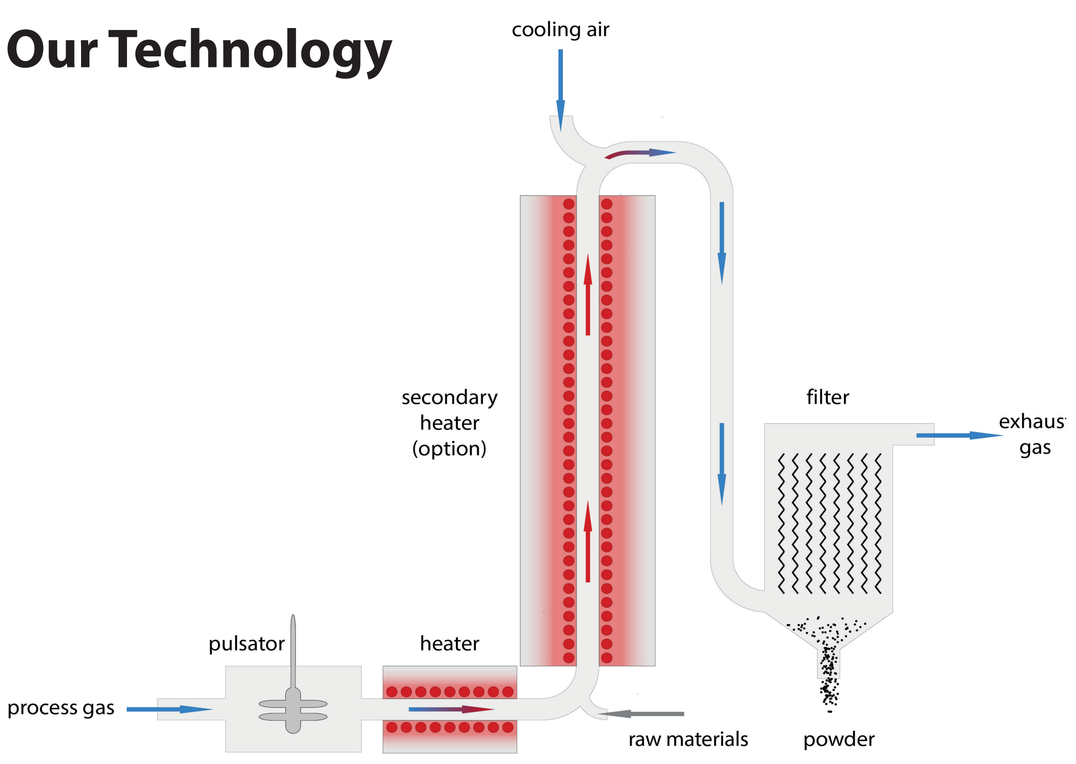
THE Glatt POW(D)ER SYNTHESIS

Preparation and Characterization of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ for Alkaline Water Electrolysis

