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A New Cathode Design for Alkaline Fuel Cells (AFCs)

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Plan

I. Introduction to AFCs

II. AFC Gas Diffusion Electrode

III. Study of a new electrode substrate

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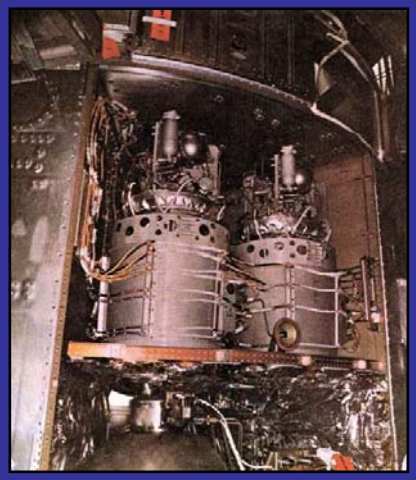
AFC achievements

Dr. Francis Thomas Bacon

Late 1950s: farm tractor equipped with an Allis Chalmers fuel cell system



The NASA Apollo fuel cell system

Early 1970s: Dr. Kordesch Austin A40

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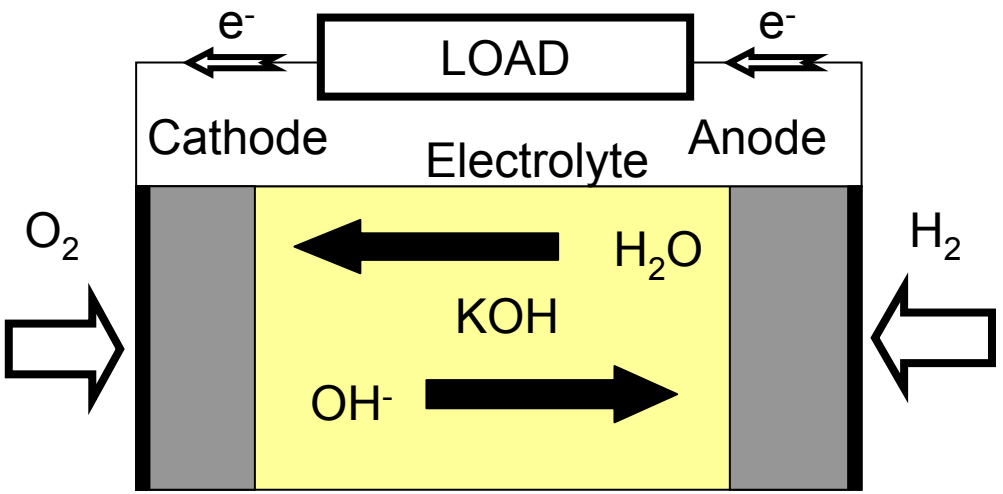
Fundamentals of an AFC



Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (1)

Anode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$ (2)

Overall: $O_2 + 2H_2 \rightarrow 2H_2O$ (3)

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Advantages/disadvantages of AFCs

Advantages:

• Oxygen reduction in alkaline media is more facile than in acid media which means that higher voltages at comparable current densities are obtained, leading to a higher efficiency of the system.

• The utilisation of non-noble metal catalysts and liquid electrolyte makes the AFC a potentially low cost technology.

Disadvantage:

• The AFC electrolyte is very sensitive to CO_2

$$CO_2 + 2OH^- \rightarrow CO_3^{2-} + H_2O$$

$$CO_3^{2-} + 2K^+ \rightarrow K_2CO_3$$

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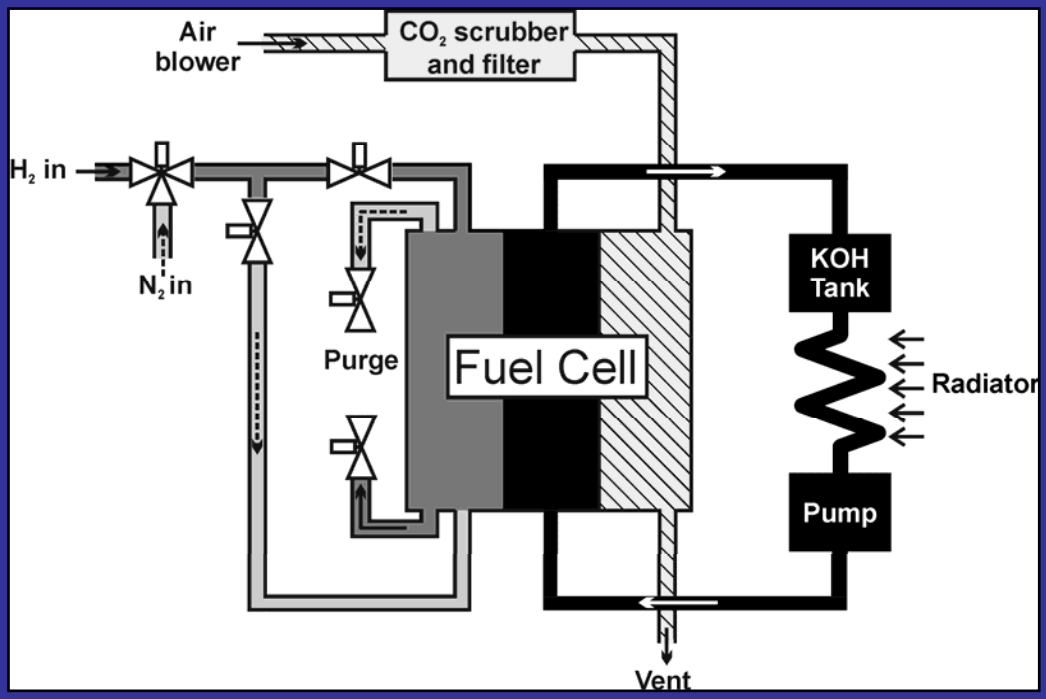
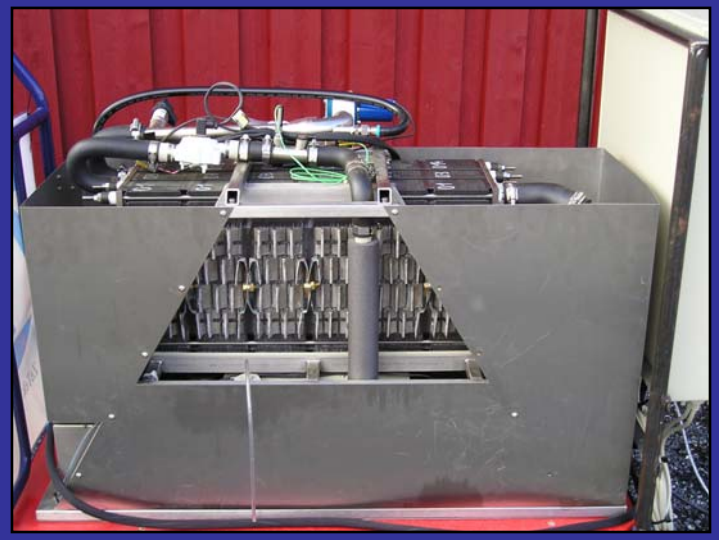
Circulating electrolyte alkaline system



