



# Development of a low-temperature methanation self-catalytic reactor using a metal 3D printer

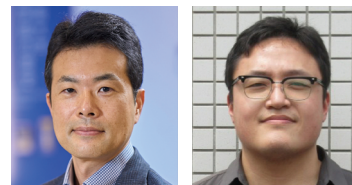
Division of Materials and Manufacturing Science, Graduate School of Engineering

Professor Kohsuke Mori



<https://researchmap.jp/7000018582?lang=en>

Specially Appointed Assistant Professor Hyo-Jin Kim



## Abstract

We developed a layered  $\text{Na}_2\text{Ti}_3\text{O}_7$ -supported Ru catalyst as a stabilizer of low-valence Ru that enables  $\text{CO}_2$  activation at low temperatures (Fig. 1). This catalyst leads to a  $\text{CH}_4$  production rate of 33.6 and 139.1  $\text{mmol g}_{\text{cat}}^{-1} \text{h}^{-1}$  at 140 and 180 °C, respectively, with a gas hourly space velocity of 24,000  $\text{mL g}^{-1} \text{h}^{-1}$  at ambient pressure (1 bar), significantly surpassing state-of-the-art catalysts performance. Moreover, the catalyst demonstrates robustness to on-off intermittency and 220-hour long-term stability tests, indicating its reliability under challenging conditions. The catalyst was also successfully synthesized at the gram scale and on a 3D-printed metal self-catalytic reactor (SCR) by a facile ion-exchange method, confirming its excellent scalability. This study marks a significant step forward in the design of catalysts for the low temperature  $\text{CO}_2$  hydrogenation.

## Background & Results

The application of metal 3D printing techniques in the field of catalyst design has recently been considered a new strategy to simplify the catalyst development process and provide a wide range of functions. Design flexibility is one of the most important advantages; creating complex internal and external geometries enables enhanced mass transfer and catalytic efficiency. Another important characteristic is versatility in material selection. A wide range of metal sources, including alloys, composite materials, and even catalyst-functionalized powders, can be used. In addition, metal 3D printing technology can be easily scaled up for mass production, ensuring cost-effectiveness. Particularly, AM-based catalysts have emerged as a cutting-edge fusion technology that serves as both catalysts and reactors, referred to as self-catalytic reactors (SCR). (Fig. 2)

## Significance of the research and Future perspective

Metal 3D-printed SCRs are a newly emerged research field, and thereby there is a lack of comprehensive information on SCRs. Further research is essential to establish a robust SCR design database containing materials, surface functionalization, geometrical structure, and mechanistic study results. This database would enable the creation of various scaled-up SCR shapes, i.e., heat exchangers and high-density reactors, for improved cost-effectiveness and industrial application with maximization of the advantages of SCRs. Despite these challenges, SCRs are anticipated to be a technology that explores potential future advancements in both 3D printing technology and catalytic reactor design.

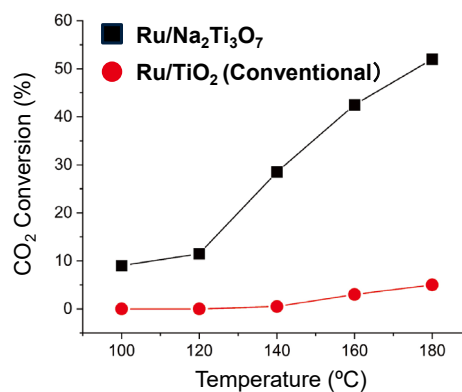
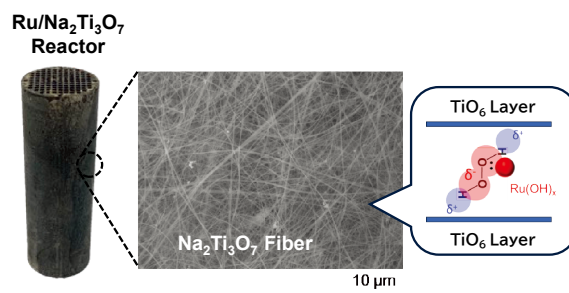


Fig. 1 Ru/Na<sub>2</sub>Ti<sub>3</sub>O<sub>7</sub> reactor fabricated by metal 3D printer and CO<sub>2</sub> methanation activity.

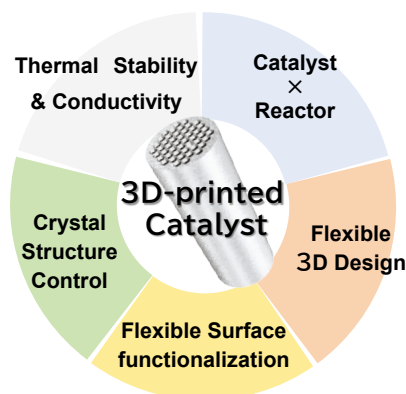


Fig. 2 Characteristics of the 3D-printed metal catalyst

**Patent** Japanese Patent Application No.2025-177864, No.2025-102633

**Treatise** Kim, H.-J.; Mori, Kohsuke; Nakano, Takayoshi et al. Layered  $\text{Na}_2\text{Ti}_3\text{O}_7$ -supported Ru catalyst for ambient  $\text{CO}_2$  methanation. *Nature Communications*. 2025, 16, 2697. doi: 10.1038/s41467-025-57954-9

Kim, H.-J.; Mori, Kohsuke; Nakano, Takayoshi et al. Robust self-catalytic reactor for  $\text{CO}_2$  methanation fabricated by metal 3D printing and selective electrochemical dissolution. *Advanced Functional Materials*. 2023, 33, 2303994. doi: 10.1002/adfm.202303994

**URL** <http://www.mat.eng.osaka-u.ac.jp/msp1/mori/en/index.html>

**Keyword** self-catalytic reactor, metal 3D printing, CO<sub>2</sub> methanation