# Direct Ammonia Solid Oxide Fuel Cells

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## Introduction

Ammonia is one of the major hydrogen carriers being explored in recent years. Ammonia contains 17.6 wt% of hydrogen and has an energy content similar to liquid fuels like methanol. Furthermore, ammonia can be liquefied under far milder conditions, and significant infrastructure for its production, storage, and transportation is already available. One of the major hurdles in the application of ammonia as an energy carrier is the limited number of options for the utilisation of stored and transported ammonia for electricity generation. Traditional approaches involve energy-intensive multi-step processes (cracking of ammonia, hydrogen separation, and then utilisation in fuel cells) to generate electricity from ammonia.

## Project objectives

This project proposes direct ammonia solid oxide fuel cells (DA-SOFCs) for converting ammonia into electricity in a single step. This technology offers the highest electrical efficiency (50-55%) for ammonia conversion to electricity among all competing technologies, and nearly 80% of fuel utilization can be achieved [1-3]. The key project objective would be to develop a high-performance anode electrode material with optimal electrical and catalytic properties tailored explicitly for the direct use of ammonia fuel, build a prototype stack and perform techno-economic/life-cycle analysis.

## Key expected project outcome

The project's outcome would be a modular and scalable direct ammonia fuel cell module (1 kW) with newly developed electrode materials operated for several hundred hours, proving the technology's viability.