Schematic of a circulating electrolyte alkaline system



Picture of a monopolar Zetek stack (University of Agder, Norway)

F. Bidault, et al., J. Power Sources (2008), doi:10.1016/j.jpowsour.2008.10.106

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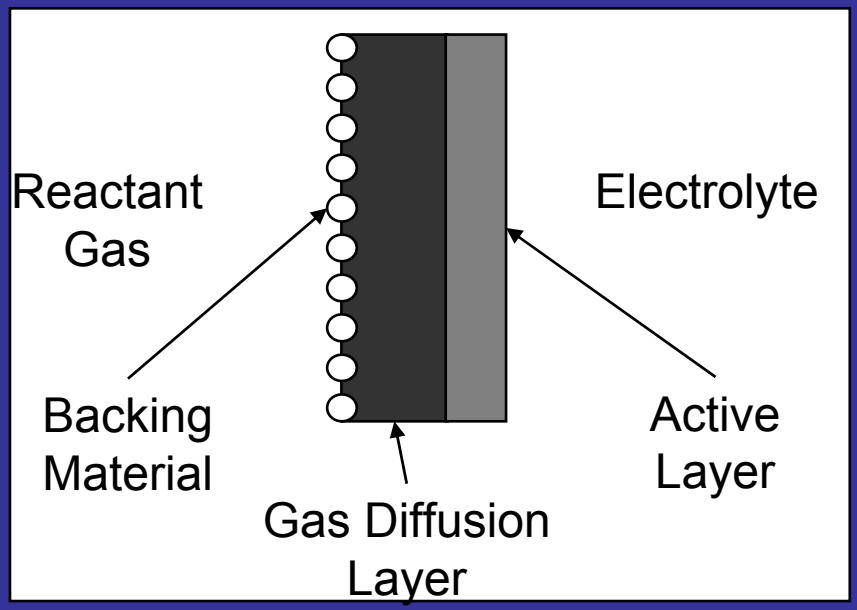
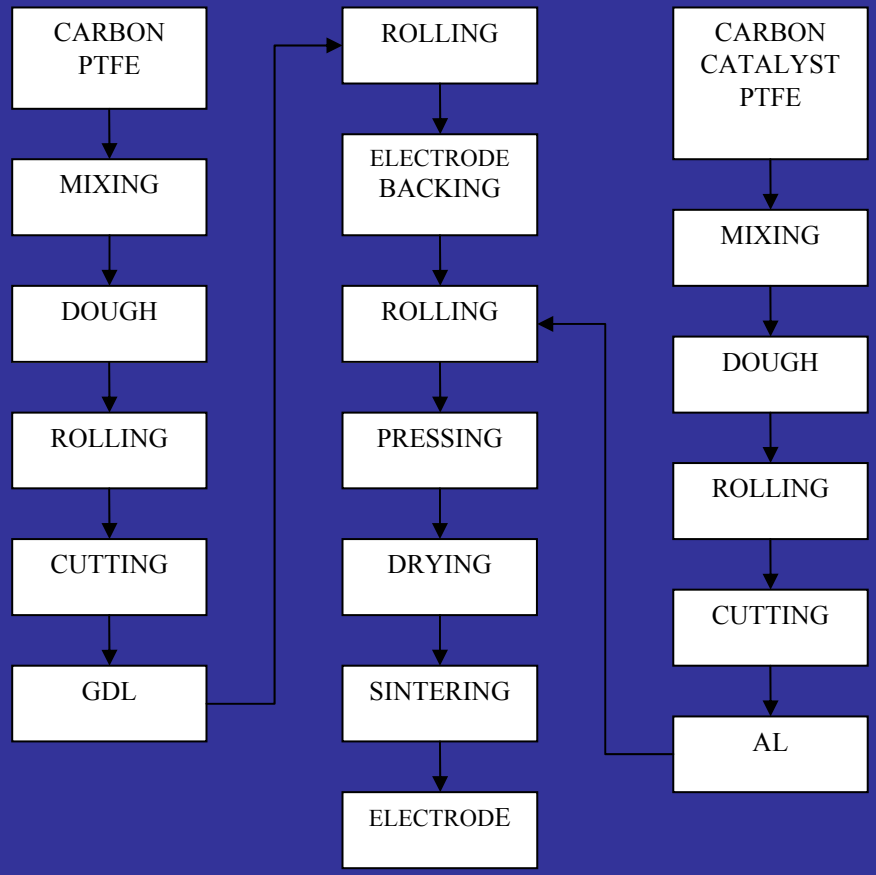
AFC Gas Diffusion Electrodes



