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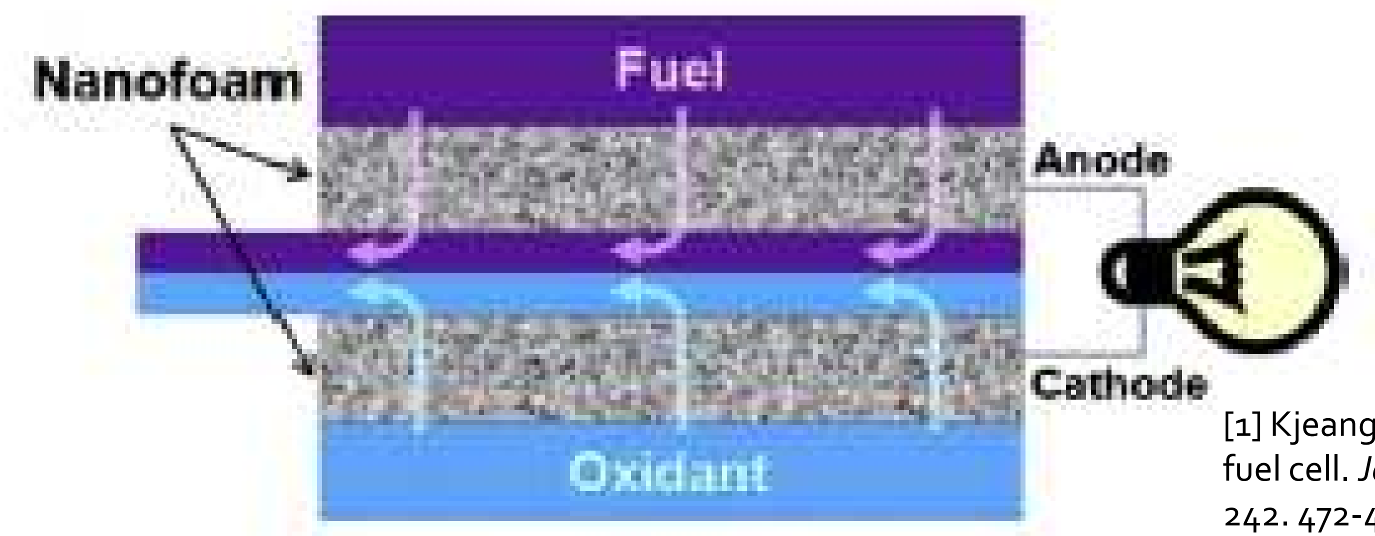
Nanofluidic Fuel Cells

Outline

- Introduction
- Nanofluidic Fuel Cell
  - Construction
  - Characteristics
  - Performance
  - Advantages/Disadvantages
- Conclusion

Introduction

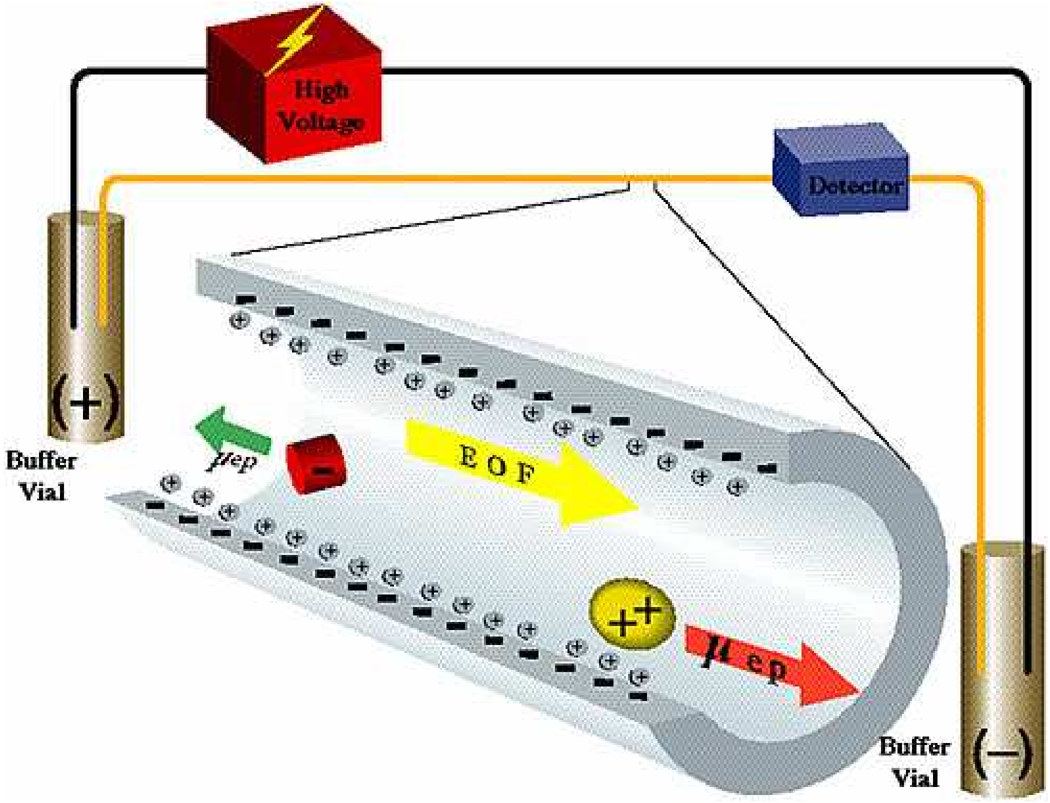
- Size range: 10μm – 1mm
- Usually co-laminar parallel streaming dependent on Reynolds number (Re)
  - When this becomes too high it is turbulent
- The flow induced causes an electric voltage



