Fuel Cells with Dynamic Response Capability Based on Energy Storage Electrodes with Catalytic Function

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Needs and Rationales

Current Electric Delivery System Relies On Centralized Plants and Grid Transmission

- *High fuel-to-electricity efficiency*
- *Vulnerable & difficult to integrate with renewable energy technologies*

Fuel Cells Technologies

- *Potentials: an excellent complementary for small and reliable distributed generation*
- *Difficulties: fuel supply, cost, operation condition, transient load*
- *Solution: intermediate temperature fuel cells (ITFCs) with dynamic response capability*

Goal and Objectives

- *To develop fuel cells with dynamic responsive capability*

Strategy

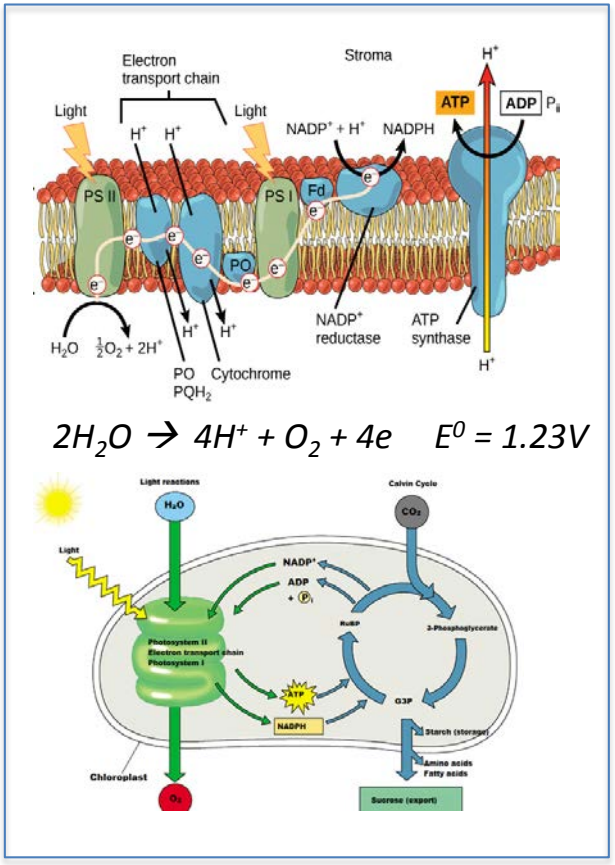
- *Incorporate energy-storage component to the fuel cell electrodes*

Tasks

- *Seeking for suitable energy-storage materials*
- *Integration with fuel cell electrodes (starting from PEMFC, Solid Acid..)*

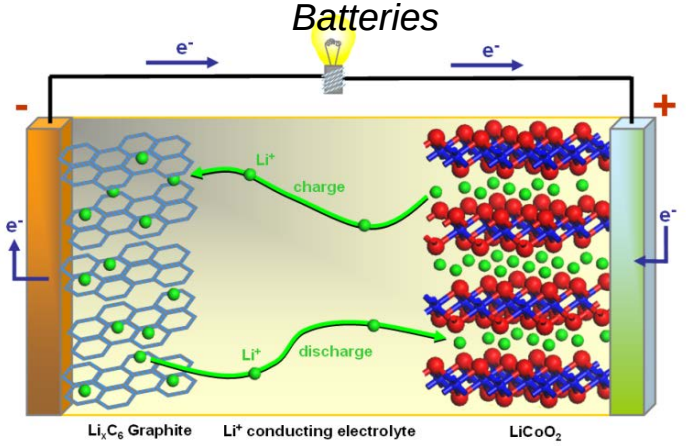
Material Design towards Energy Storage and Conversion

Photosynthesis

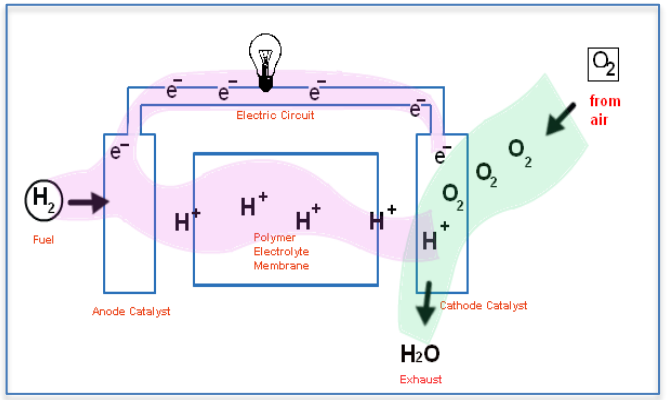


$2H_2O \rightarrow 4H^+ + O_2 + 4e \quad E^0 = 1.23V$

Batteries



Fuel Cells



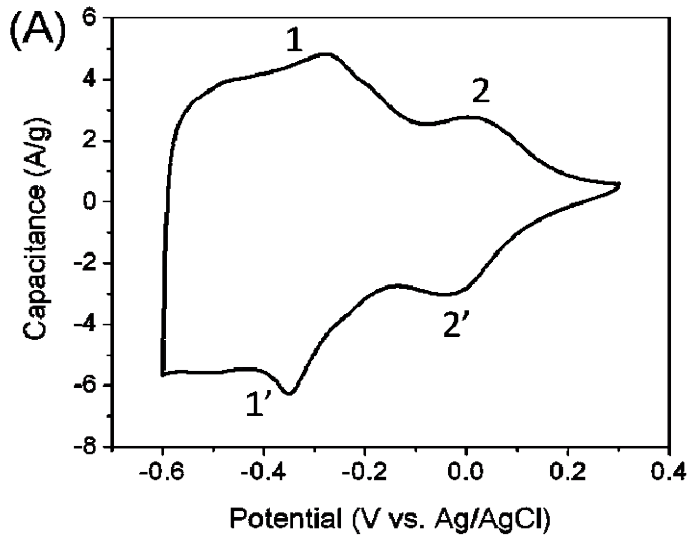
Energy storage & conversion achieved through simultaneous translocations of electrons and ions