Design of a double layer electrode for a bipolar stack design



Electrode fabrication: The rolling method

F. Bidault, et al., J. Power Sources (2008), doi:10.1016/j.jpowsour.2008.10.106

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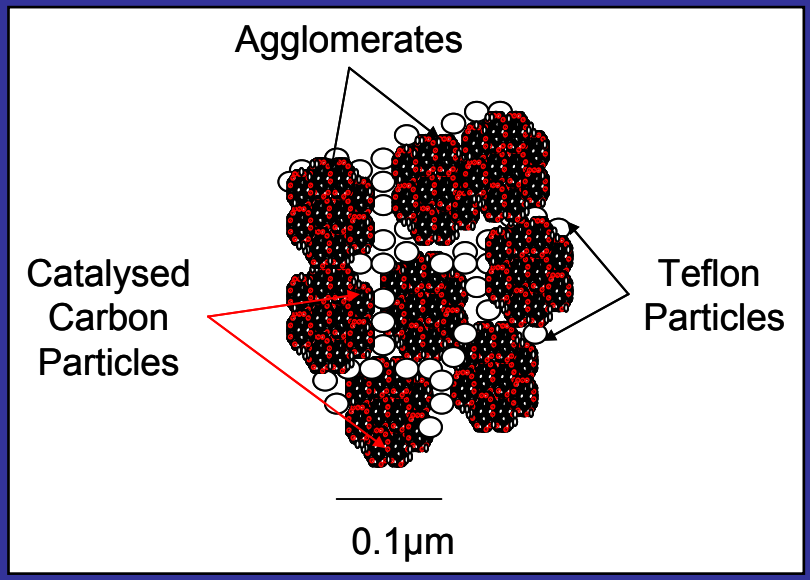
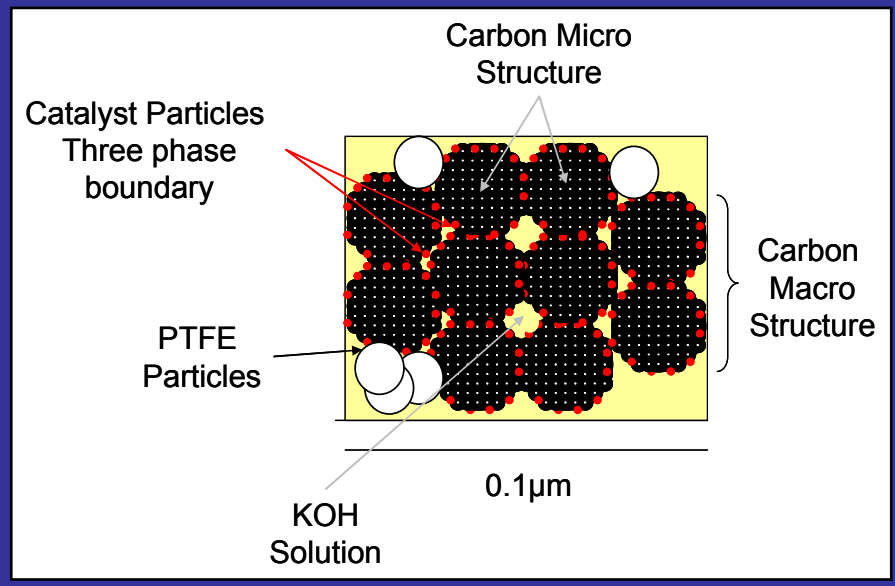
AFC Gas Diffusion Electrodes



Schematic illustration of the flooded agglomerate structure



Schematic illustration of the carbon macro and micro structure within the active layer

F. Bidault, et al., J. Power Sources (2008), doi:10.1016/j.jpowsour.2008.10.106

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AFC Gas Diffusion Electrodes

Backing Material should have:

- High permeability to gases
- High structural strength
- Good corrosion resistance
- High electronic conductivity

Picture of the commonly used Nickel mesh

F. Bidault, et al., J. Power Sources (2008), doi:10.1016/j.jpowsour.2008.10.106

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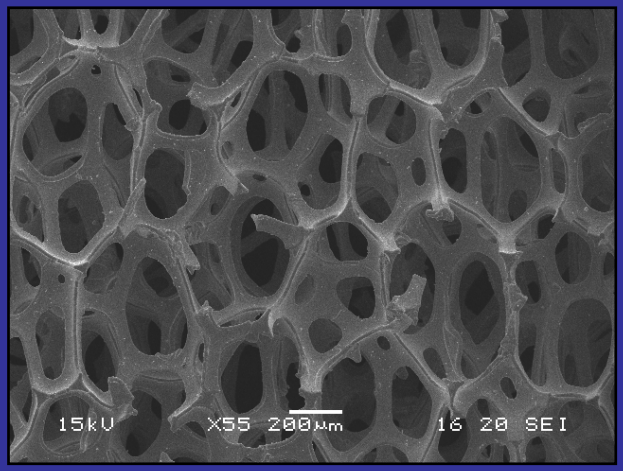
Comparison of nickel mesh and nickel foam

Parameters	Nickel mesh	Nickel foam
Weight-surface ratio (g cm^{-2})	0.0415	0.0366
Price ($ m^{-2})	60	20

Weight and price comparison of nickel mesh and nickel foam



SEM picture of Ni foam

Parameter	Nickel Foam
Density (kg m^{-3})	220
Mean Porosity	0.975
Electrical Resistivity (Ω m)	1.09×10^{-5}

