Catalysis chemistry, Petroleum chemistry, Carbon neutral

Development of advanced catalytic technology for utilization of carbon dioxide at low temperature

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Abstract

Carbon dioxide (CO_2) is considered to be the main cause of global warming, and efforts have been devoted to reduce its emissions on a global scale. On the other hand, carbon monoxide (CO), which is obtained by hydrogenation of CO_2, is a useful chemical raw material for liquid hydrocarbons such as alcohol, gasoline, jet fuel, etc. The reaction of CO_2 with hydrogen (H_2) to obtain CO (reverse water-gas shift reaction) conventionally requires a high temperature of 500℃ or higher. Yamashita Laboratory has discovered that CO can be obtained efficiently and selectively from CO_2 and H_2 at around 140℃ using a catalyst composed of molybdenum oxide coupled with platinum (Pt) nanoparticles. Furthermore, the reaction rate significantly increased when the catalyst was irradiated with light.

Background & Results

CO_2 is considered to be a major contributor to global warming, and efforts have been devoted to reduce its emissions on a global scale. Japanese government declared an intention to achieve zero emissions of greenhouse gases including CO_2 by 2050. To achieve this goal, development of technologies to recover CO_2 as a carbon resource and utilize it as a useful material (CO_2 capture and utilization technology) has been required. If CO_2 can be efficiently converted to CO, it will be possible to produce useful substances while reducing CO_2 emissions, thereby contributing to the problems of global warming and depletion of fossil resources. However, the reaction to produce CO by reacting CO_2 with H_2 (reverse water-gas shift reaction, equation: ($CO_2 + H_2 = CO + H_2O$) conventionally requires a high temperature of 500℃ or higher, and only a low reaction rate can be obtained at low temperatures due to equilibrium constraints.

Our research group has succeeded in selectively producing CO from CO_2 using a catalyst composed of molybdenum oxide coupled with platinum (Pt) nanoparticles, allowing the reaction to proceed efficiently and selectively at approximately 140℃, a much lower temperature than that reported earlier. Interestingly, we also found that the reaction rate is significantly improved when the catalyst is irradiated with light. In particular, the catalyst consisting of Pt nanoparticles immobilized on nano-sheet molybdenum oxide with a thickness of about 40 nm showed a CO production rate 1.5 times higher than that using particulate molybdenum oxide, and CO was produced at a reaction rate of 1.2 mmol/g/h under visible light irradiation. The key to achieve this result are (i) the formation of oxygen defects as active sites by combining molybdenum oxide with Pt nanoparticles, and (ii) the change of the optical property of the molybdenum oxide which originates from surface plasmon resonance.

Significance of the research and Future perspective

This catalyst has the basic features essential for practical use, such as simple preparation, easy separation of the catalyst, and low temperatures required for operation where waste heat can be used. Furthermore, the reaction rate is significantly increased under the irradiation of light. This technology is expected to be a clean catalytic technology for converting CO_2 into industrially useful substances with low energy consumptions.

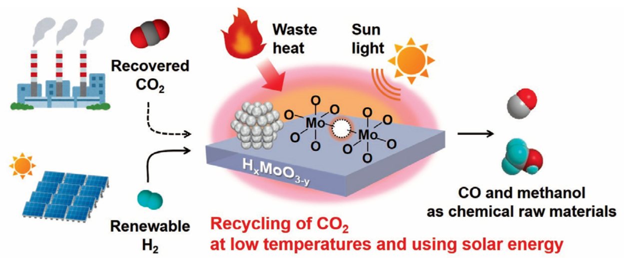

Figure 1 Catalyst development for energy-saving CO_2 recycling

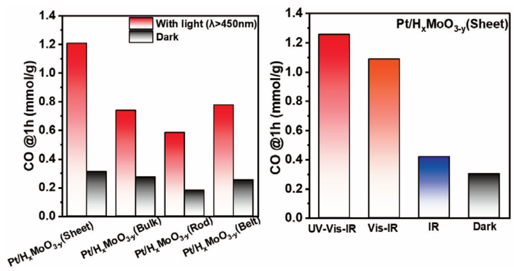

Figure 2 Results of CO_2 hydrogenation using molybdenum oxide-supported Pt nanoparticle catalysts

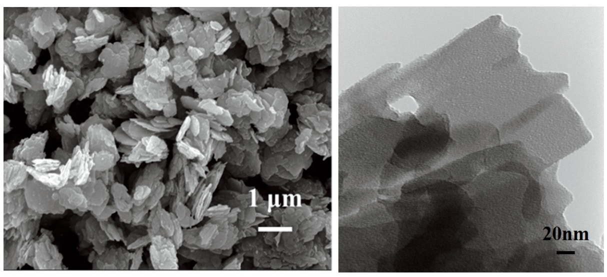

Figure 3 Scanning electron microscope (SEM) image and transmission electron microscope (TEM) images of molybdenum oxide-supported Pt nanoparticle catalysts

Patent Japanese Patent Application No. 2020-093711

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Keyword CO_2 capture and utilization, CO_2 reutilization, molybdenum oxide, surface plasmon resonance