Innovative Perovskite Materials for High-performing Reversible Solid Oxide Cells

Ubong Essien and Dragos Neagu

Department of Chemical and Process Engineering, University of Strathclyde

BACKGROUND OF THE STUDY

❑ Green-ticks on Reversible Solid Oxide Cell (RSOC)

- ✓ Combines the capability of electrolytic cell and fuel cell into one device;
- ✓ Convert excess generated renewable energy into green hydrogen for storage;
- ✓ Enables on-demand production of green hydrogen and electricity;
- ✓ Can facilitate a just net zero society with hydrogen as the main energy carrier.

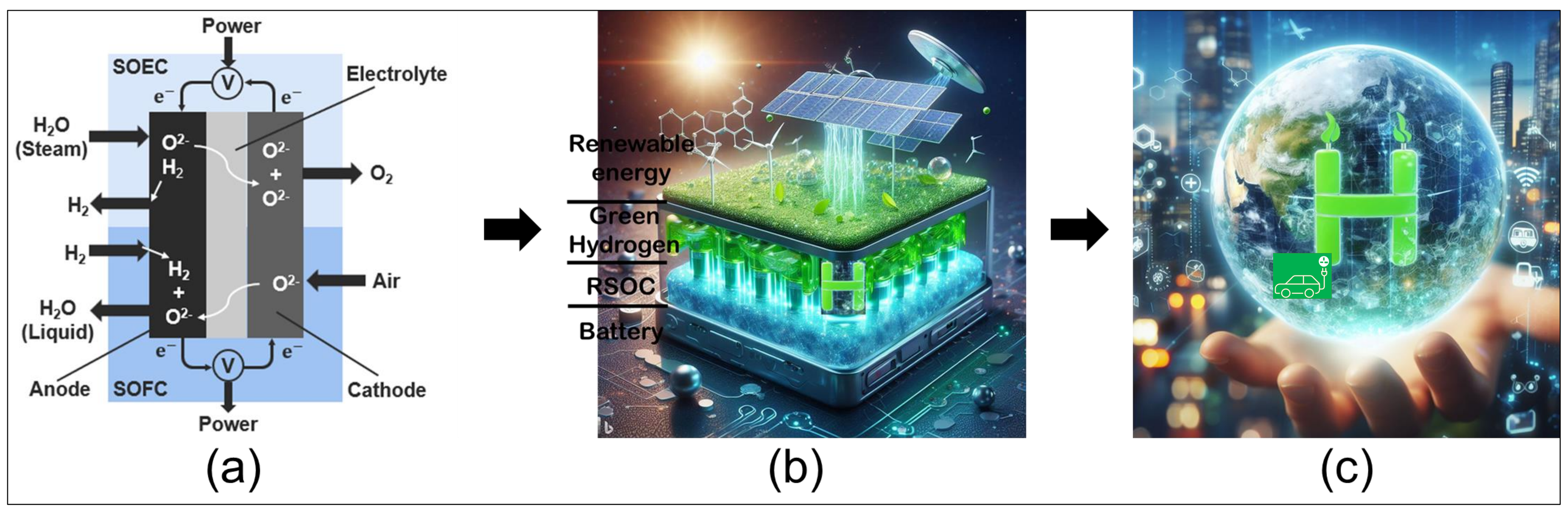


Figure 1: (a) a RSOC, (b) a net zero energy system built on the potentials of renewable energy and green hydrogen, and (c) a net zero society with hydrogen as the primary energy carrier.

❑ Drawback to Full Commercialisation of RSOC

- Stringent electrochemical requirements: high ionic and electronic conductivity, high catalytic activity, durability, stability, etc;
- High operating temperature requirement;
- Need for innovative electrode materials.