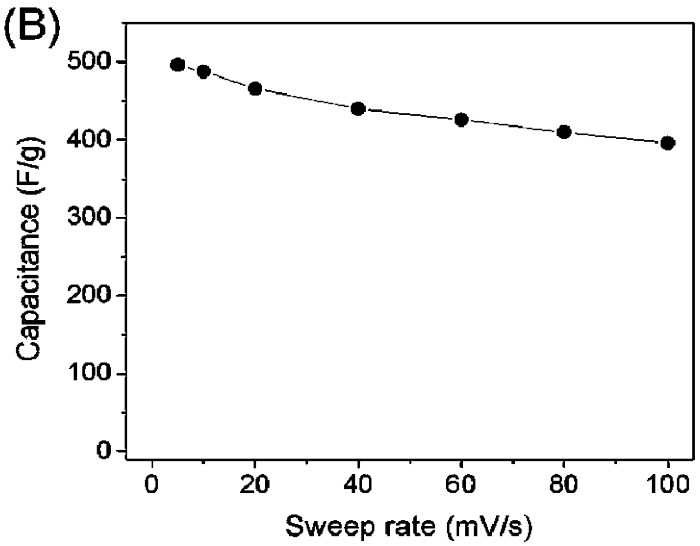
- *Electron-ion transport kinetics determine power*
- *Number of electrons & ions hosted determine capacity*
- *Structure robustness during cycling determine cycling life.*

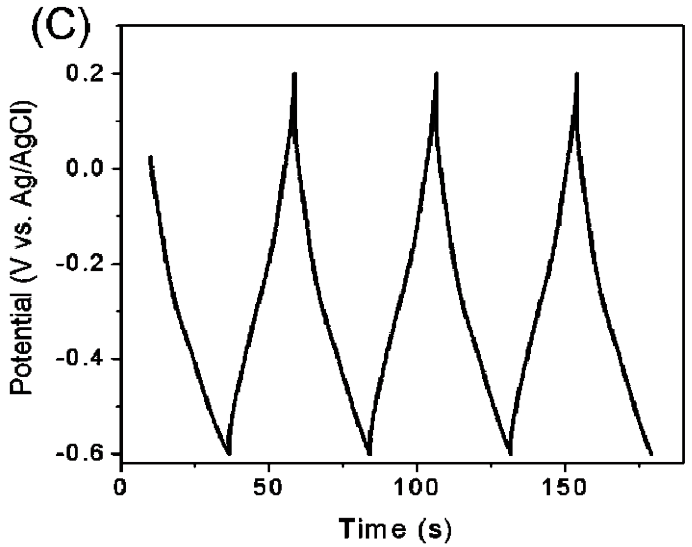
mixed electron-proton conductivity, high capacitance, and structure robustness in acidic environment

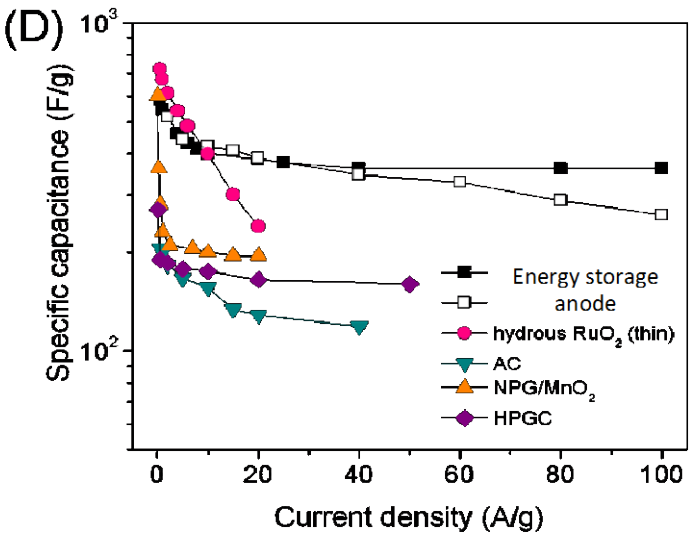
Acid-Stable Mixed Conductor with High Capacitance and Rate Performance