[1] Kjeang, E.; Lee, J.W. Nanofluidic fuel cell. *Journal of Power Sources*. 242. 472-477. 2013.

Electroosmotic flow

- The movement of ions through a solute under the control of an applied potential.
- Once the electric double layer is formed on the walls of the surface the bulk fluid is dragged along towards the cathode.



[2] Beckman Coulter: Capillary Electrophoresis.

Electric double layer / debye length

- The EDL occurs on the surface when in contact with charged fluid
- Counter-ion concentration increases as EDL increases due to the increase in space
- When concentration of bulk fluid is decreased EDL increases because of a higher net concentration of ions

Nanofluidic Fuel Cell

- Sample Reaction
  - $$V^{3+} + e^{-} \leftrightarrow V^{2+}$$

$$VO_2^{\ +} + 2H^{+} + e^{-} \leftrightarrow VO^{2+} + H_2O$$

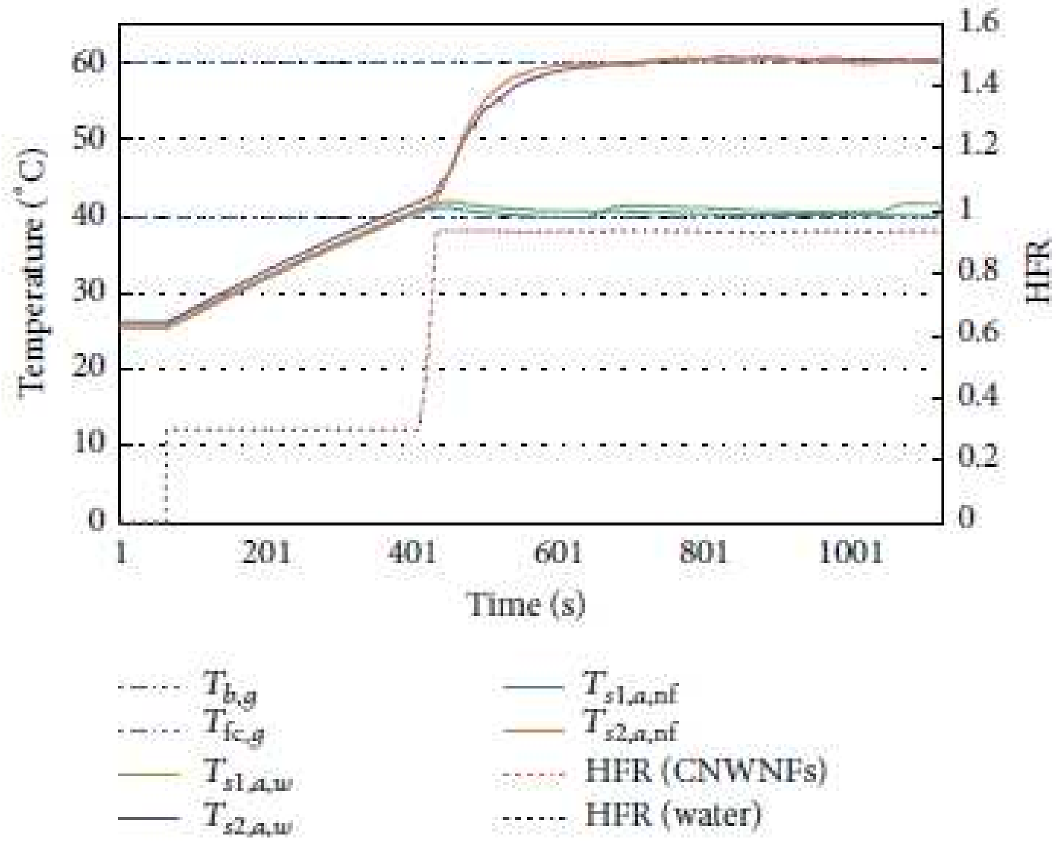
- Major benefit: catalyst free
- Two U-channels micro machined to the bottom then joined together by 55 parallel nanochannels Electric double layer overlap in nanochannels cause an increase in proton conductivity
  - Overlap occurs when height is decreased

