Low temperature catalytic ammonia synthesis in an electric field

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Introduction

Compared to other hydrogen carriers, ammonia has advantages of easy-handling and a high hydrogen density. (17.6wt%) [1] Therefore, ammonia is expected as a new hydrogen carrier. However, much energy is required for synthesizing ammonia; and more efficient process is anticipated. Recently it is noticed that a catalytic reaction is activated in an electric field. [2,3] Accordingly, we demonstrated a low temperature catalytic ammonia synthesis with the electric field. 9.9wt%Cs/5wt%Ru/$SrZrO_3$ showed high ammonia synthesis activity even at low reaction temperatures in the electric field. Kinetic analyses indicated that the dissociation of N_2 bond, which is generally regarded as a rate-determining step, was extremely promoted in the electric field.

Experimental

A fixed-bed flow-type reactor was used for the activity test. For application of the electric field, stainless steel rods were inserted and 6 mA direct current was imposed to the catalyst bed under N_2 and H_2 atmosphere as shown in Fig.1. N_2 isotopic exchange tests were conducted under $^{28}N_2$, $^{30}N_2$, H_2 and Ar flow in the electric field.

Results and discussion

Figure 2 shows the ammonia synthesis rate and N_2 dissociation rate on a catalytic reaction in the electric field (423 K) and that on a conventional catalytic reaction (573 K and 623 K). As shown in Fig.2, the ammonia synthesis was promoted with the electric field, and the activity at 423 K with the electric field exceled that at 623 K without the electric field. N_2 dissociation rate is markedly enhanced during application of the electric field as shown in Fig.2. In addition, the N_2 dissociation rate extremely surpassed total ammonia synthesis rate. Therefore, there is a possibility that the rate-determining step for the ammonia synthesis during application of the electric field is not dissociation of N_2 bond but the subsequent hydrogenation steps.

Conclusion

In conclusion, catalytic ammonia synthesis was extremely promoted with an application of electric field. In addition, results of kinetic analyses indicated that the dissociation of N_2 bond was markedly promoted by the electric field, and the rate-determining step was shifted from the N_2 bond dissociation to hydrogenation step.

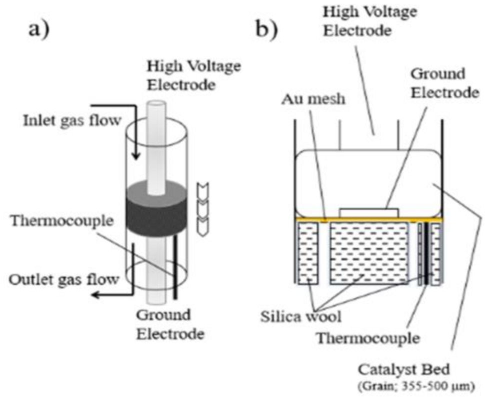

Fig.1 A schematic image of catalytic reactor with an electric field; a) overall b) sectional view.

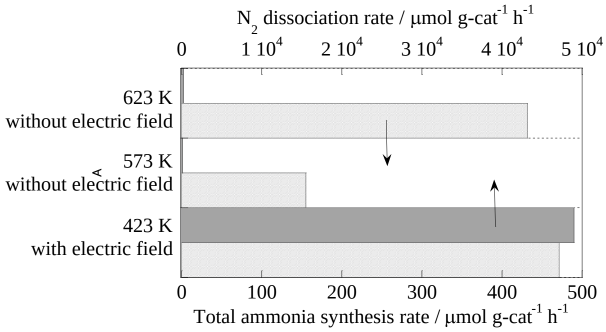

Fig.2 Ammonia synthesis rates and N_2 dissociation rates; at 423 K with electric field, 573 K without electric field, 623 K without electric field.

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