$$A + H^+ + e^- \rightleftharpoons AH$$





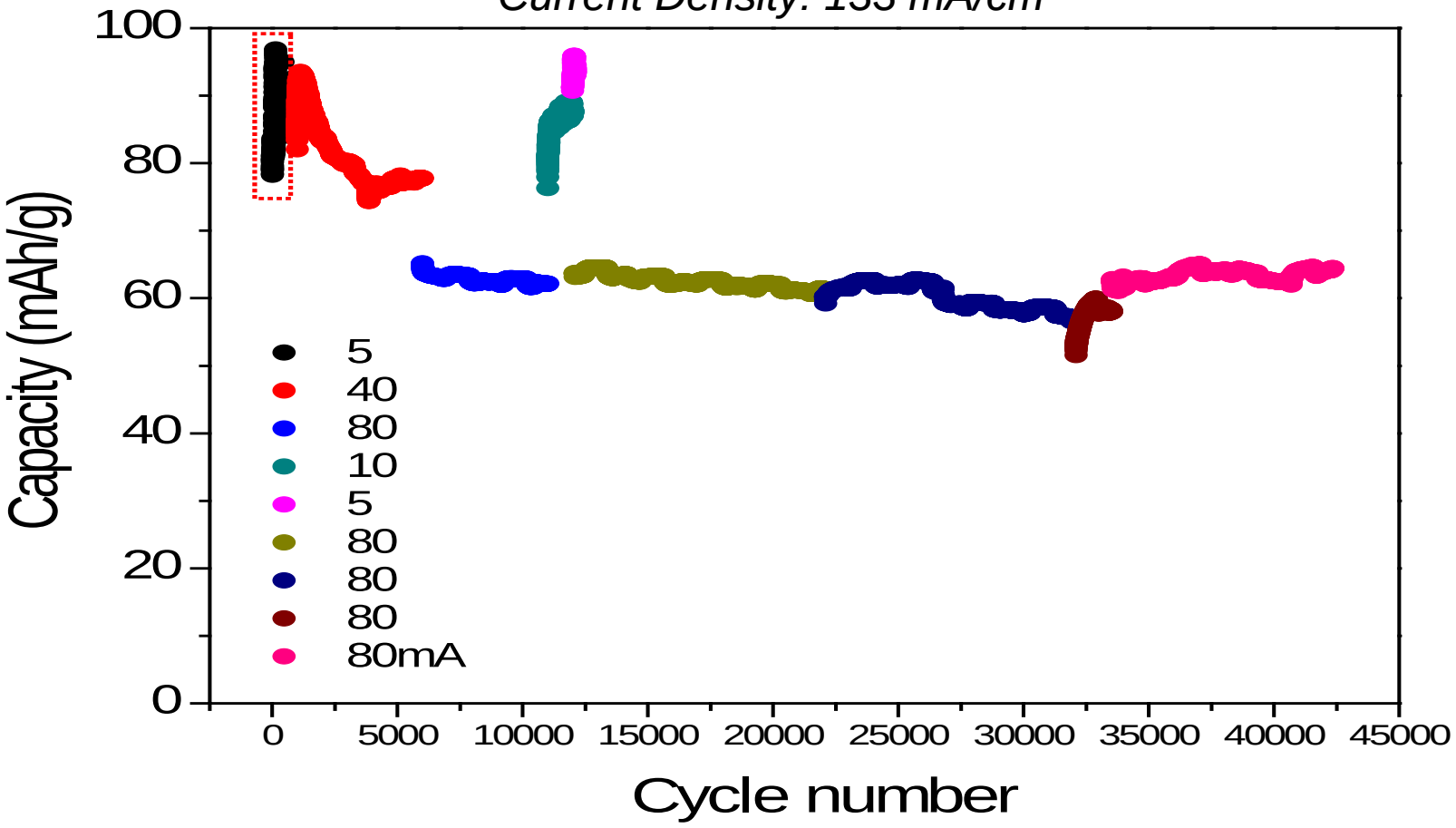




Cycling Stability of the Storage Electrode at Different Current Density

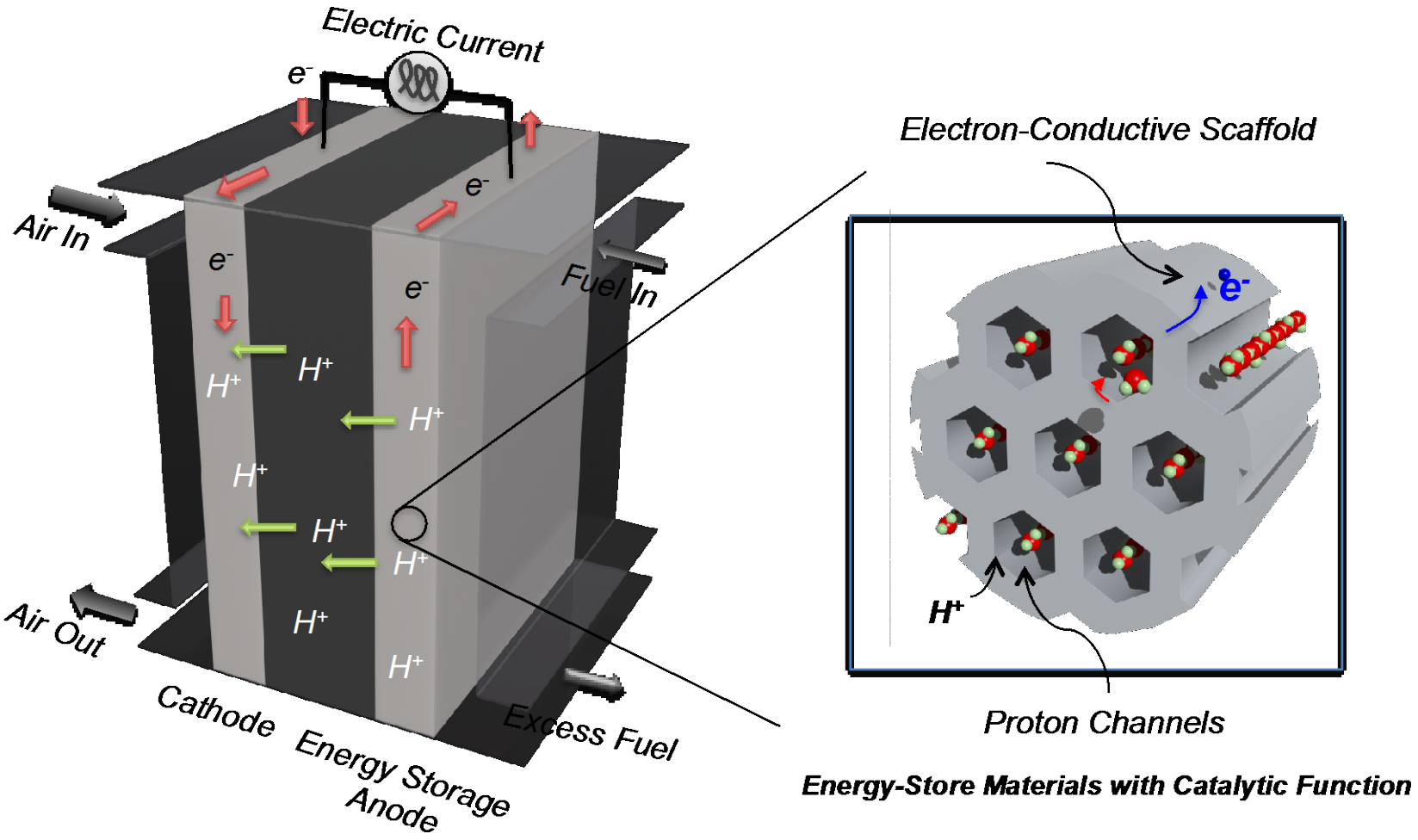
(mass loading 5 mg & electrode area 0.6 cm²)