## Working principle of DA-SOFCs

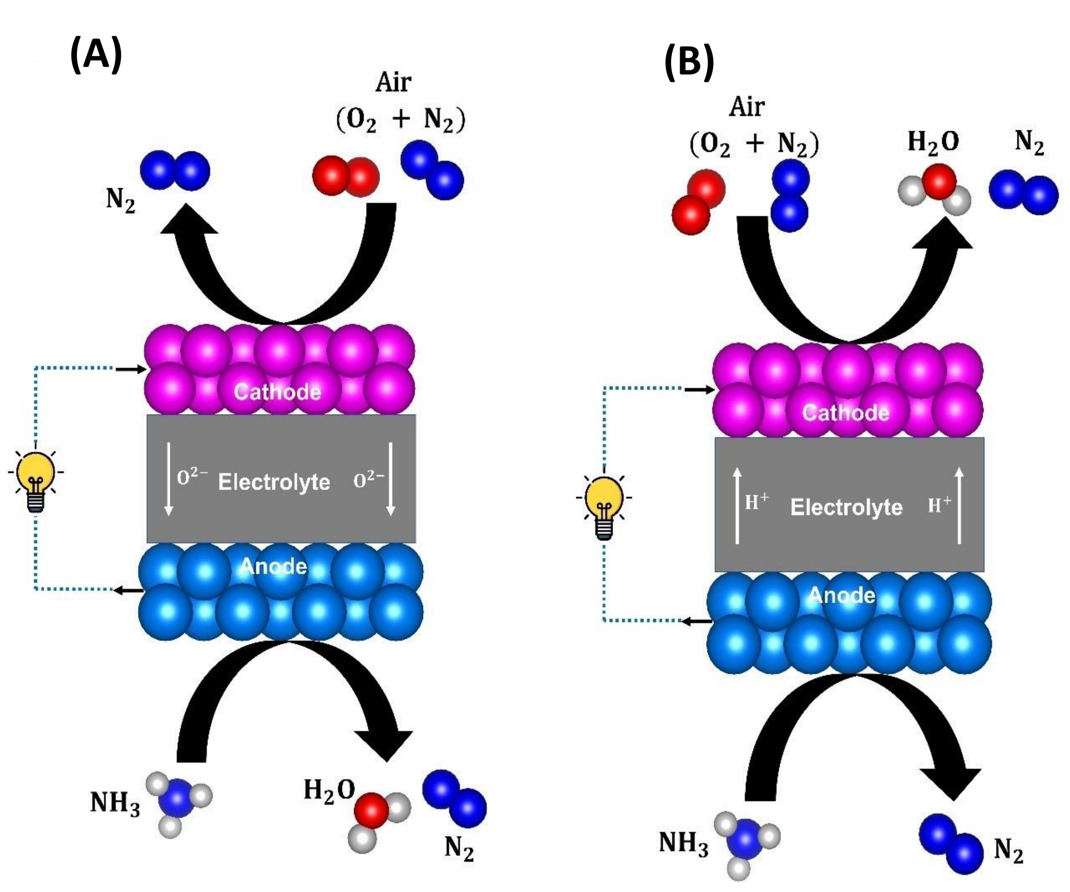


**Figure 1:** The DA-SOFCs working principle based on (A) oxide-ion-conducting (O-SOFC) and (B) proton-conducting (H-SOFC) electrolytes.

## DFT modelling: Ni-YSZ (111) anode

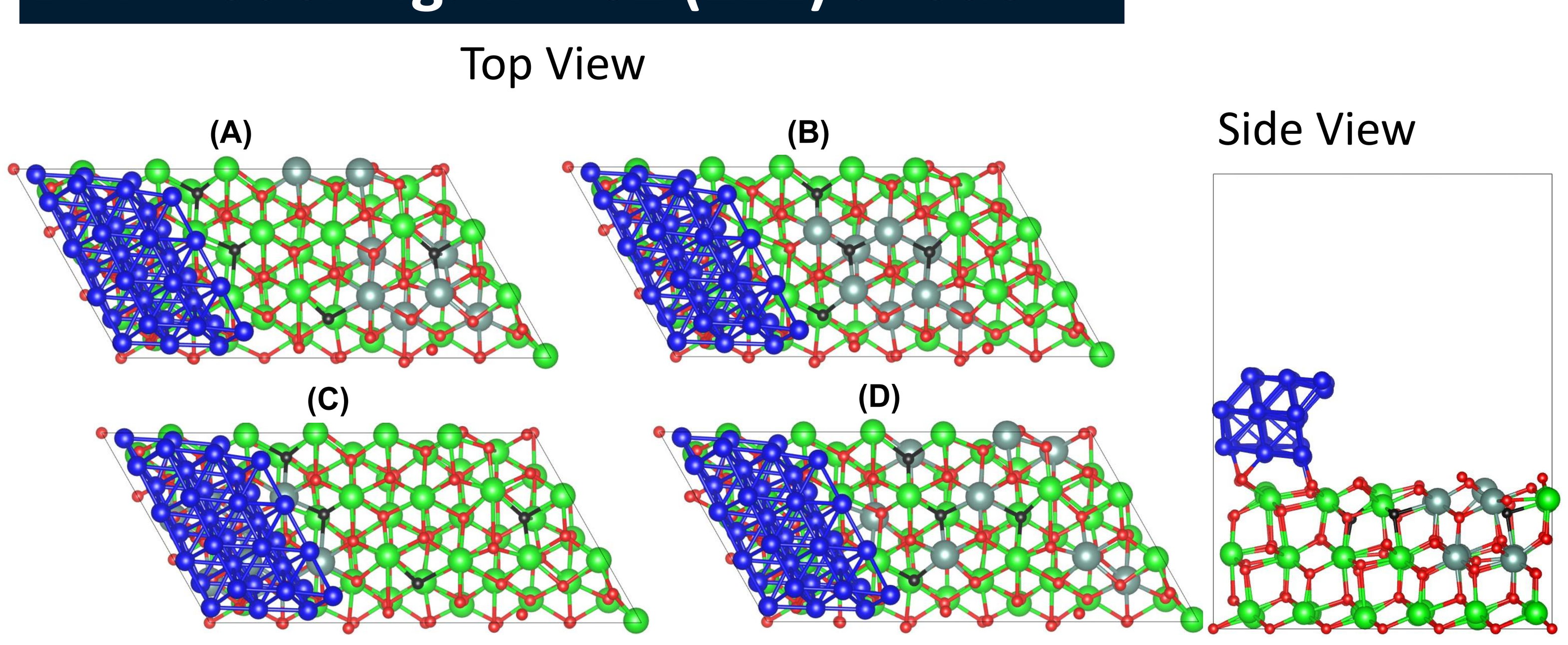


**Figure 2:** Top views of various configurations (A-D) of Ni-YSZ (111) surface ; (Ni: blue; Zr: green; Y: gray; O: red; and oxygen vacancy (Ov): black).

