Developing a novel black liquor-feed direct fuel cell

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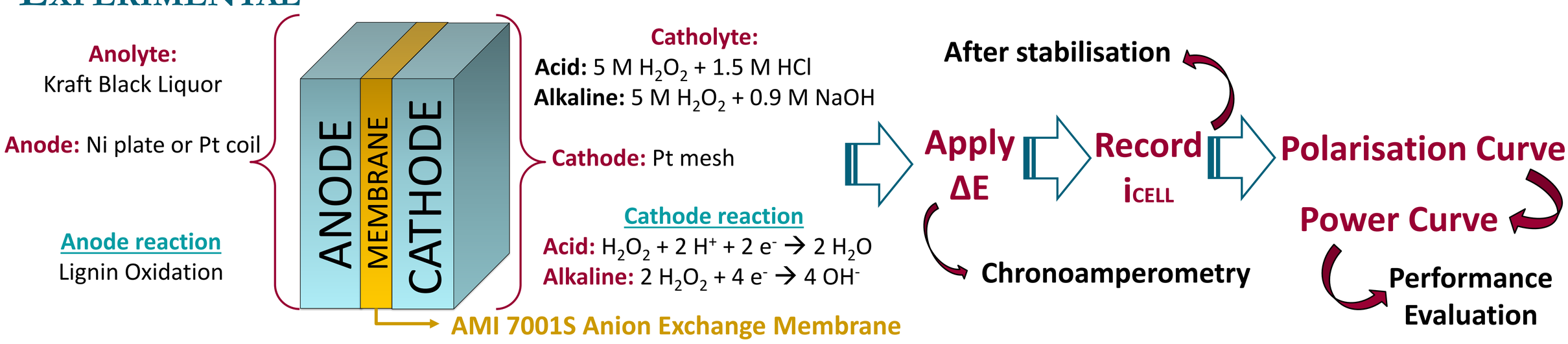
Motivation

Black liquor is an effluent from the pulp and paper mills, more precisely from the pulping process. The most common industrial process is named the Kraft process. During the Kraft process the black liquor is evaporated in order to increase its solids content (initially about 15 wt.%) to a value around 75 wt.%. After that, the concentrated solution, known as strong black liquor, is burned in a recovery boiler to generate heat and energy [1]. Black liquor contains lignin, an organic polymer with high economic value and many applications in the market, including as dispersant in pesticides and insecticides, as additive for soil breeding, and ultimately as a fuel. It is estimated that 90 % of the lignin contained in black liquor is simply burned [2].

Electrochemical methods hold great promise to extract the lignin from the black liquor. Black liquor electrolysis has demonstrated the feasibility of depositing a thick layer of lignin at the anode while simultaneously generating hydrogen at the cathode [2]. On the other hand, it is known that direct liquid-feed fuel cells are efficient energy conversion devices, which can be fed by a variety of liquid fuels, namely methanol, ethanol, ammonia, or borohydride solutions [3]. Considering the above factors, we propose a new type of direct liquid-feed fuel cell, which uses black liquor as the fuel, and that was coined as the black liquor fuel cell (BLFC).

Experimental



Results

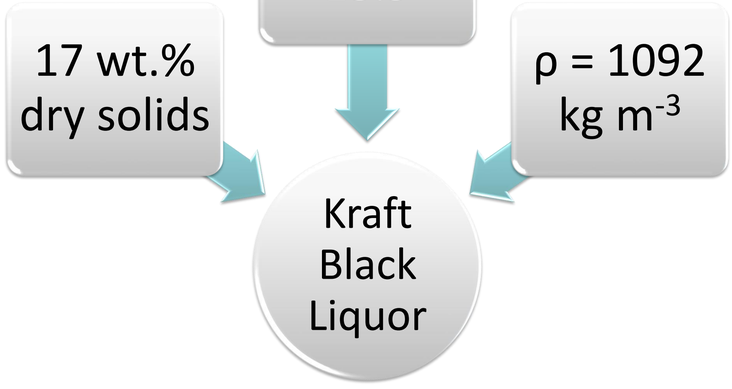


Table 1: Recorded black liquor fuel cell operation parameters using Pt or Ni anodes and Pt mesh cathode at room temperature. Catholyte composition was 5 M H_2O_2 + 0.9 M NaOH or 5 M H_2O_2 + 1.5 HCl, depending of using alkaline or acid oxidant media, respectively.

Anode / Oxidant pH	OCV / V	Peak power density / mW cm^{-2}	Current density at peak power density / mW cm^{-2}	ΔE at peak power density / V
Pt / Acid	1.20	1.30	2.7	0.50
Pt / Alkaline	0.50	0.47	3.1	0.15
Ni / Acid	1.15	0.74	2.1	0.35
Ni / Alkaline	0.58	0.22	1.0	0.23