Current Density: 133 mA/cm²

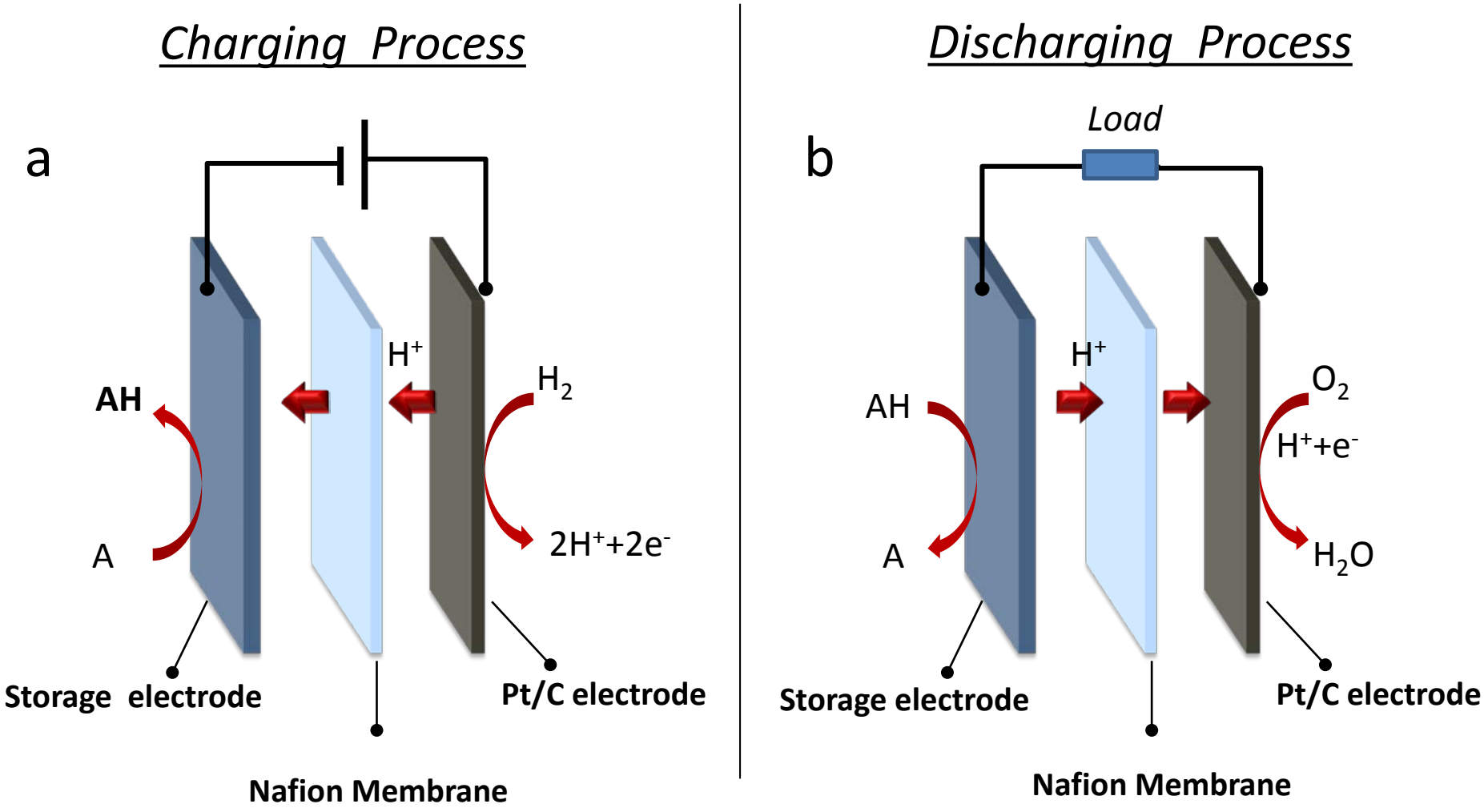


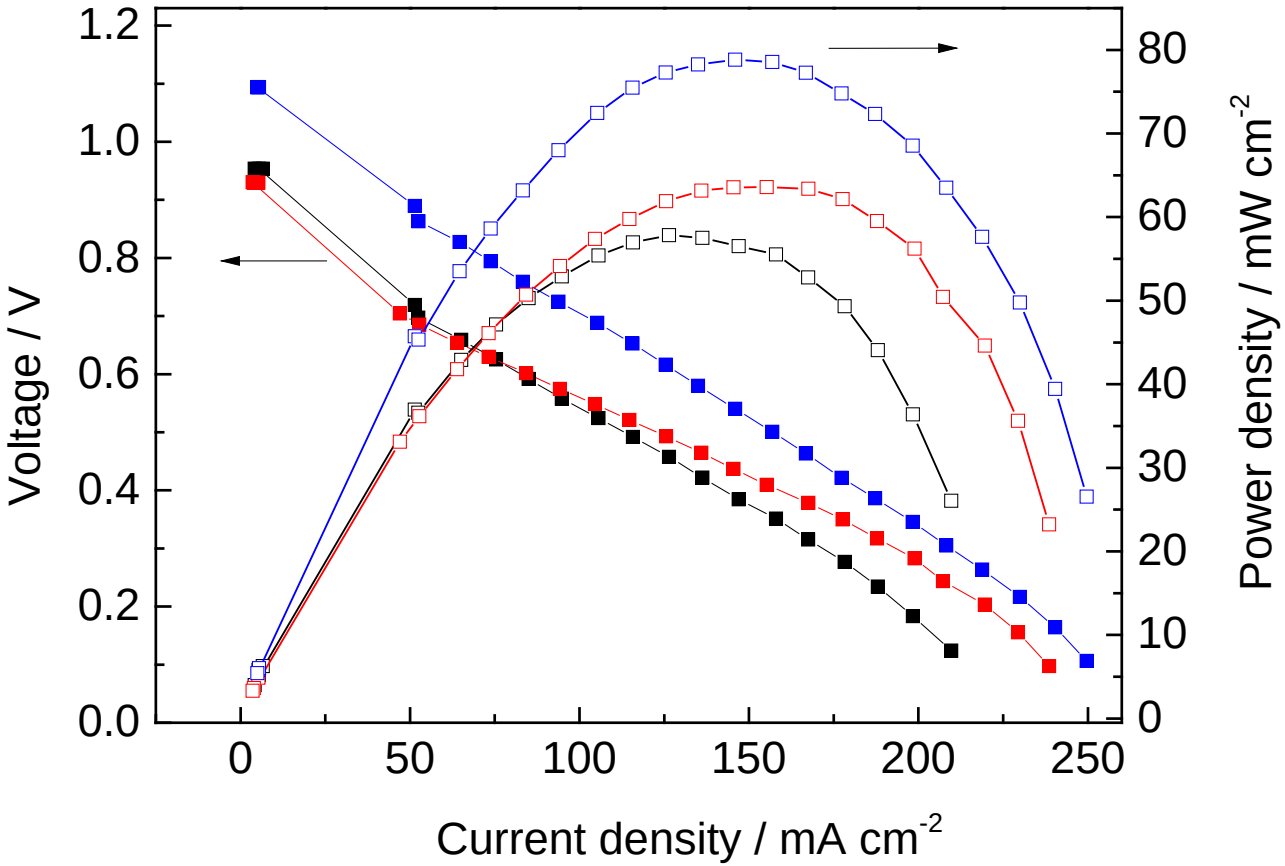
Thermally stable up to 400 °C

Fuel Cells with Dynamic Responsive Capability



