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Utilisation of renewable feedstocks in solid oxide fuel cell technology: biohydrogen

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Introduction. Biologically produced mixtures of H_2 and CO_2 (biohydrogen) from processes such as dark fermentation or photo-fermentation are versatile feedstocks which can potentially be utilised in solid oxide fuel cell (SOFC) technology. SOFCs are high temperature (500 – 1000 °C) electrochemical energy conversion devices made with ceramic and metallic materials. They are highly efficient, operate silently and can be sized from 1 kW_e to 1 MW_e upwards due to their modular and scalable design. They can utilise hydrogen or carbon-based feedstocks either in fuel cell mode to produce electrical power and heat, or electrolysis mode to produce useful chemicals such as synthesis gas (H_2 + CO). This work investigates the performance and products of a solid oxide fuel cell operating on biohydrogen in both fuel cell mode and electrolysis mode.

Results. On entry into the SOFC, approx. 30% of biohydrogen is converted into CO and H_2O via the reverse water-gas shift (RWGS) reaction (see Figs. 1 and 2): $\mathbf{H_2 + CO_2 \rightleftharpoons CO + H_2O}$

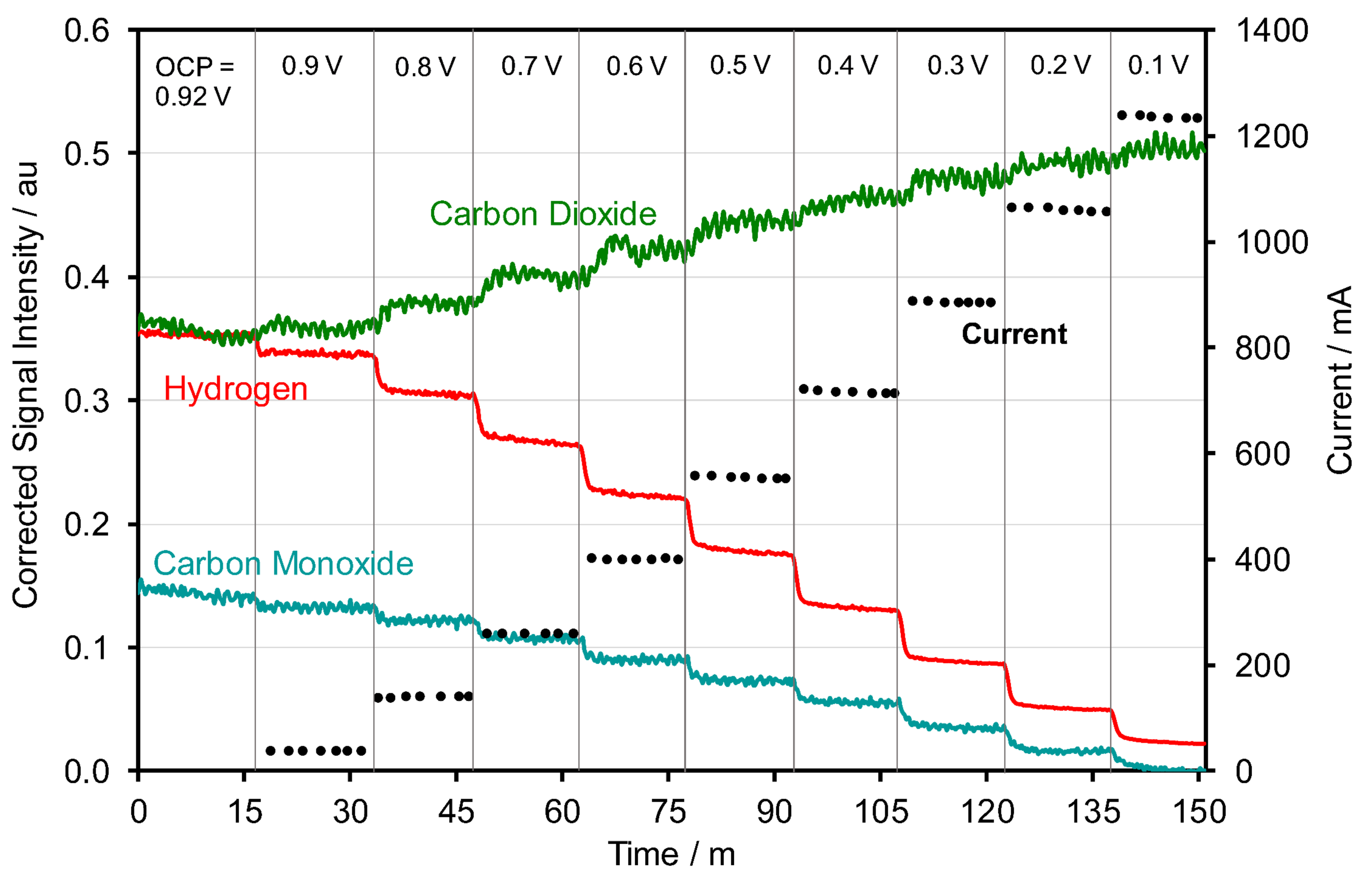

Figure 1. Utilisation of biohydrogen in SOFC in fuel cell mode. The emissions and current output of the cell are shown.