## SEM images of cells

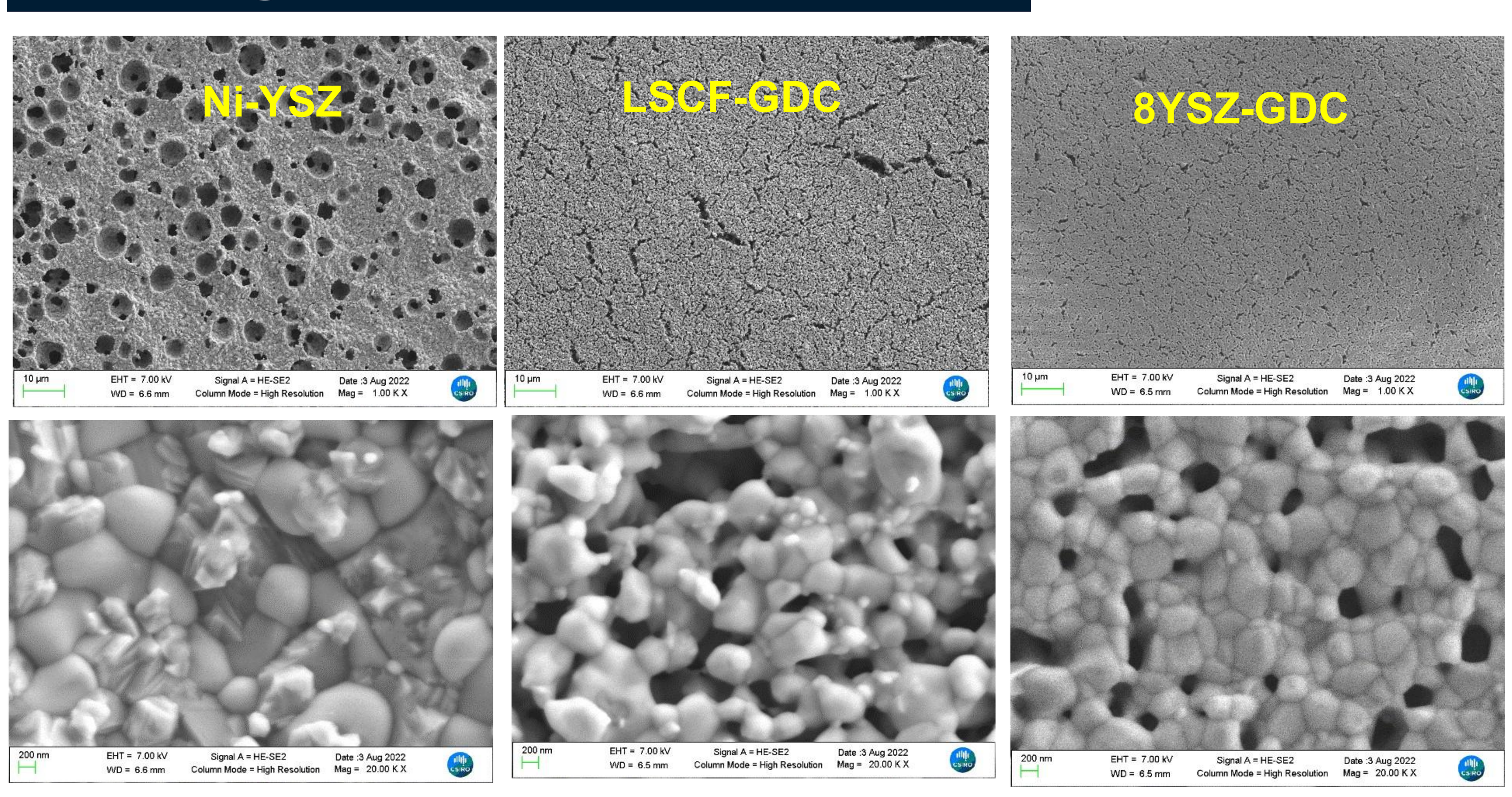


**Figure 3:** SEM micrographs of Ni-YSZ||YSZ||GDC-LSCF cell.

## DA-SOFCs test station

**Figure 3:** DA-SOFCs test station.

