Catalysts for Green Ammonia Synthesis

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Ammonia (NH_3) is the most important chemical for the production of synthetic fertilizers and various nitrogen-containing chemicals. The global production of NH_3 reaches 160 million tons per year. Approximately 80% of the produced NH_3 is consumed as artificial fertilizers, which sustains the global food supply chain. Recently, ammonia has also attracted much attention as an excellent candidate for hydrogen storage and transport because of its high volumetric and gravimetric hydrogen capacity and facile liquefaction under mild conditions. In addition, CO_x-free hydrogen is available from NH_3 decomposition in contrast to hydrogen derived from natural gas. The industrial NH_3 synthesis process (Haber-Bosch process) is typically conducted at temperatures of 400-500℃ and pressures around 10-30 MPa, resulting in effluent NH_3 concentration of *ca* 20%. A highly active iron-based catalyst promoted by irreducible oxides such as K_2O, Al_2O_3, and CaO is used for this process.

Nowadays, small-scale and on-site NH_3 synthesis processes are in demand for green ammonia, in which ammonia should be produced from H_2 electrolyzed by renewable energy. To realize the on-site ammonia process, it is necessary to develop a new catalyst system that works effectively under low reaction temperatures. We started the research on novel catalysts appropriate green NH_3 synthesis (low P & low T).The key process is how to reduce the energy barrier to dissociate N≡N. Our approach is to utilize low work function (strong electron donation power) of electrides in which electrons serve as anions. Figure 1 shows the progress in electride catalysis for NH3 synthesis. The max performance reaches ~8% NH_3 at 360℃-0.9MPa. Our research on electride materials and application to chemical reactions focusing on green NH_3 synthesis were recently summarized in a comprehensive review article [1].

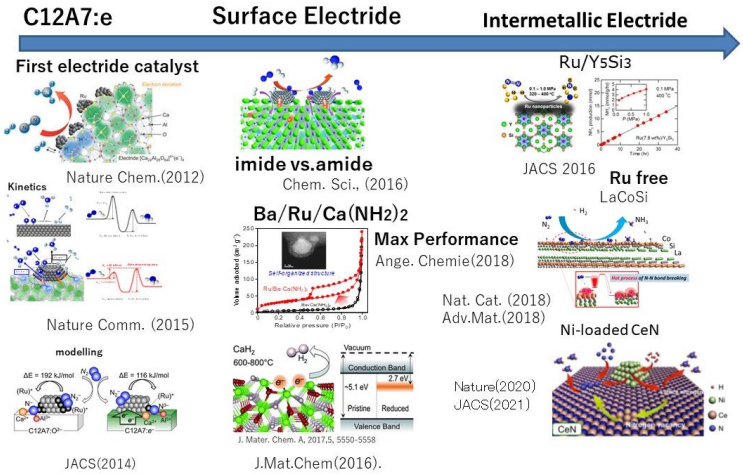

Fig.1. Progress of Electride Catalysts for Green NH_3

[1] H.Hosono, M.Kitano, Chemical Reviews, 121(5), 3121-3185(202