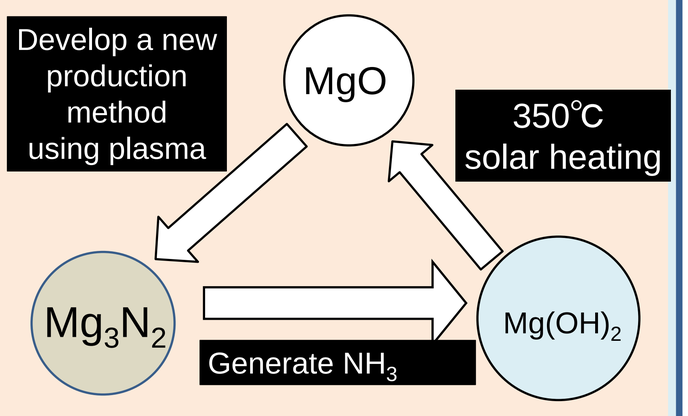
- Explosive gas
- High pressure
- Poisonous Material (<0.1%)
- Terrible smell

Mg_3N_2 — Propose as a new energy carrier material

- Reacts chemically with H_2O and generates NH_3
- A solid-state compound
- Chemically stable
- High Weight density of NH_3 (34 mass%)
- Available as fuel

- No efficient production method

Indirect ammonia synthesis



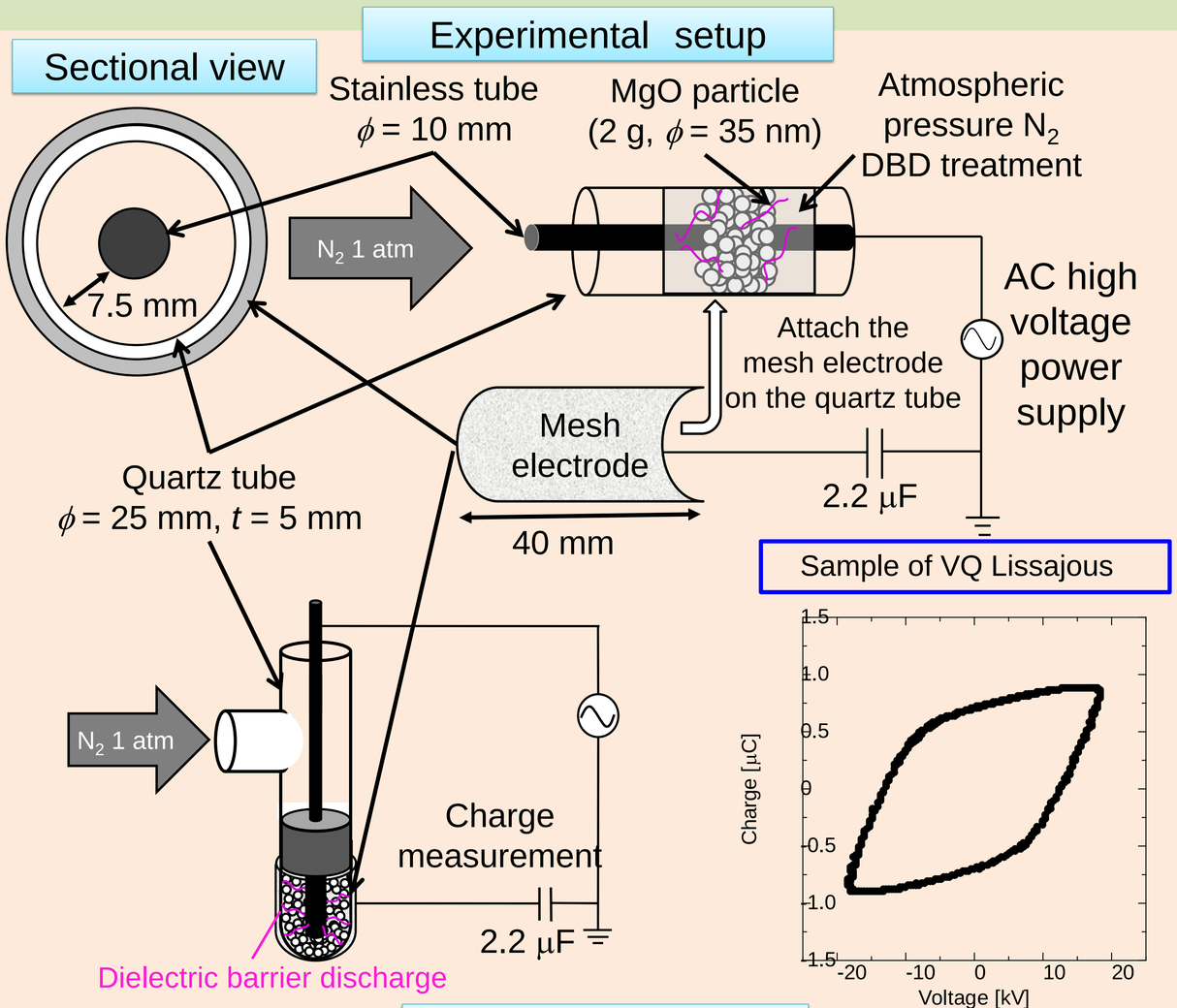
$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$

If a new production method can be established, a CO_2-free ammonia synthesis system is completed.