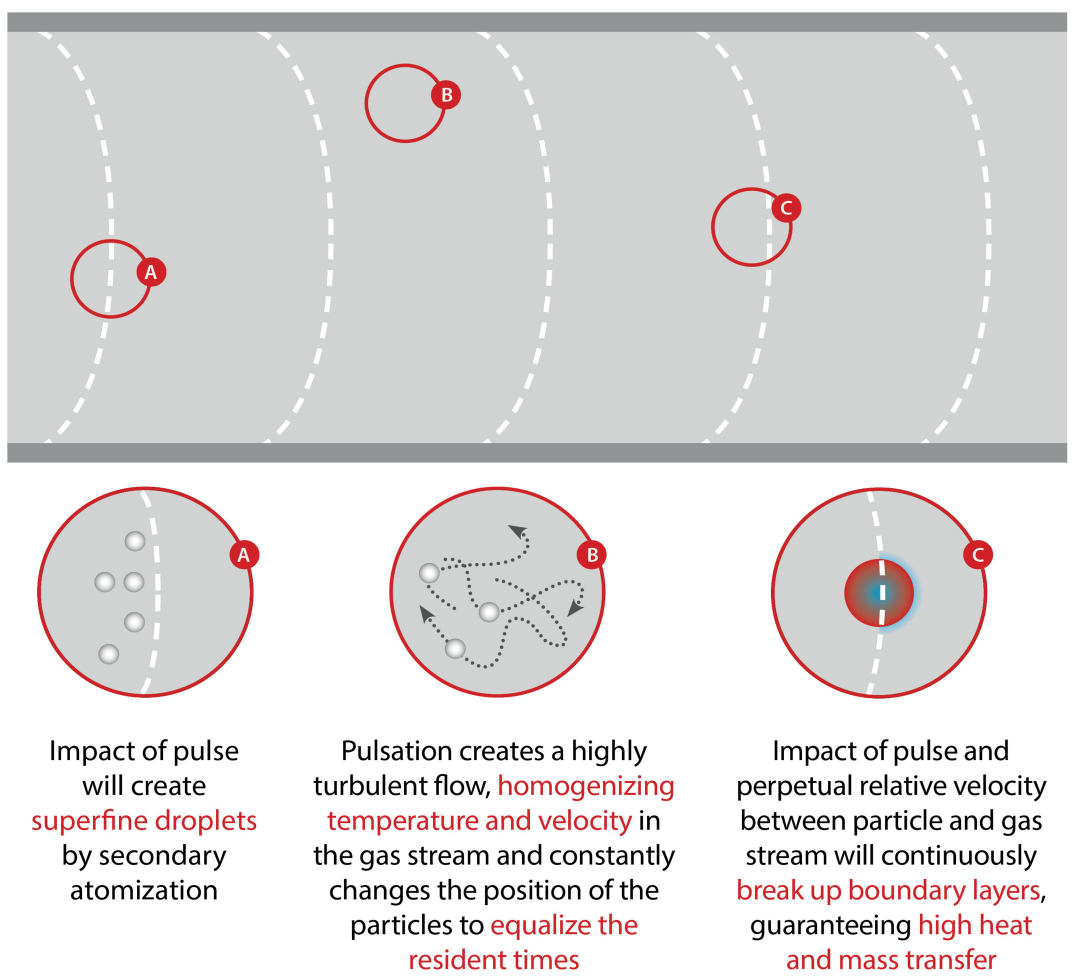
Introduction

Hydrogen is a cornerstone of future clean energy systems. Among its production methods, green hydrogen – produced via water electrolysis using renewable energy – is the most sustainable. Alkaline water electrolysis (AWE) is an efficient and low-cost approach, and the Hydrogen Evolution Reaction (HER) is its key catalytic step. Mixed oxides such as BSCF have emerged as promising HER catalysts due to their tunable composition and high stability. In this work, the material $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ is synthesized as a crucial step in the process. This method presents a significant advantage over the traditionally used solid-state reaction, primarily due to its ability to achieve a more uniform particle size and enhanced phase purity. The precise control of synthesis conditions in a pulsating hot gas flow allows for improved homogeneity of the final product, which is critical for optimizing catalytic performance. Additionally, the Glatt Powder Synthesis can reduce reaction times and energy consumption, making it a more efficient alternative for producing high-performance catalysts for the Hydrogen Evolution Reaction.

Our Technology



Pulsation makes the difference!



Johannes Buchheim, Viktor Drescher, Torben Vockenberg
Glatt Ingenieurtechnik GmbH, Weimar, Germany

Further information can be found on our website
powdersynthesis.glatt.com

Glatt Powder Synthesis Technology

The BSCF oxide was prepared by spray pyrolysis of a solution containing stoichiometric amounts of $BaCO_3$, $SrCO_3$, $CoCO_3$ and $Fe(NO_3)_3 \cdot 9H_2O$ dissolved in a citric acid solution. The molar ratio of cations to citric acid was set to 1.75:1 (ccat = 5.4 mol/l). The solution with an oxide content of 30 wt % was sprayed by a two-substance nozzle from the bottom into the reaction chamber using a 2 mm liquid insert and a spray pressure of 3.0 bar. The pulse frequency was set to 80 Hz, and the spray rate was maintained between 30-50 g/min to ensure stability in the outlet temperature at the reactor exit at 1240 °C.