Some Ni foam characteristics

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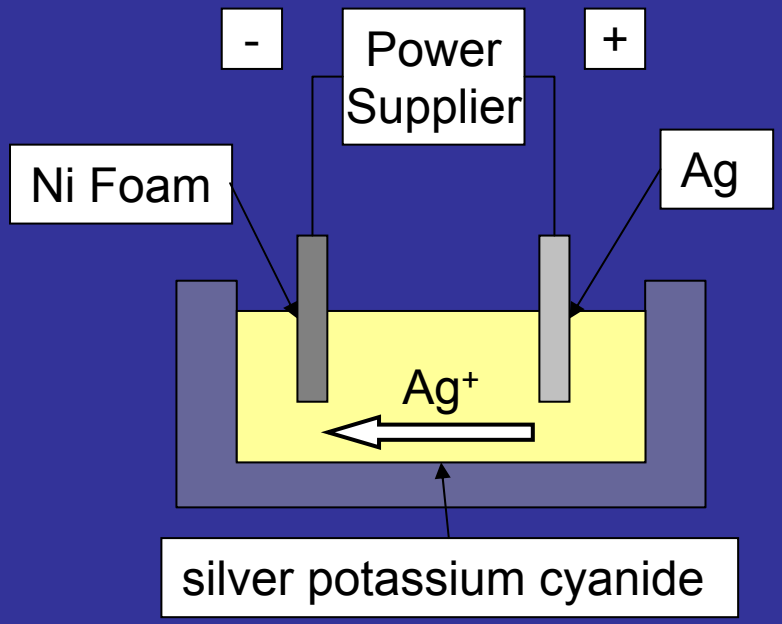
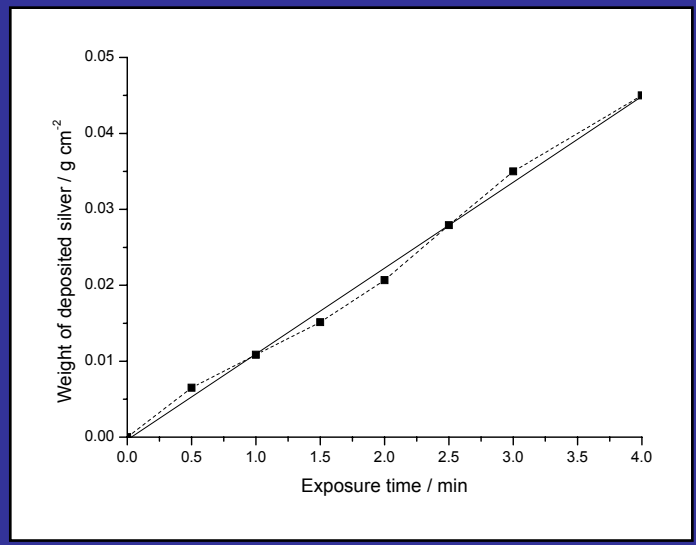
Electroplating



Electroplating Cell

BATH	Voltage (V)	Time (s)
Electro-cleaning	5	30
Strike	3	10
Heavy	2	60

Silver electroplating conditions



Amount of deposited silver as a function of exposure time in the heavy bath (plating conditions 2 V, 5.8 A)

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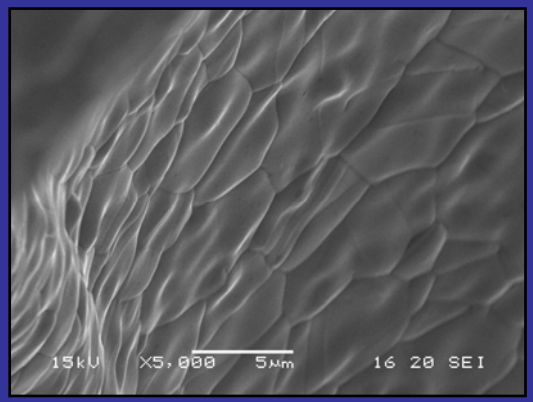
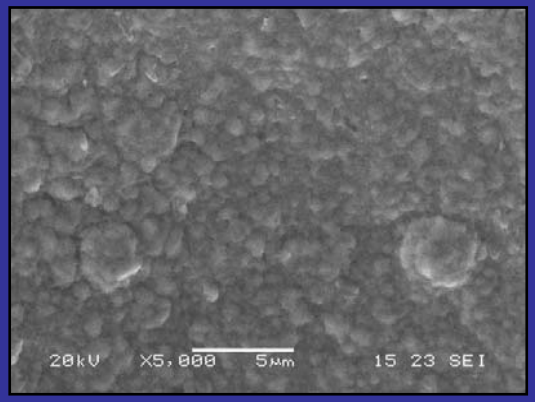
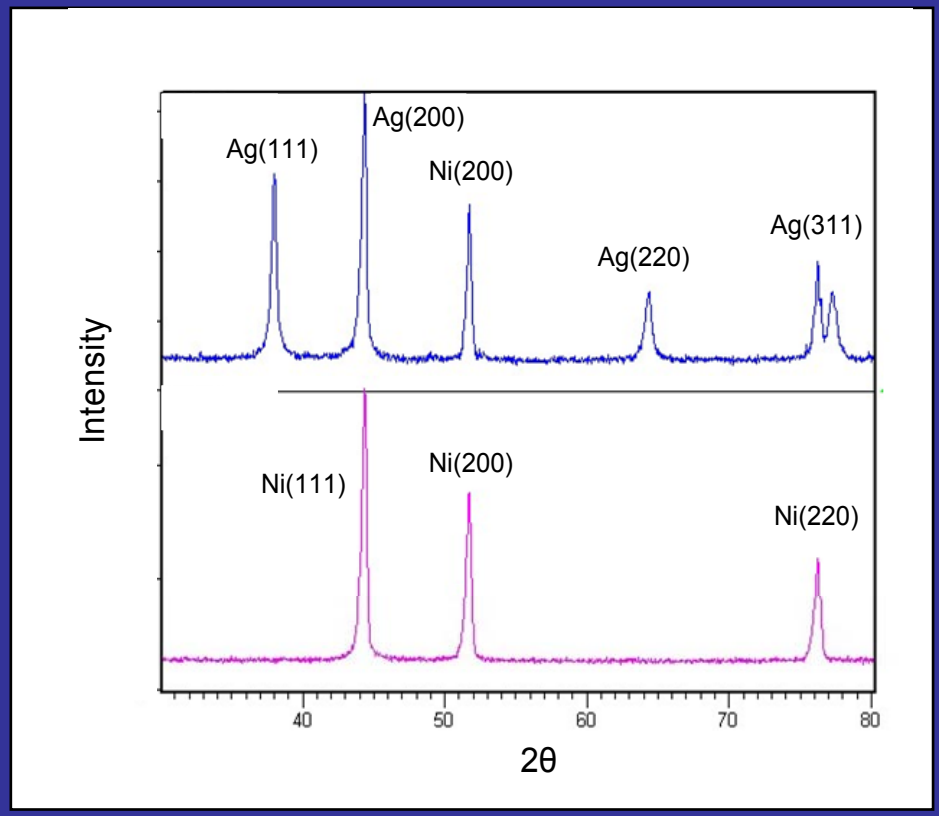
SEM pictures and XRD of Ni foam and Ag plated Ni foam



