Additive Manufacturing of Fe catalysts by Direct Ink Writing and their application in plasma-catalytic NH_3 decomposition

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Highlights

- 3D-printing allows fabrication of structured catalysts for plasma-assisted processes.
- Printed catalyst showed higher NH_3 conversion than the conventional powder catalyst.
- Direct Ink Writing combined with impregnation enables efficient fabrication of structured catalysts.

1. Introduction

In recent years, 3D-printing has gained considerable attention in the field of catalysis due to its ability to produce highly controlled and complex catalyst architectures that are difficult to achieve using conventional shaping techniques. Additive manufacturing enables the design of structured catalysts with optimised mass and heat transfer properties and improved mechanical strength. Among various 3D printing techniques, DIW stands out for its simplicity, low cost, and compatibility with ceramic materials, making it particularly attractive for the fabrication of supports and catalysts [1-2]. In addition, the growing interest in sustainable catalytic materials and resource-efficient processing routes has stimulated the development of structured catalysts designed for energy transition technologies, including ammonia-based hydrogen carriers. In this context, ammonia synthesis and decomposition have emerged as key reactions due to ammonia's role as a carbon-free fuel and hydrogen vector. Structured catalysts manufactured via DIW enable precise control over porosity, channel geometry, and active phase distribution, offering new opportunities to enhance reaction kinetics, reduce diffusion limitations, and improve thermal management in both ammonia synthesis and cracking processes. Such tailor-made architectures are particularly promising for next-generation Fe-based catalysts, where optimised heat transfer and minimised pressure drop are essential for high efficiency. Consequently, 3D-printed catalytic structures are gaining recognition as an enabling technology for compact, modular ammonia reactors suitable for distributed hydrogen production and renewable-energy storage systems.

2. Methods

In this study, the fabrication of 3D-printed catalyst supports for plasma-assisted ammonia decomposition was investigated. The optimisation of Nd_2O_3- and Al_2O_3-based pastes composition (selection of proper type and amount of dispersant, solvent and plasticiser) was performed on the basis of rheological measurements of selected dispersions. Then, printing parameters were adjusted. Supports were printed on a DIW 3D printer and, after calcination, were impregnated with an iron precursor. Materials were characterised by their mechanical parameters, including hardness and fracture toughness. The properties of the obtained materials were determined through N_2 physisorption, H_2-TPD, TPR, X-ray Diffraction and Scanning Electron Microscopy. Activity tests were conducted in a plasma-catalytic gliding discharge reactor.

3. Results and discussion

The 3D-printed catalyst supports were successfully fabricated using DIW to achieve the desired structural integrity (Figure 1.). Rheological optimisation of ceramic pastes enabled precise extrusion, resulting in well-defined porous architectures. Catalytic performance tests confirmed that all types of supports allowed the obtaining of functional catalysts for plasma-assisted ammonia decomposition, with variations in activity and efficiency.

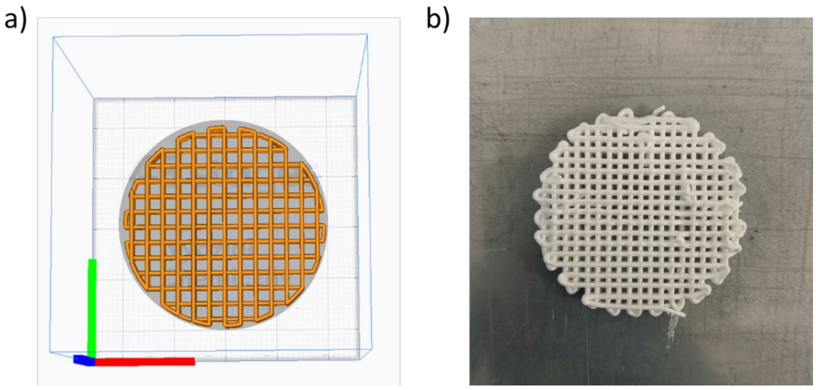

Figure 1. Design and fabrication of DIW-printed catalyst support: CAD model (a) and 3D-printed support structure (b).

4. Conclusions

The study demonstrates that DIW is an effective strategy for structuring Fe catalysts, thereby improving performance in plasma-assisted ammonia decomposition. Such architectures open new opportunities for developing sustainable catalytic systems for hydrogen-oriented technologies.

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