ALKALINE BLFC: 5 M H_2O_2 + 0.9 M NaOH AS CATHOLYTE

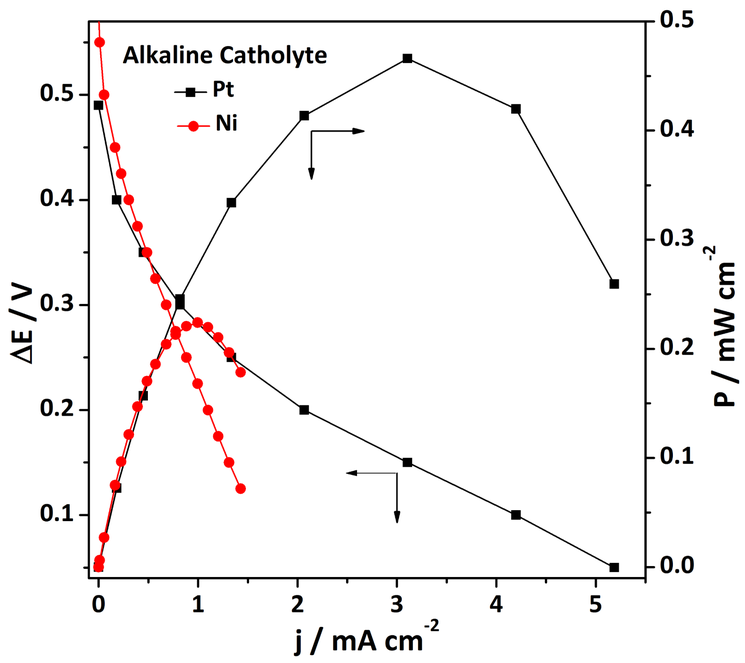


Fig. 1: Polarisation and power density curves for a alkaline BLFC employing a Pt or Ni as anode and a Pt mesh as cathode. Catholyte was 5 M H_2O_2 + 0.9 NaOH and black liquor was used as anolyte.

ALKALINE/ACID BLFC: 5 M H_2O_2 + 1.5 M HCl AS CATHOLYTE

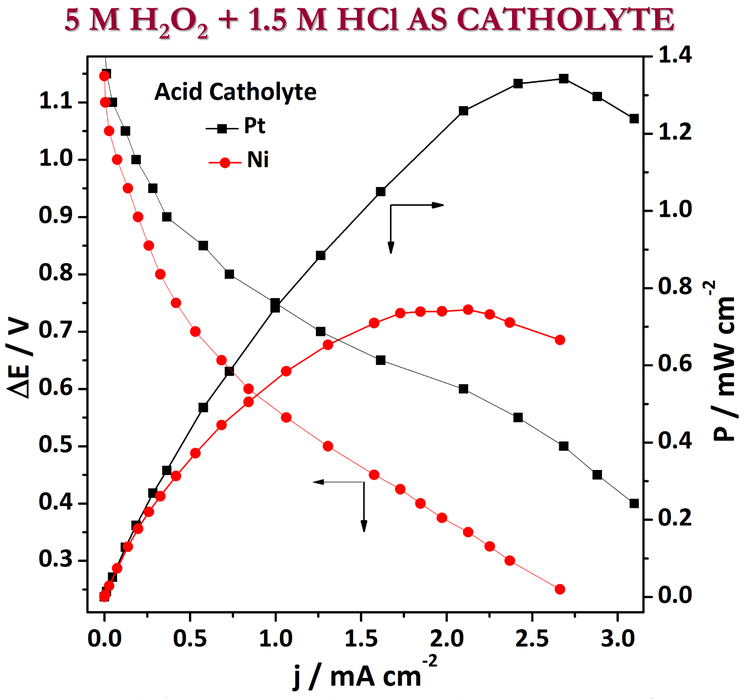


Fig. 2: Polarisation and power density curves for a alkaline/acid BLFC employing a Pt or Ni as anode and a Pt mesh as cathode. Catholyte was 5 M H_2O_2 + 1.5 HCl and black liquor was used as anolyte.

COMPARISON BETWEEN ALKALINE AND ALKALINE/ACID BLFC

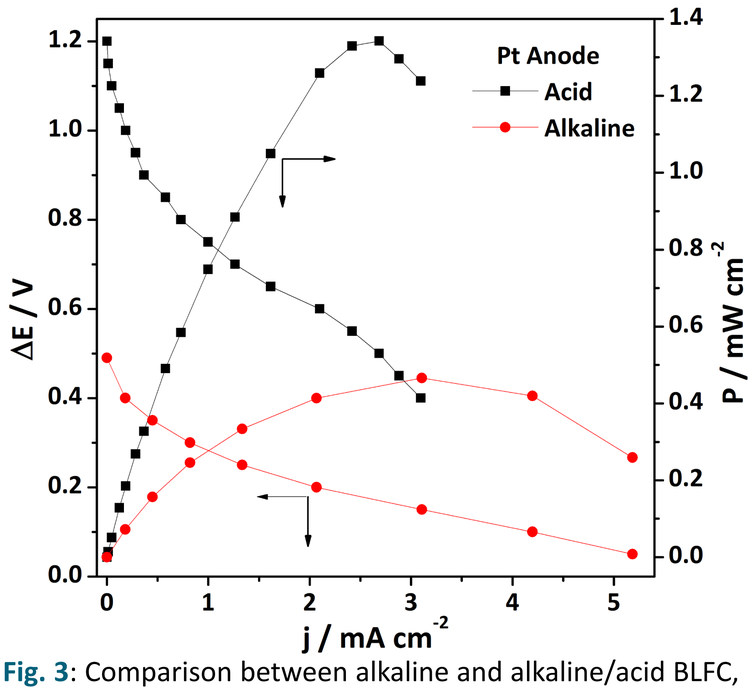


Fig. 3: Comparison between alkaline and alkaline/acid BLFC, employing a Pt coil as anode and a Pt mesh as cathode. Catholyte was 5 M H_2O_2 + 0.9 M NaOH (alkaline) or 5 M H_2O_2 + 1.5 HCl (acid) and black liquor was used as anolyte.

Conclusions

- The black liquor fuel cell presents best performance than the emerging direct urea fuel cell [5].
- An acid media in the cathode compartment performed a power three times higher than that in alkaline media.
- The BLFC with the Pt anode presented power densities 1.8 and 2.1 times higher than that with the Ni anode, using acid and alkaline catholytes, respectively.
- The proposed BLFC concept has been demonstrated to work but further studies are necessary to optimize the fuel cell performance.

References

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