Ni foam surface



Ni foam surface after silver plating



XRD of nickel foam (bottom) and silver plated nickel foam (top)

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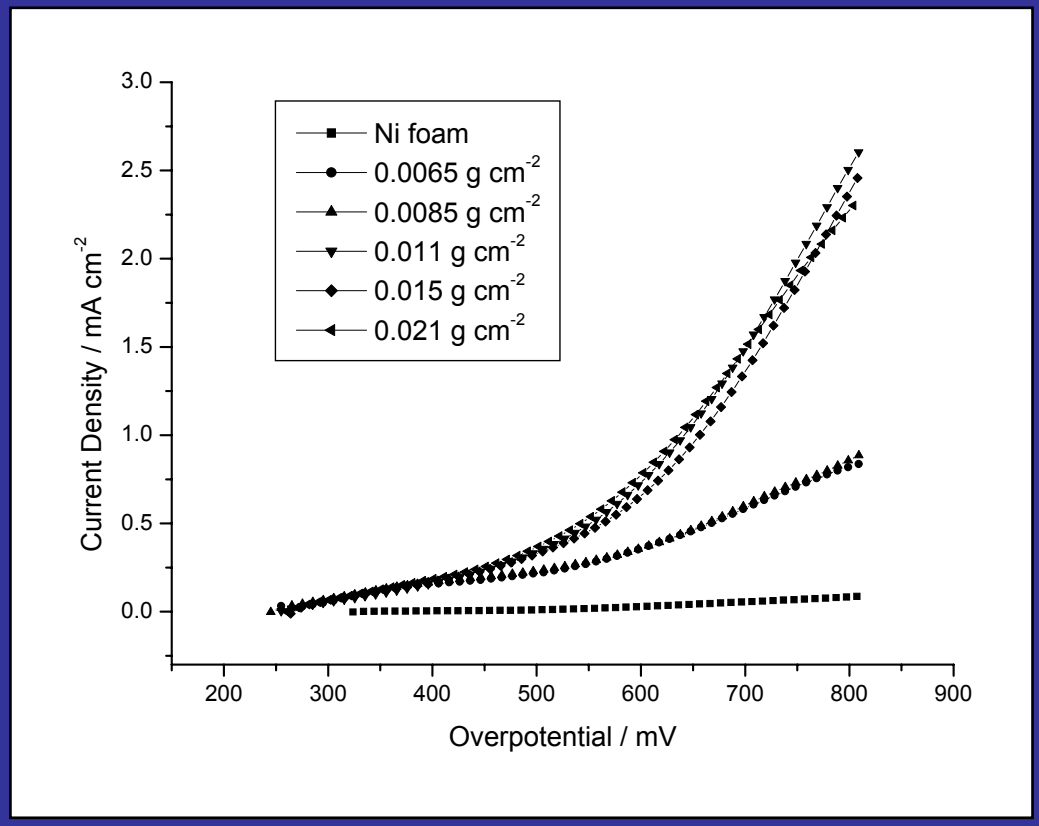
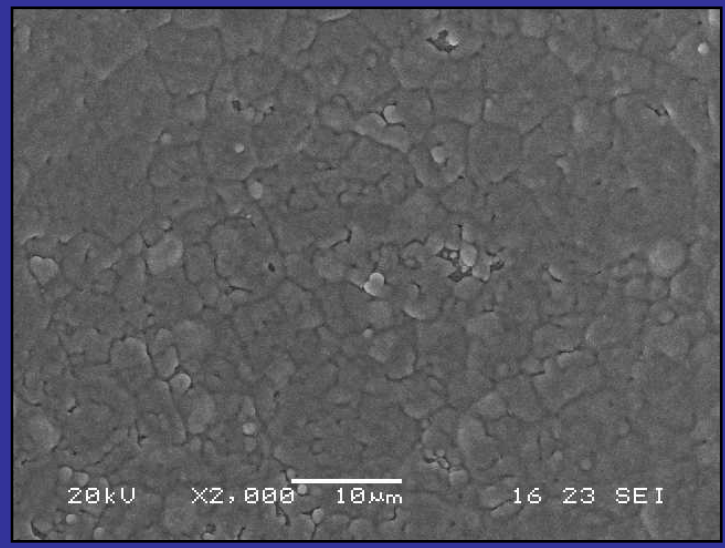
Electrochemical performance



Effect of silver loading on the electrochemical performance of nickel foam in aerated 30 wt. % KOH solution.