Material Characterisation

The synthesis of $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ was realized by the combustion of a solution containing the stoichiometric amounts of raw materials using the Glatt Powder Synthesis. The phase purity of the synthesized BSCF was confirmed using X-ray powder diffraction (Figure 1). All diffraction lines were found to correspond to the cubic perovskite structure with space group Pm-3 m. Electron microscopy (Figure 2) images reveal a spherical morphology with compact and dense particles. The narrow particle size distribution facilitates high packing densities, which is advantageous for catalytic applications, enhancing the overall efficiency of the BSCF catalyst in the HER (Figure 3).

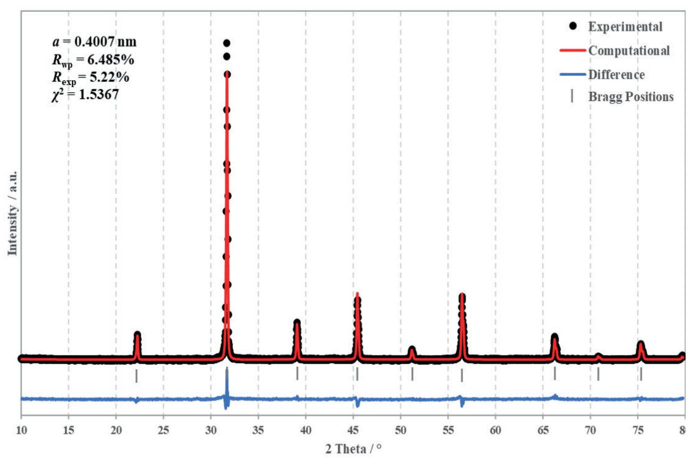


Fig. 1: Diffraction pattern of the synthesized BSCF

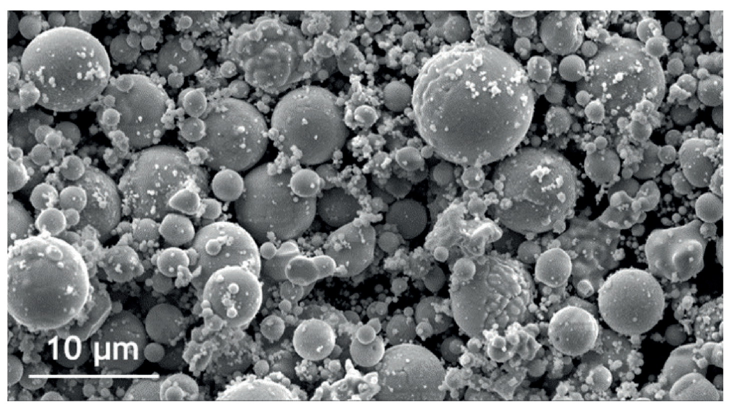


Fig. 2: SEM images of the synthesized BSCF

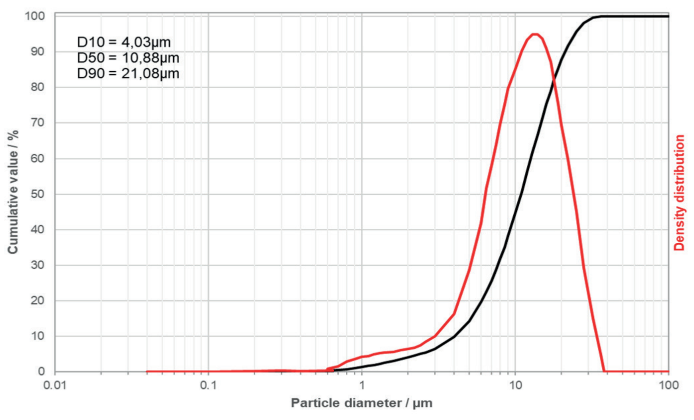


Fig. 3: Particle size distribution of the synthesized BSCF

Electrocatalytic Performance

The electric potential was corrected for iR losses, ensuring accurate measurement of the electrochemical performance of the materials during the HER (Figure 4). In order to gain a more precise insight into the mechanism involved, Tafel plots were calculated (Figure 5). The rate- limited step of the HER can be determined by the Tafel slope. Tafel slopes of 120, 40 and 30 mV·dec⁻¹ give a direction to Volmer, Heyrorvsky and Tafel determining rate steps (1,2). The BSCF materials shows a Tafel slope of 216 mV·dec⁻¹.