Rechargeable Air Battery

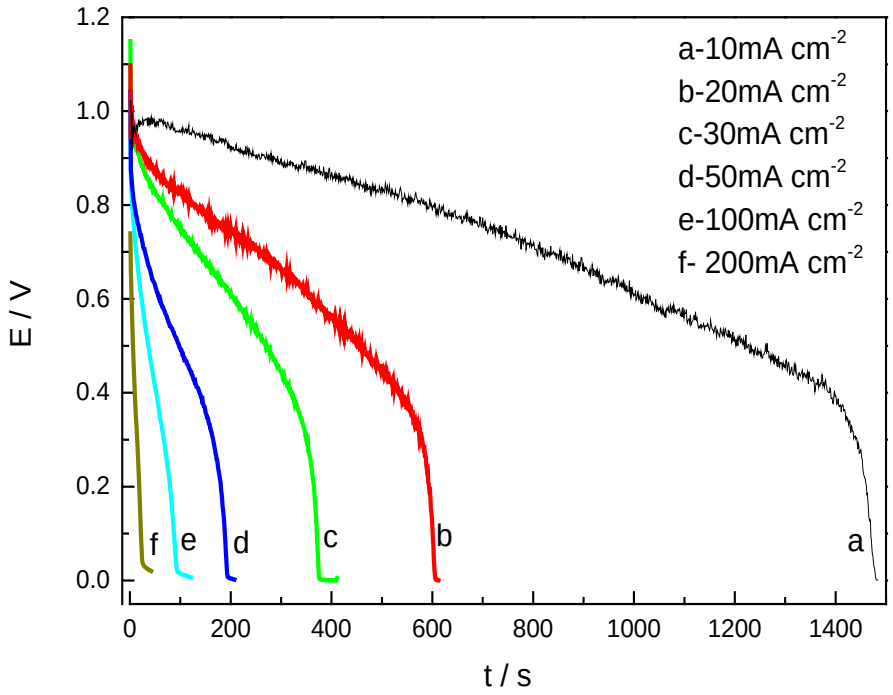


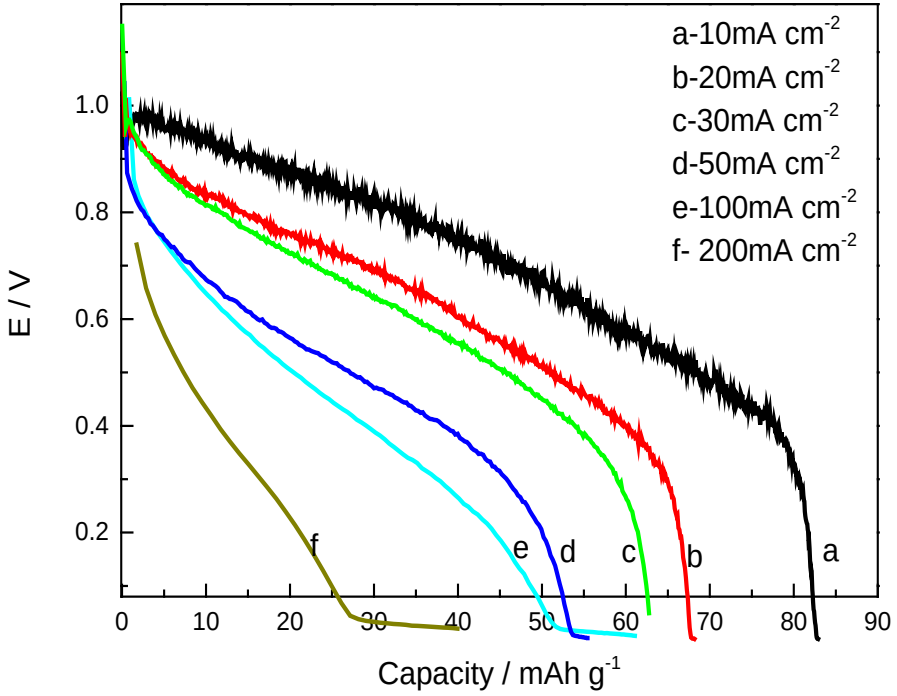


The peak power density is ~ 80 mW cm^{-2}, comparable to that of DMFC at 60°C.