SEM picture of 0.0065 g cm^{-2} silver plated nickel foam

BET surface area: 0.0350 m^2 g^{-1}

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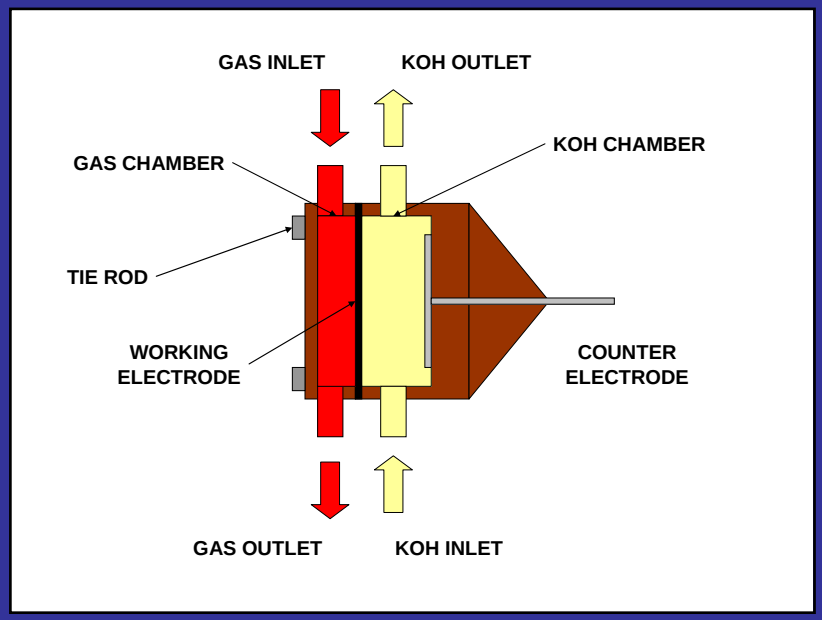
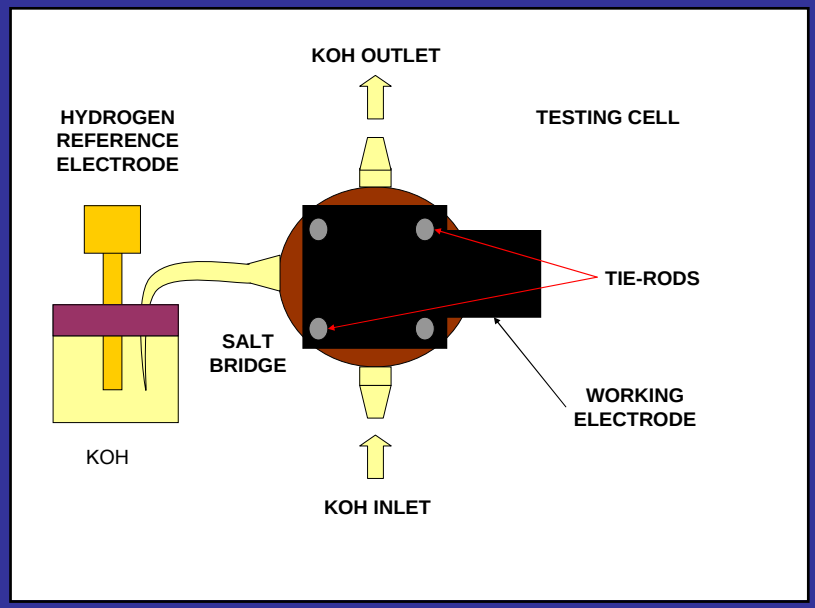
Schematic of the half cell testing



cross section



front view

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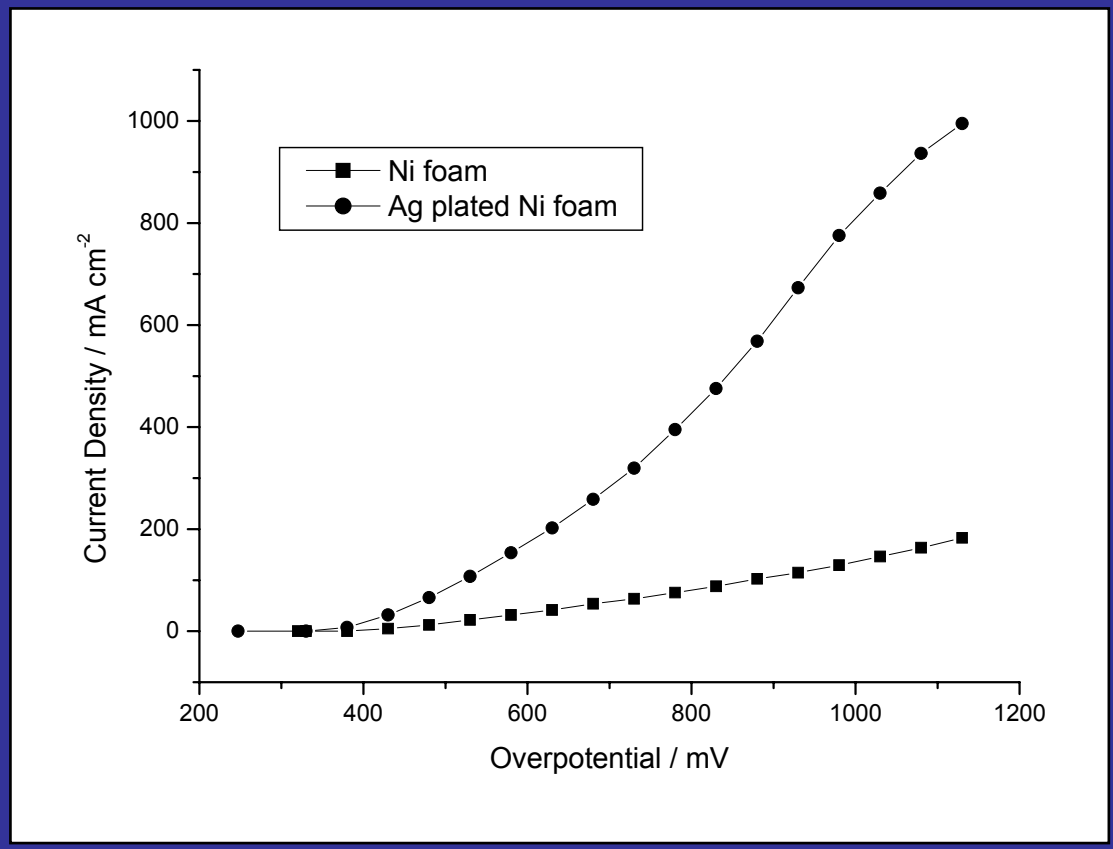
Cathode performance