Characteristics & Specifications

- Designed with carbon aerogels
  - Increased porosity
  - Increased surface area
  - Ultrafine porous sizes (less than 50nm)
- High proton conduction
- Minimized fuel crossover when Re is low
- Nanochannel depth: 50 nm
- Fuel: 1M methanol in 1mM H_2SO_4
- Oxidant: 1mM $KMnO_4$

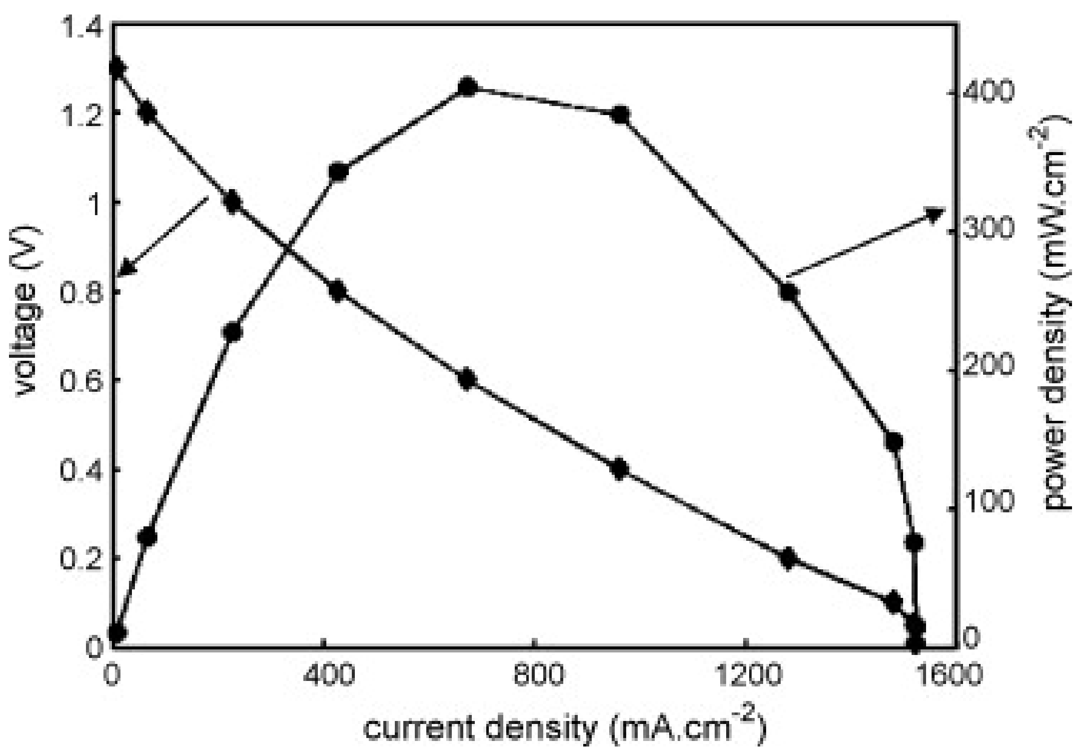
Performance

- Carbon aerogels: good for high voltage response with high overall fuel efficiency
- In general, fuel cells will use high concentration acids in fuel – nanochannels can use high proton conductivity at low concentrations because of the EDL overlap
- Approximate operational temperature: 60°C



[4] Hung, Y.H.; Gu, H.J. *Journal of Nanomaterials.* 2014. 1-13.