## Cell components, assembly, and OCV

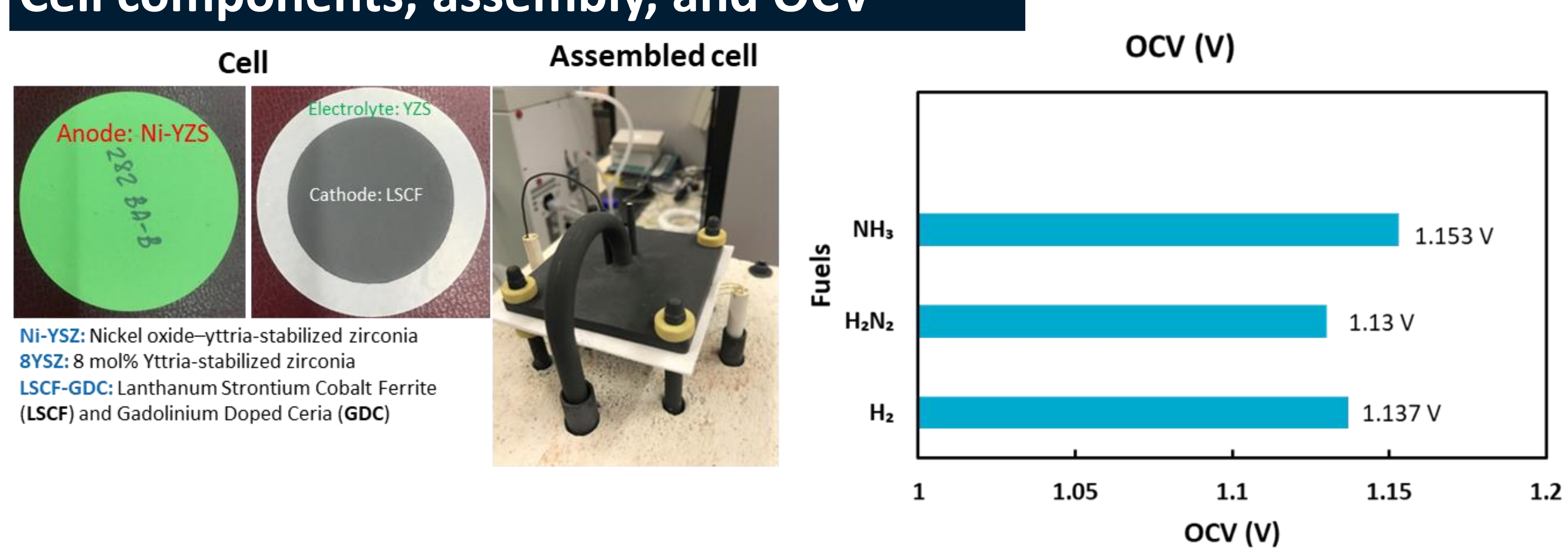


**Figure 4:** Cell components, assembly, and open-circuit voltage (OCV) measurement of Ni-YSZ||YSZ||GDC-LSCF cell under $NH_3$, $H_2$, and $H_2/N_2$ fuels at 800°C.