Galvanostatic Discharging Curve of the Air Battery

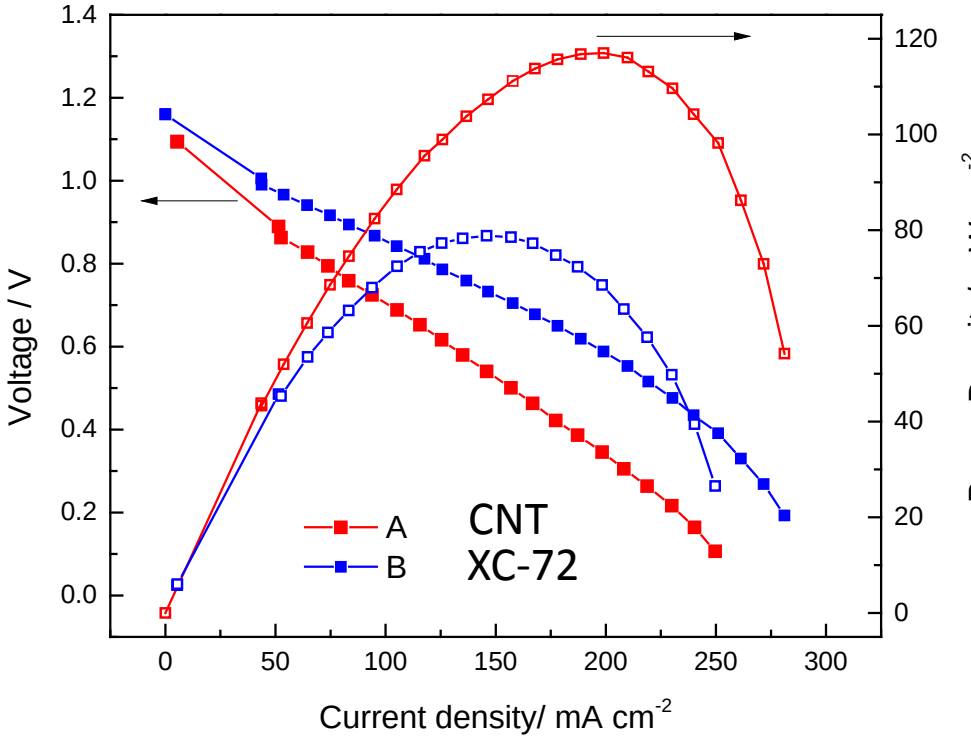
(Carbon paper coated with A, XC-72, Nafion and charged to -0.3 V vs. DHE)