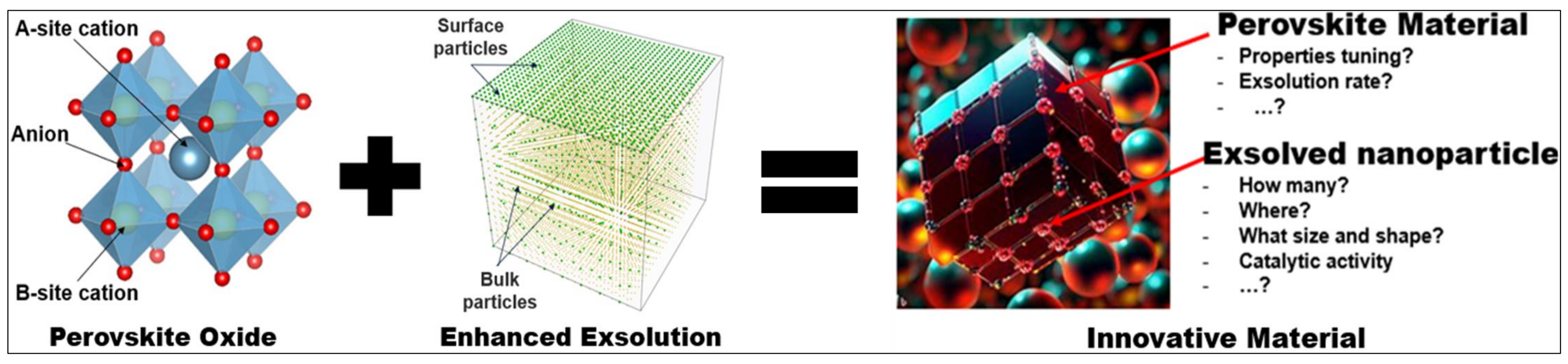


Figure 2: Schematics of innovative perovskite material enabled by enhanced exsolution process

OBJECTIVES OF THE RESEARCH

This research aims to develop novel perovskite materials capable of surface and bulk exsolution processes (in-situ formation of metallic nanoparticles) to fulfil the multiple electrochemical requirements of RSOCs.

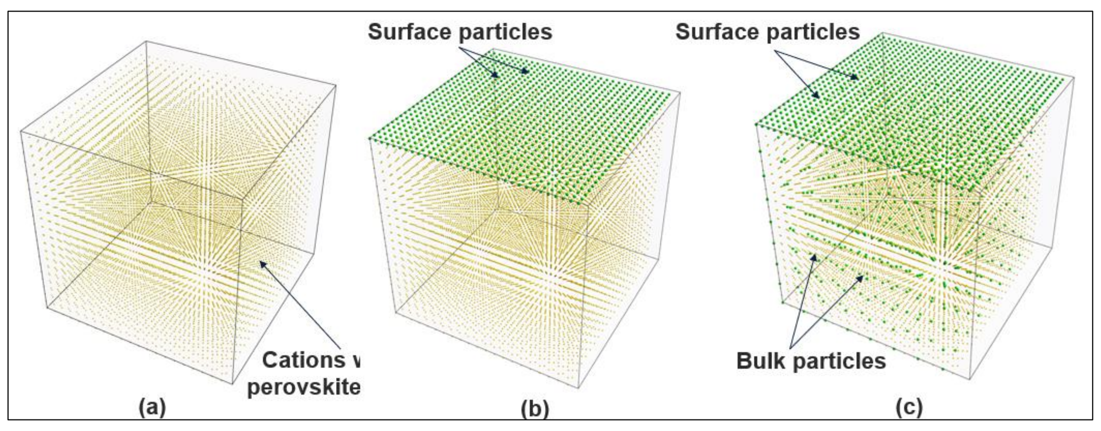
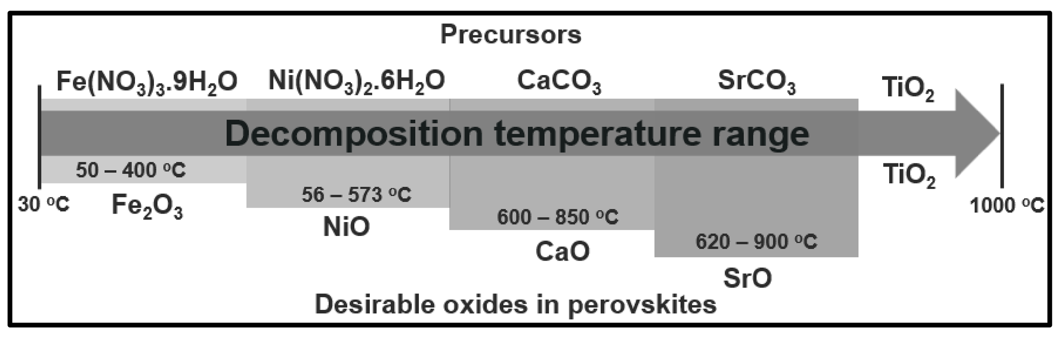