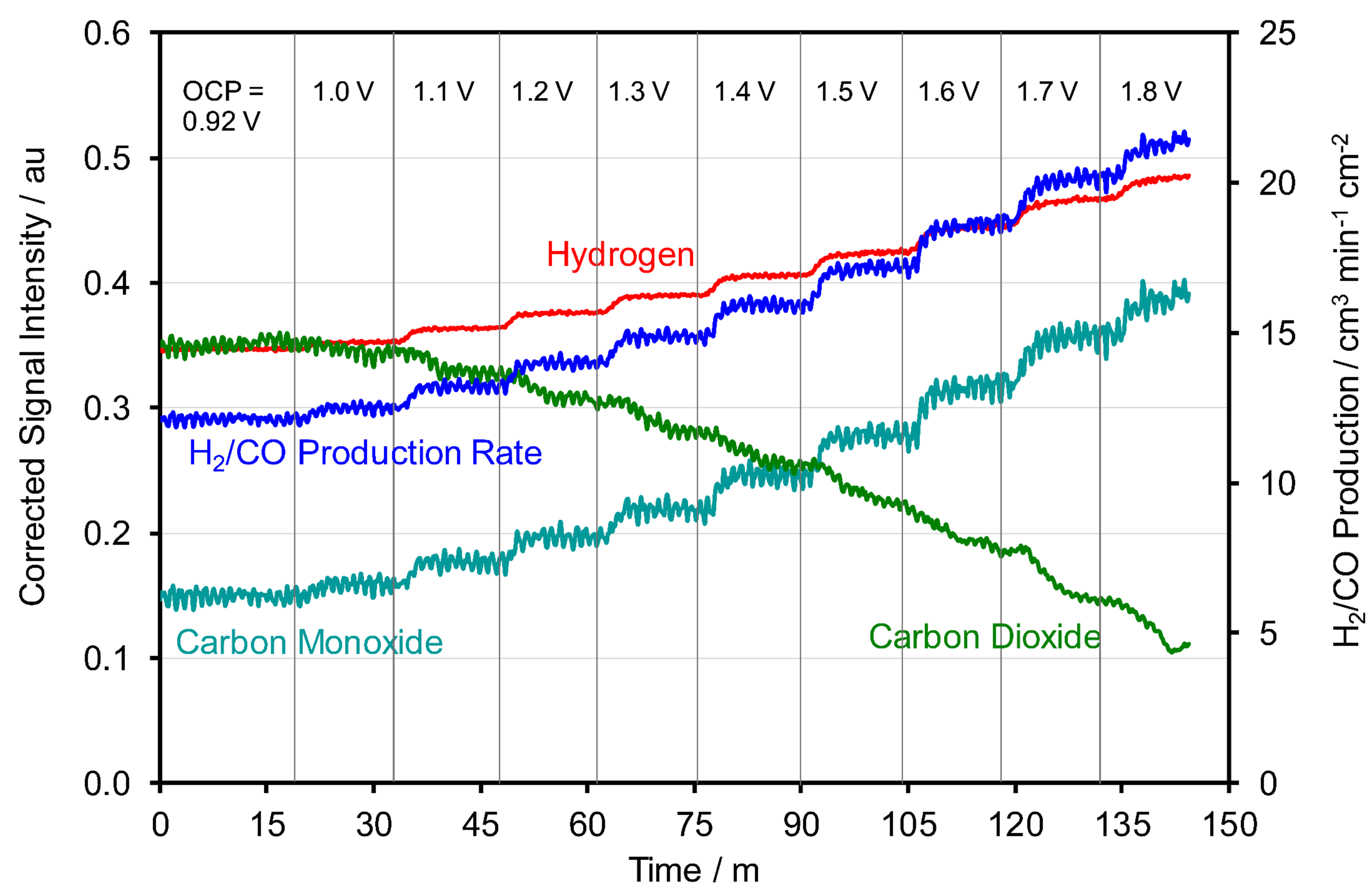

Figure 2. Utilisation of biohydrogen in SOFC in electrolysis mode. The syngas production rate and output gases are shown.

In fuel cell mode (see Fig. 1), the SOFC converts H_2 into **electrical power and heat**. CO is converted via reaction with H_2O and does not contribute to power production. When the cell is operated at high fuel utilisation efficiency (at 0.1 V in Fig. 1), emissions of CO are minimal.

In electrolysis mode (see Fig. 2), the SOFC converts CO_2 into CO, yielding **synthesis gas**. The H_2/CO ratio can easily be controlled in the range 1.2-2.3 by adjusting the operating voltage of the cell.

Biohydrogen is inherently variable; however, Fig. 3 shows the electrochemical performance of the cell is not significantly affected by fuel variability provided the H_2 content of biohydrogen stays within the range 40-60 vol%.

