Reaction efficiency of hydrogen and carbon monoxide on an amorphous substrate of Mg-Fe-bearing silicate

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Abundant hydrogen and carbon monoxide gases have a greater chance for reaction to be more complex molecules on a cold surface of cosmic dust particles in the molecular cloud and/or primitive solar nebula. Generation of organic molecules and subsequent evolution to organic materials in the solar nebula may contribute to the primordial organic system of the Earth. Catalytic chemical reactions should be non-negligible production pathway of organic materials in the solar nebula after the formation of simple molecules on nanometer sized cosmic dust particles (presolar grains) in the molecular clouds. Experimentally, organic molecules ranging from methane (CH_4), ethane (C_2H_6), benzene (C_6H_6) and toluene (C_7H_8), to more complex species such as acetone (C_3H_6O), methyl amine (CH_3NH_2), acetonitrile (CH_3CN) and N-methyl methylene imine (H_3CNCH_2) have been produced using such as the Fischer-Tropsch type (FTT) and Haber-Bosch type (HBT) reactions on analogs of naturally occurring grain surfaces [1].

Previous studies performed experiments at higher-temperature (>573 K) and pressure (~1 atm) than the expected conditions in the solar nebula [2-5]. In case of actual environment in the early nebula, the temperature and pressure should be below 500 K and lower than 10^2 Pa, respectively. It is not obvious that the results of the reaction experiments are able to extrapolate to the actual early nebula environment, because we still do not fully understand the fundamentals of catalytic reactions. To determine the chemical reaction rates at lower temperature and pressure, we prepared an experimental system, which was originally designed and constructed based on a new concept to conduct catalytic experiments on a substrate simulated dust surfaces at relatively low- temperature (50-750 K) and pressure conditions (lower than 10^3 Pa). The temperatures of the cold head and substrate are measured using a silicon diode and a thermocouple, respectively.

Initially, we used substrates of iron, nickel and iron-nickel alloys with 1 % or 10 % of Ni contents and detected formation of methane, water and carbon dioxide by FTT, Water-gas shift and Boudouard reactions in a wider temperature range under a mixture gas of hydrogen and carbon dioxide with a ratio of roughly 2:1. The efficiency for methane and water formations by FTT reaction is 5×10^{-11} s^{-1} at 750 K for instance. In this presentation, in addition to concluding results for metallic substrate, we will focus on our recent results performed using an amorphous substrate of magnesium-iron-bearing silicate, which was prepared by a RF sputtering method in Institute for Planetary Materials, Okayama University.

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