Polarization curves of cathodes made of nickel foam and silver plated nickel foam (loading: 0.015g cm-2) under air at 25^{o}C in 30 wt. % KOH solution.

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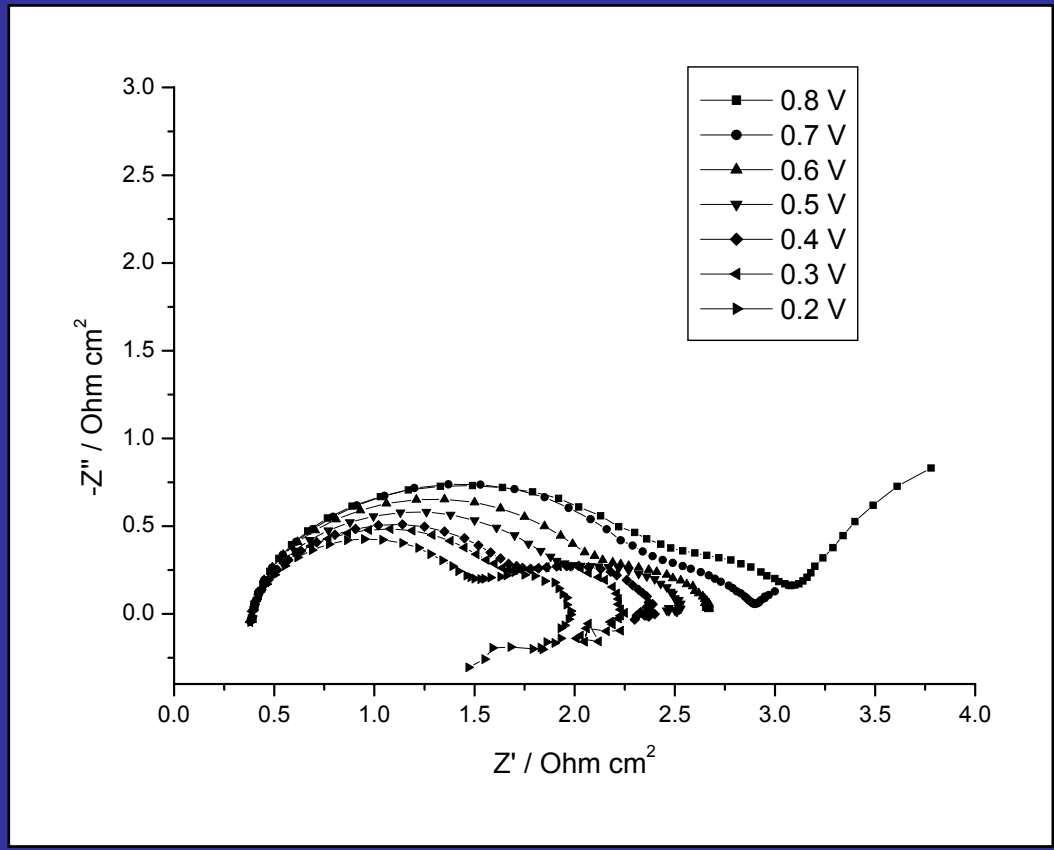
Impedance on Ni foam cathode



Impedance measurements over a range of electrode voltages of a cathode made of nickel foam under air at 25°C in 30 wt. % KOH solution from 10 kHz to 0.01 Hz.