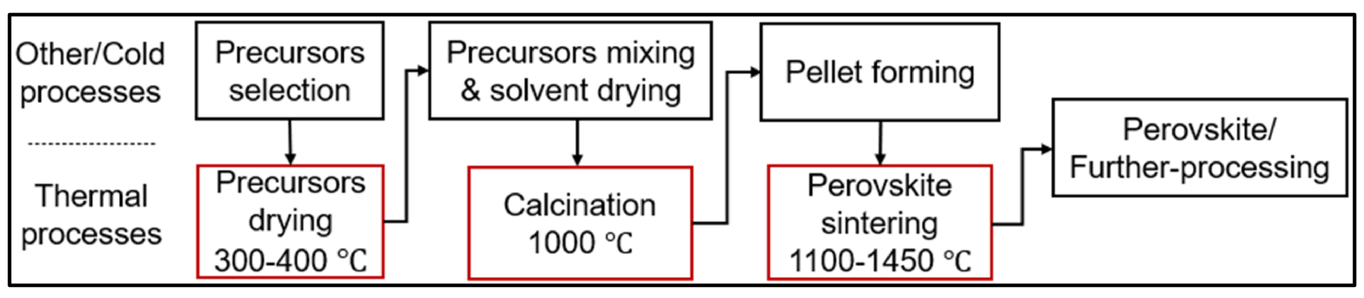
Figure 3: Schematics of a nanoscale representation of a perovskite lattice at (a) cations segregation, (b) surface exsolution, and (c) bulk and surface exsolution.

METHODOLOGY

Selected precursors and established synthesis parameters → Synthesized perovskites by solid state method → Characterized the perovskites (TGA, XRD, SEM, etc.) → Reduced the perovskite to study exsolution process



(a)

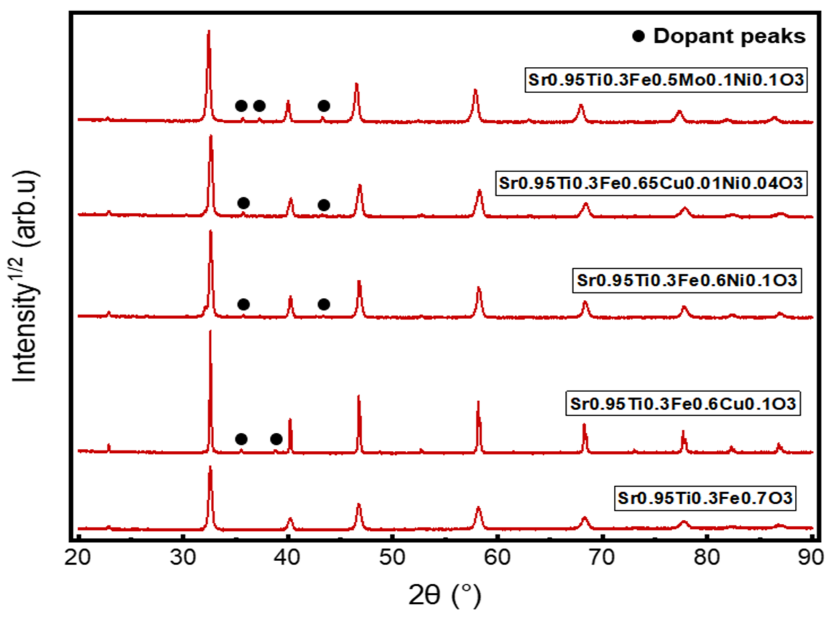


(b)