Experimental result and discussion

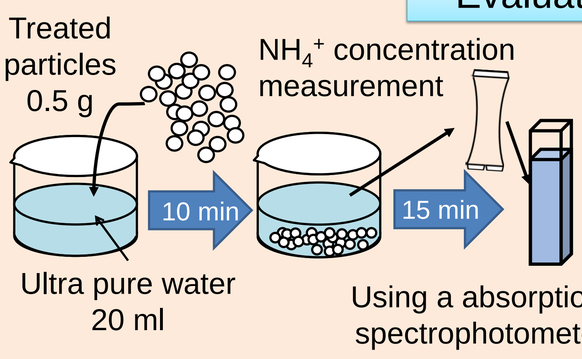
Experimental setup

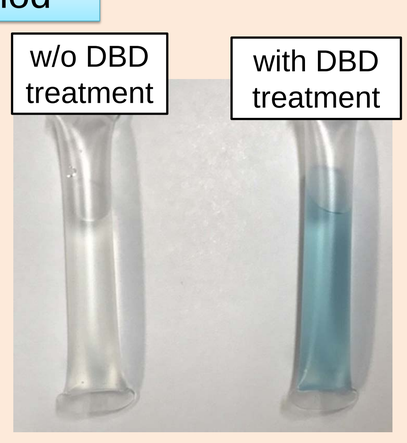
Sectional view



Sample of VQ Lissajous

Evaluation method



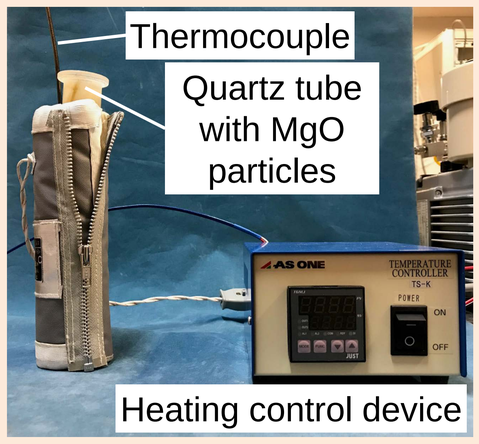


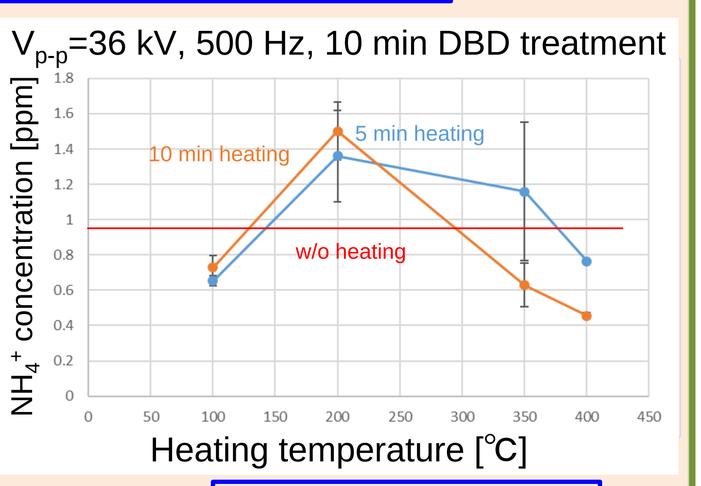
$Mg_3N_2 + 6H_2O \rightarrow 3Mg(OH)_2 + 2NH_3$

Evaluate the production amount of Mg_3N_2 by measuring the NH_4^+ concentration

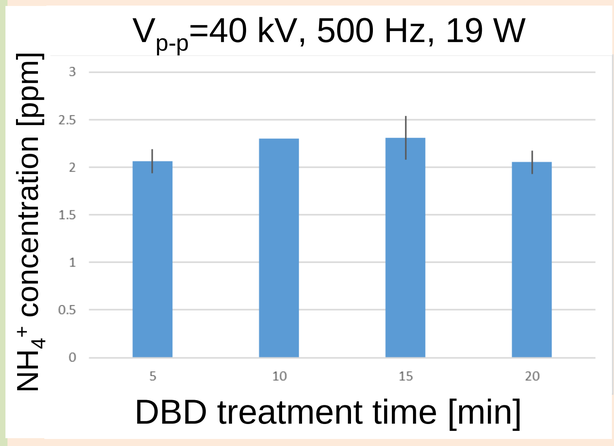
Results and discussion

Preheating treatment effect of MgO particles

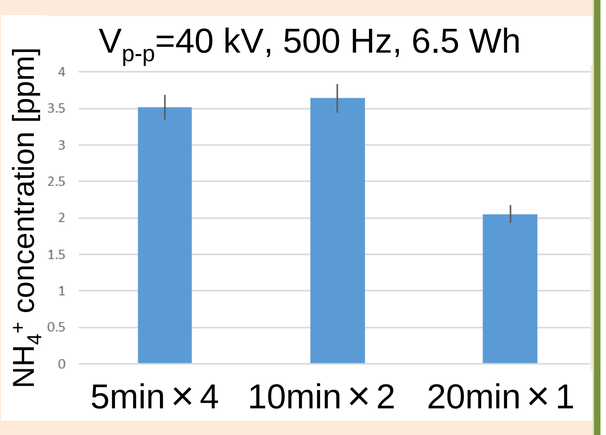




DBD treatment time



Intermittently operating DBD treatment



Atmospheric pressure N_2 DBD treatment can generate Mg_3N_2 from MgO.

$3MgO + N_2 \rightarrow Mg_3N_2 + 1.5O_2$ - 1576kJ

- The production amount of Mg_3N_2 was increasing by preheating treatment.
- Saturated tendency was seen in the production amount of Mg_3N_2.
- Saturated tendency was able to improve by intermittently operating DBD treatment.