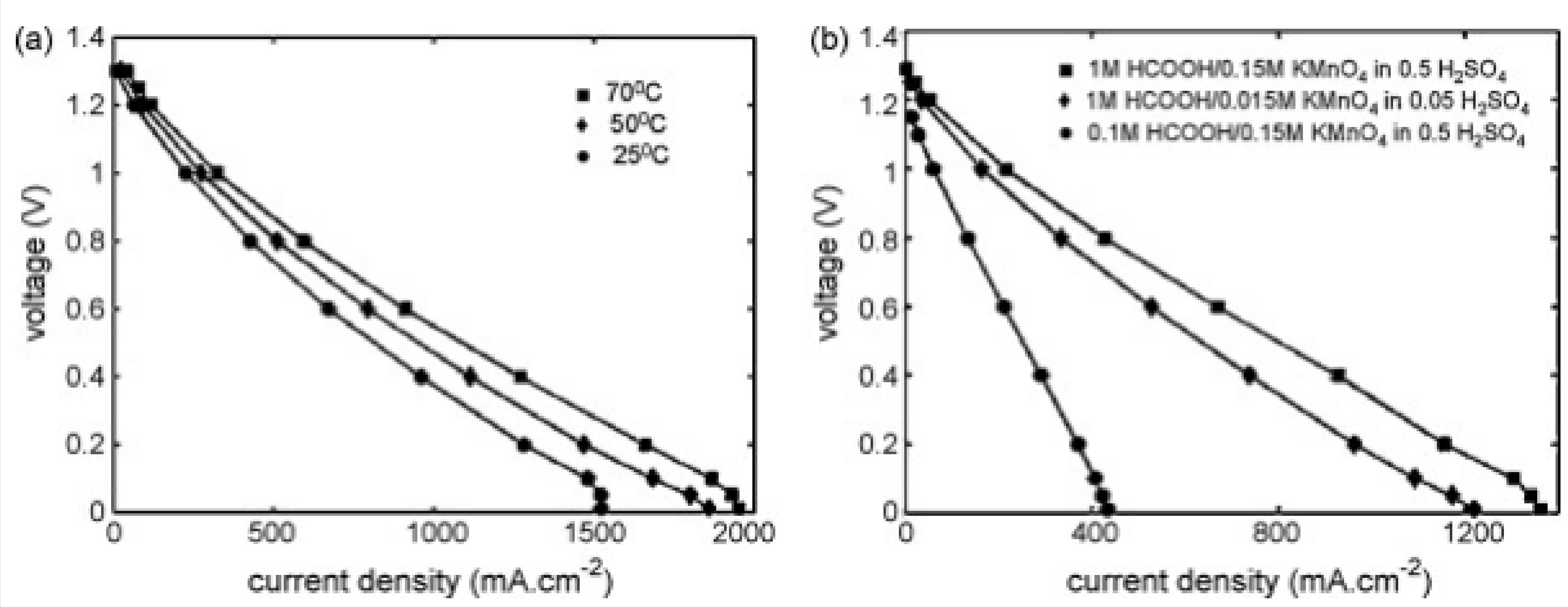
Advantages & Limitations



[3] C.J. Wadsworth. N. Yanagisawa, D. Dutta. *Journal of Power Sources*. 195. 3636-3639.

- Maximum power density: 400 mW/cm^2
- Higher temperature operation capabilities
- With a unibody design compatibility with micromachining increases and makes for improved performance

Effect of Temperature and Fuel and Oxidant Concentrations



- As the temperature increases the maximum current density increases approximately 500 mA.cm^2
- The increase in fuel or oxidant increased the current density of the fuel cell

Drawbacks

- Single outlet design → little to no regeneration
- Modifications required to facilitate any type of recharge for the cycle
- Oxidant caused deposition on the membrane
- Fuel cell life is too easily reduced by change in oxidant

Conclusions

- Microfluidic fuel cells generally more
- Microfluidic fuel cells have a high proton conductivity
- Can be put together in stacks in order to raise the power output
- Different polymer membranes within nanochanels can be altered to raise power output

References

1. Kjeang, E.; Lee, J.W. Nanofluidic fuel cell. *Journal of Power Sources*. 242. 472-477. 2013.
2. https://www.beckmancoulter.com/wsrportal/wsr/industrial/products/capillary-electrophoresis/electroosmotic-flow/index.htm
3. Wadsworth, C.J.; Yanagisawa, N.; Dutta, D. *Journal of Power Sources*. 195. 3636-3639.
4. Hung, Y.H.; Gu, H.J. *Journal of Nanomaterials.* 2014. 1-13.

Thank You