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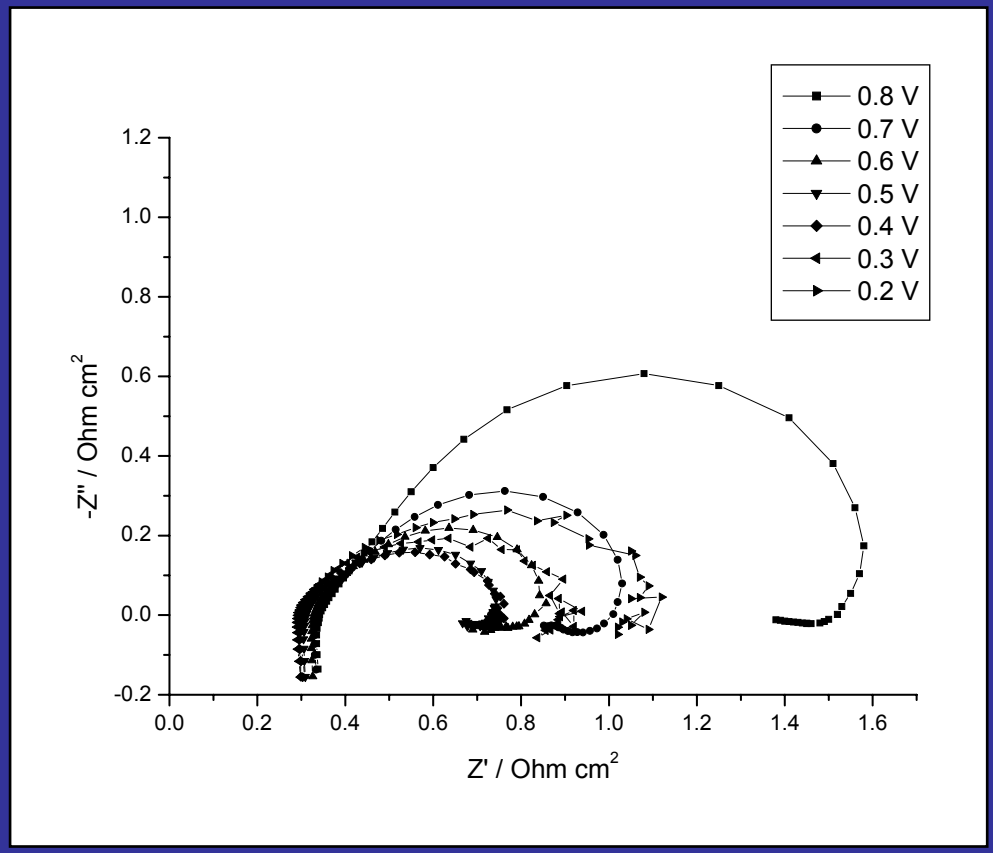
Impedance on Ag plated Ni foam cathode



Impedance measurements over a range of electrode voltages of a cathode made of silver plated nickel foam (loading: 0.015g cm-2) under air at 25°C in 30 wt. % KOH solution from 10 kHz to 0.01 Hz.

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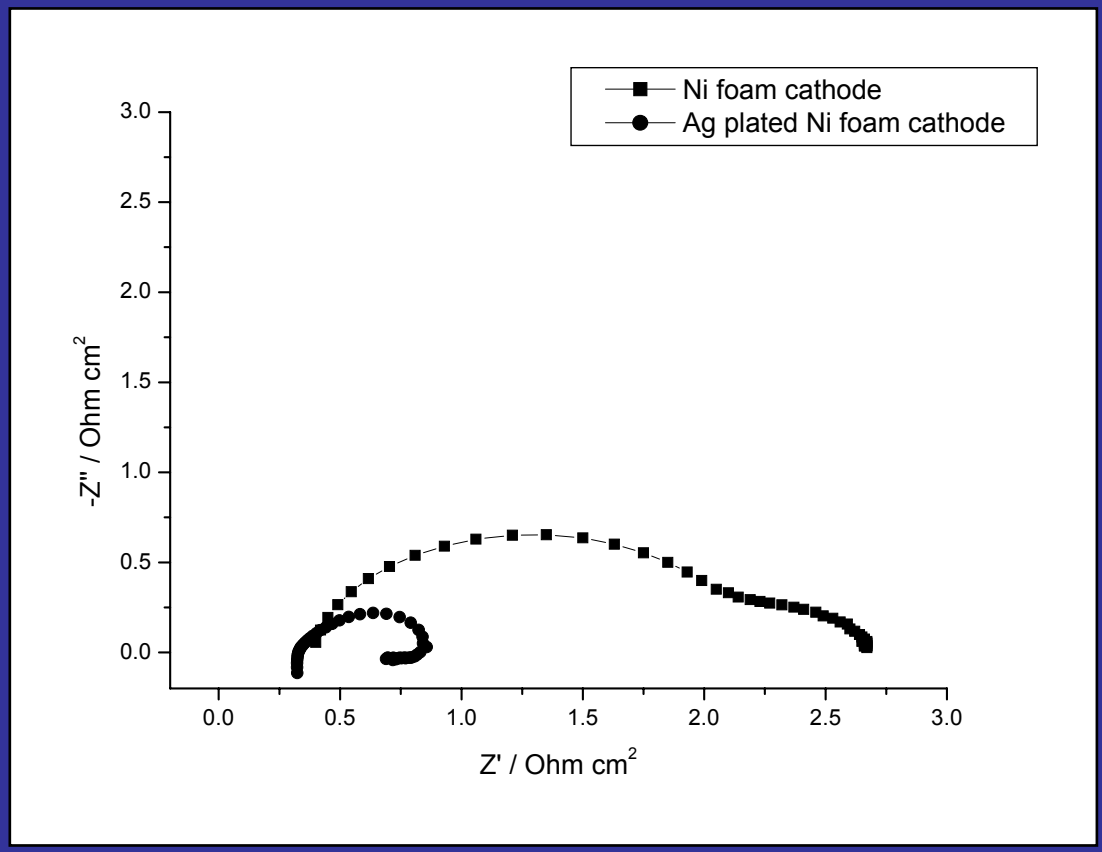
Impedance on Ni foam cathode



Comparison between the EIS response from the nickel foam and silver plated nickel foam based cathodes at 0.6 V (cell voltage) from 10 kHz to 0.01 Hz.

Conclusions

- The utilisation of non-noble metal catalysts and liquid electrolyte makes the AFC a potentially low cost technology.
- The use of a non-noble metal catalyst is possible because the oxygen reduction reaction (ORR) in alkaline media is more facile than in acid media.
- Nickel foam, which is cheaper than the commonly used nickel mesh, has been successfully used as electrode substrate for AFC electrodes.
- Cathodes made of silver plated nickel foam showed enhanced performance compare to cathodes made of nickel foam due to the reduction of the ohmic and charge transfer resistance.