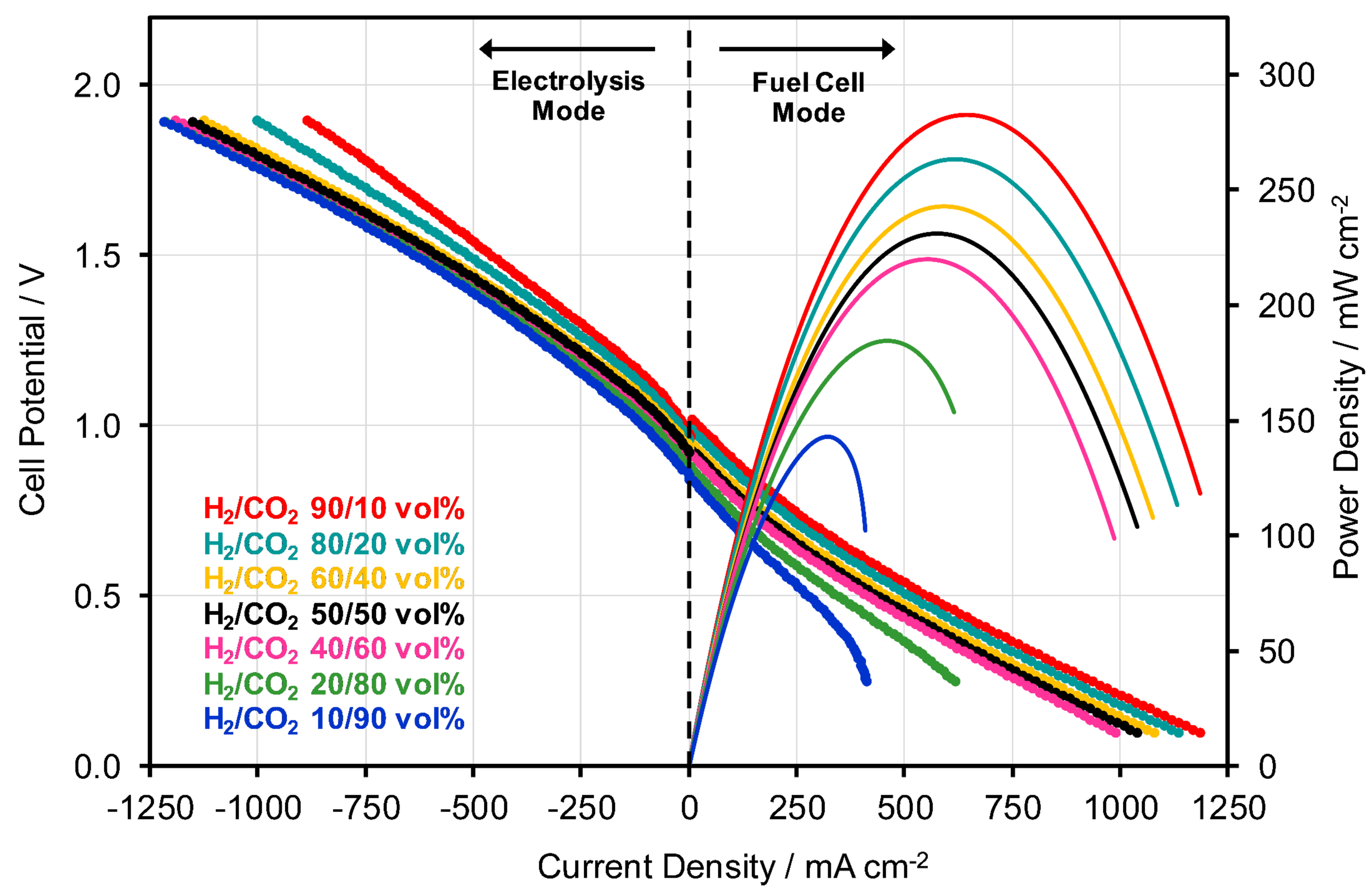

Figure 3. The effect of fuel variability on the I-V and power curves of an SOFC operating on biohydrogen. Data are shown for the cell operating on biohydrogen mixtures containing 10-90 vol% H_2.

Conclusions. Biohydrogen is a useful and renewable feedstock which can be utilised in SOFC technology to yield useful energy and chemical products. Crucially, the results show that **CO_2 scrubbing is not required** for good SOFC performance. Fuel conversion takes place via a complex interplay that exists between the fuel cell reactions and the RWGS reaction.

Further reading. Laycock CJ, Panagi K, Reed JP, Guwy AJ, *The importance of fuel variability on the performance of solid oxide cells operating on H_2/CO_2 mixtures from biohydrogen processes*, Int J Hydrogen Energy 2018 **34**;8972-82.

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Ariennir yn rhannol gan Gronfa Datblygu Rhanbarthol Ewrop drwy Lywodraeth Cymru.