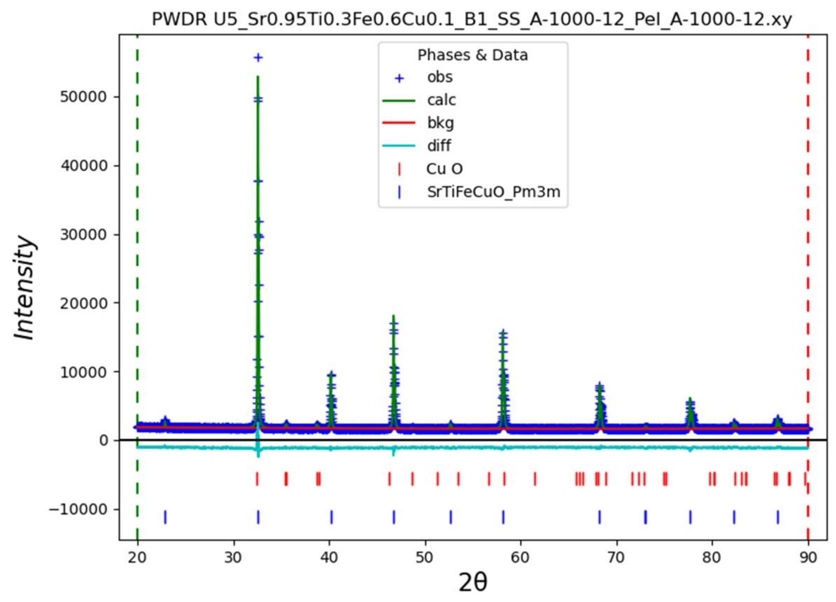
Figure 4: (a) Predicted calcination temperature of the perovskite through a thermogravimetry analysis (b) Processing steps in the solid-state synthesis method for the perovskite material.

RESULTS

❑ Perovskites synthesized



(a)



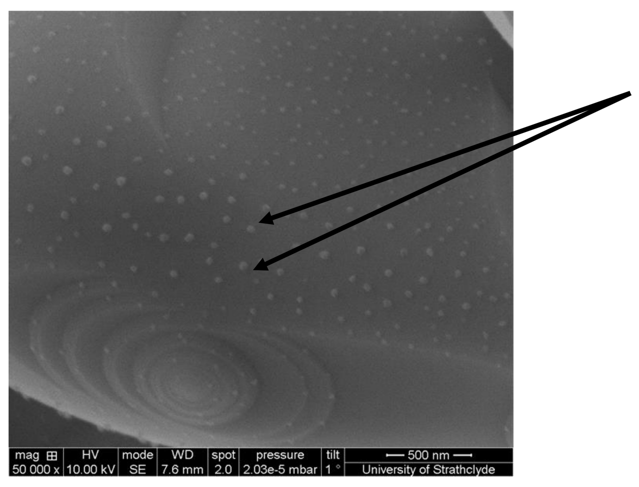
(b)

Figure 5: (a) Room temperature powder XRD pattern of four perovskites synthesized from doping **A-site deficient $Sr_{0.95}Ti_{0.3}Fe_{0.7}O_3$** with selected dopants. (a) Refined peaks of **$Sr_{0.95}Ti_{0.3}Fe_{0.6}Cu_{0.1}O_3$**

❑ Crystal Structure of the Perovskites from Rietveld Refinement

Perovskite	Cell Parameter a (Å)	Cell Type	Cell Volume (Å^3)
$Sr_{0.95}Ti_{0.3}Fe_{0.7}O_3$	3.8871	Cubic	58.7323
$Sr_{0.95}Ti_{0.3}Fe_{0.7}Cu_{0.1}O_3$	3.8822	Cubic	58.5088

❑ Exsolution on the Reduced Perovskites



Exsolved nanoparticles on a reduced sample surface.

Average particle size: 50 nm

Figure 6: SEM image of: $Sr_{0.95}Ti_{0.3}Fe_{0.5}Mo_{0.1}Ni_{0.1}O_3$ reduced in a 5% H_2 environment at 600 ℃ for 1 hour.