Hydrogen Evolution Pathways:

Volmer Reaction
$$H_2O + M + e^- \rightleftarrows M - H^* + OH^-$$

Heyrorvsky Reaction
$$M - H^* + H_2O + e^- \rightleftarrows M + H_2 + OH^-$$

Tafel Reaction
$$2M - H^* \rightleftarrows M + H_2$$

Typical Tafel slopes are reported between 40 and 120 mV·dec⁻¹ [3, 4]. This a high value could indicate that the HER process is influenced by a combination of slow steps, weak or strong proton adsorption, heterogeneous mechanisms, or even transport and diffusion barriers.

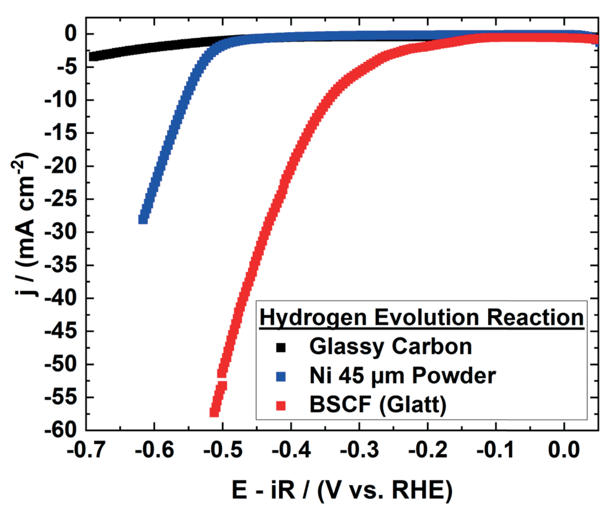


Fig. 4: Electrochemical measurement of hydrogen evolution reaction activity on glassy carbon, nickel powder (45 µm) and BSCF powder. synthesized BSCF

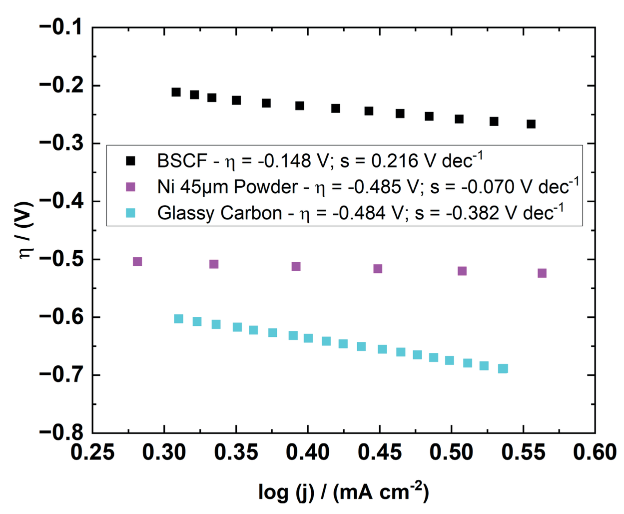


Fig. 5: Tafel plots of glassy carbon, nickel powder (45 µm) and BSCF powder.

Conclusion

This study highlights the successful synthesis of the perovskite material $Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_{3-\delta}$ using Glatt Powder Synthesis, demonstrating its potential as a highly effective catalyst for the Hydrogen Evolution Reaction.

Glatt Powder Synthesis enables efficient, scalable BSCF production with superior catalytic performance for alkaline HER. The process offers advantages in particle uniformity, crystallinity, and energy efficiency — critical for sustainable hydrogen generation.

Acknowledgements

Thanks to Karl Skadell and Artur Bekisch (Fraunhofer IKTS) for electrochemical measurements.

References

[1] Mahmood N, Yao Y, Zhang JW, Pan L, Zhang X, Zou JJ. (2017), Adv Sci, 5 (2), 1700464.

[2] Shinagawa, T., Garcia-Esparza, A. & Takanabe, K. (2015) Sci Rep 5, 1380.

[3] Md. Sofiul Alom, Chandana C.W. Kananke-Gamage, F. Ramezanipour (2022) ACS Omega, 7 (9), 7444-7451.

[4] Z. Zhang, W. Zhou, Z. Yang, J. Jiang, D. Chen, Z. Shao (2020), Int. J. Hydrog. Energy, 45 (46), 24859-24869.