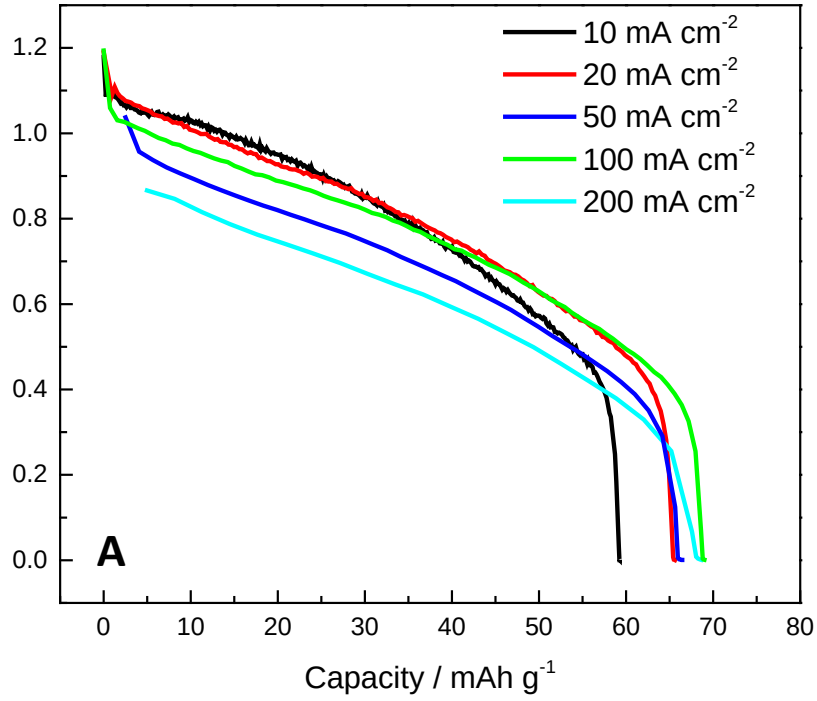




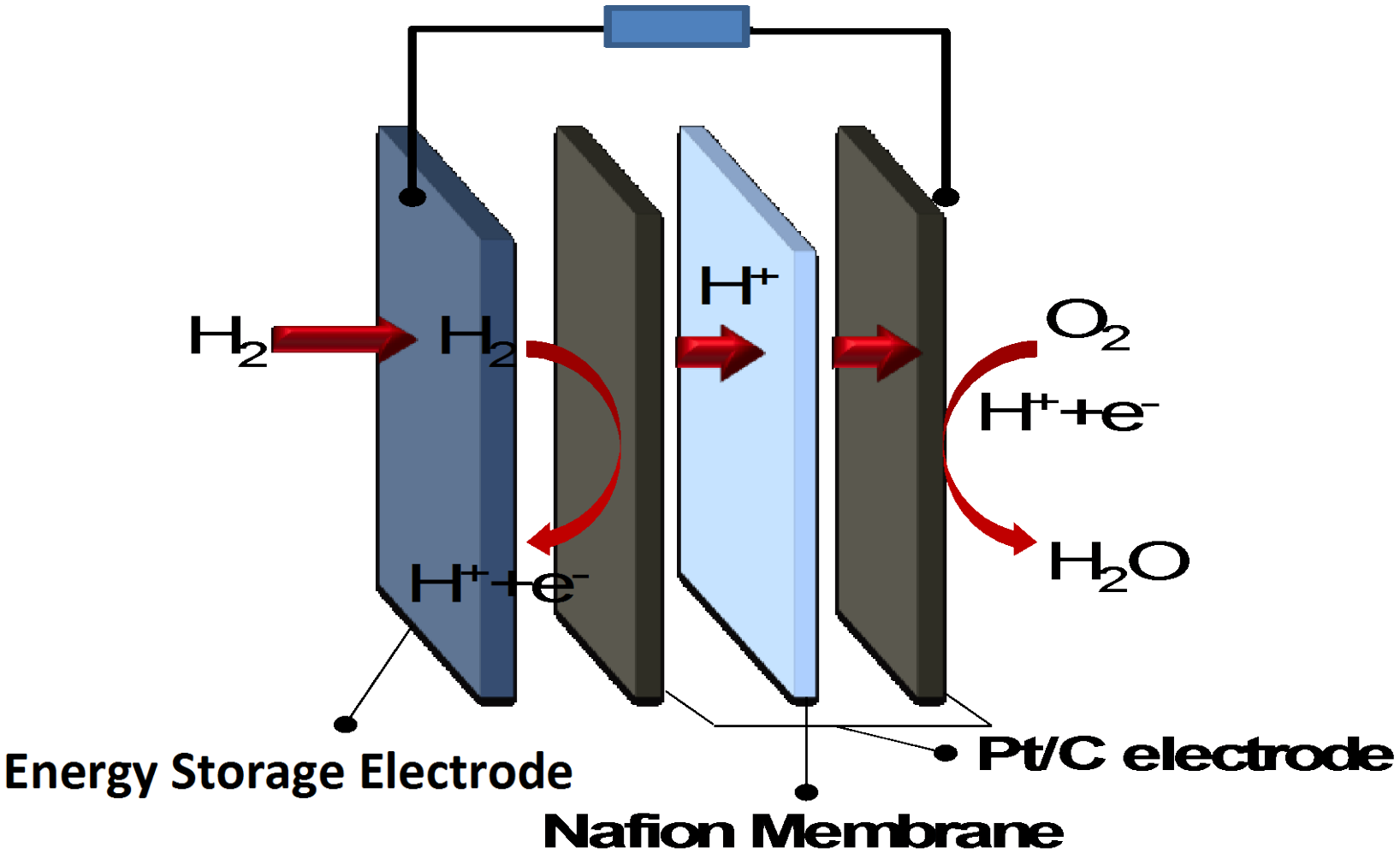
Current Density /mA cm^{-2}	a	b	c	d	e	f
	10	20	30	50	100	200
Time/s	1473	605	374	189	89	21