## Fuel cell performance under $NH_3$ and $H_2$ fuels

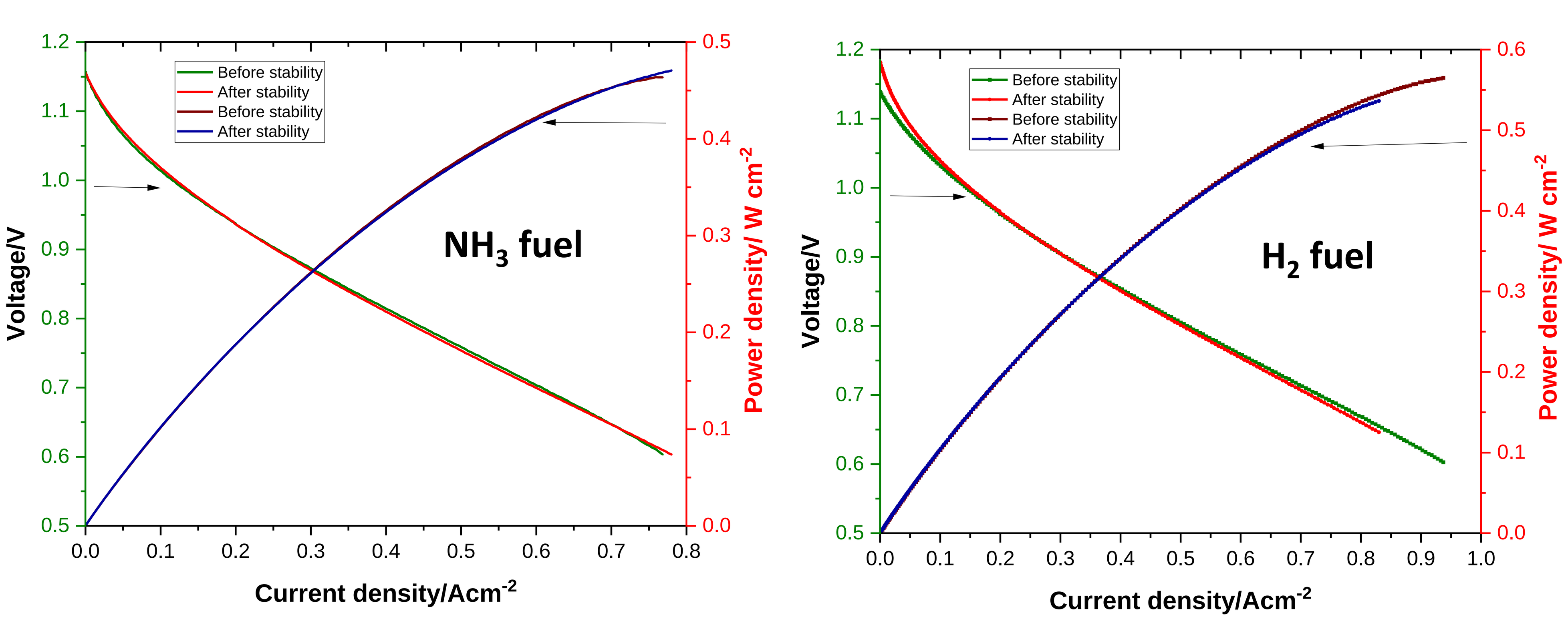


**Figure 5:** I-V-P curves of Ni-YSZ||8YSZ||LSCF-GDC cell with $NH_3$ and $H_2$ as fuel at 800°C.

## Conclusion

The direct ammonia to power generation in a single step has been demonstrated through solid oxide fuel cell technology and achieved a power density of 0.470 W/cm$^2$.



**FOR FURTHER INFORMATION**

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**REFERENCES**

[1] Giddey et al.; ACS Sustainable Chemistry & Engineering 5 10231-10239, 2017.
[2] Rathore et al.; Solids 2, 177-191, 2021.
[3] Rathore et al.; International Hydrogen Energy 46, 35365-35384, 2021.

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