❑ A Model Framework for the Exsolution Process

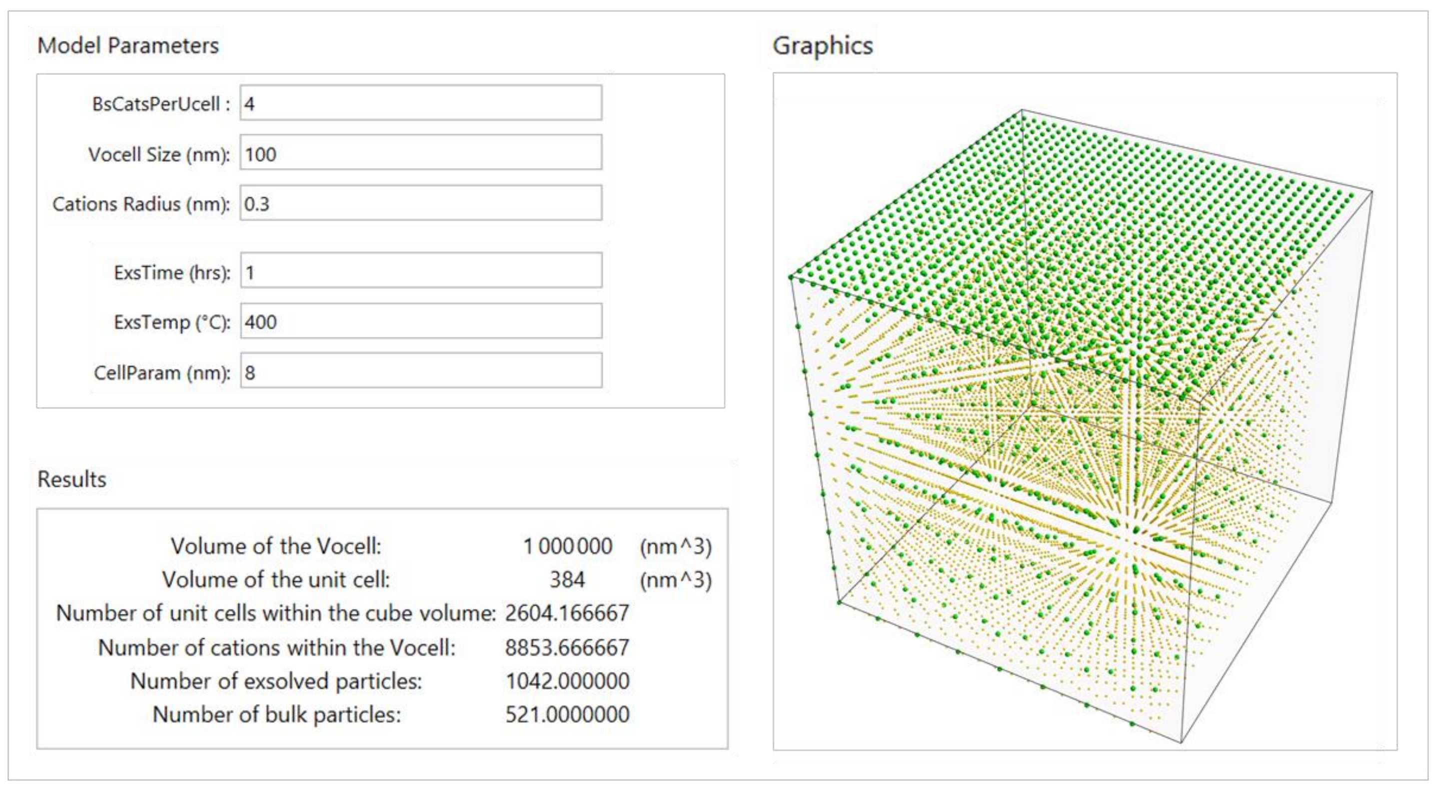


Figure 7: Schematics of a **predictive model for the exsolution process** for properties tuning in the synthesized perovskite materials.

CONCLUSION

- ❖ Achieving exsolution at **400 - 600 °C and 1 hour** in the novel perovskites has shown the possibility of low temperature operation and enhanced durability of RSOCs.
- ❖ Electrodes fabricated from the novel perovskites can overcome the electrochemical requirements of RSOCs and enhance mode switching between electrolytic and fuel cell.
- ❖ The **predictive model for exsolution process** when completed will facilitate further optimization of the novel perovskites properties for hydrogen production and power generation.

FUTURE WORK

- ❖ Exsolution analysis and study of bulk exsolution in the materials; **(Ongoing)**
- ❖ Modelling of the exsolution process for performance optimisation; **(Ongoing)**
- ❖ Fabrication of RSOCs electrodes; and
- ❖ Fabrication of RSOCs for testing and benchmarking.

ACKNOWLEDGEMENTS

Research Funder

The Royal Society of Edinburgh

Research Funder

CONTACT

Email: ubong.essien@strath.ac.uk
Phone: 07733682709

Ubong Essien
(2nd year PhD Student)

Email: dragos.neagu@strath.ac.uk

Dr Dragos Neagu
(Project supervisor)