CNT-Composite Electrodes with Improved Rate Capability



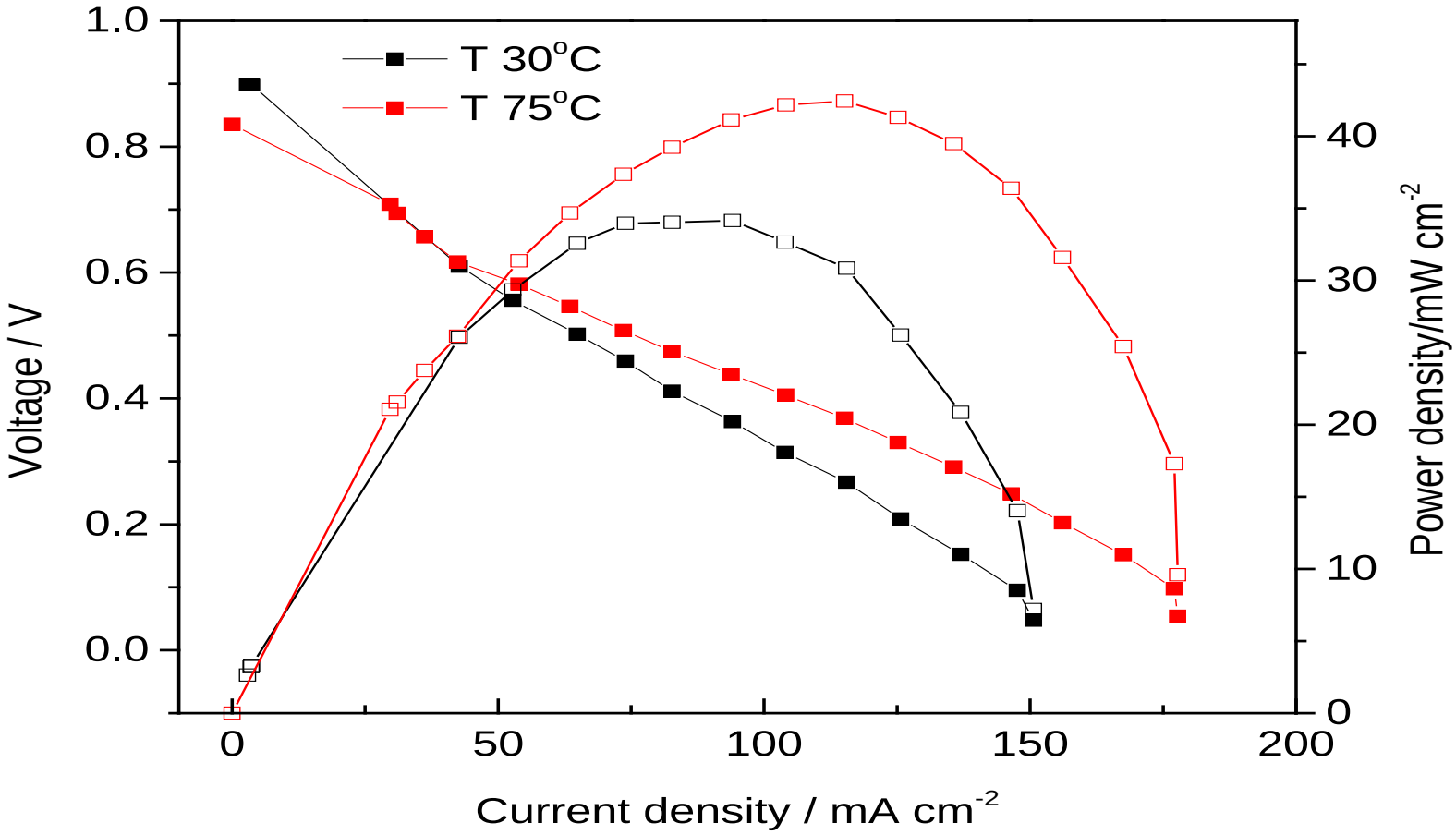


PEMFC with Energy Storage Electrode



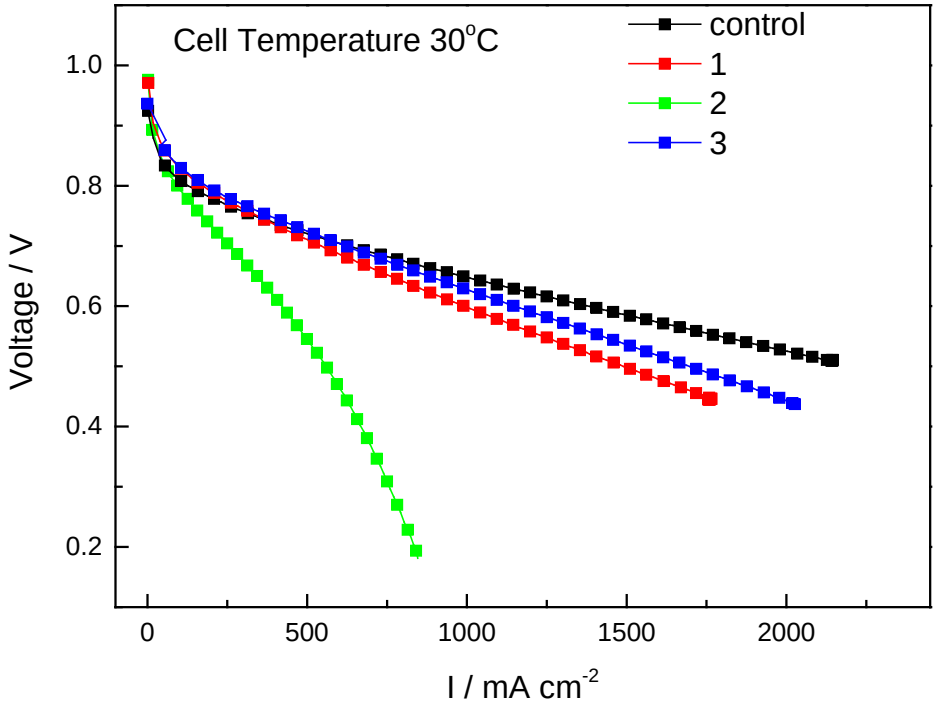
PEMFC with Energy Storage Electrode

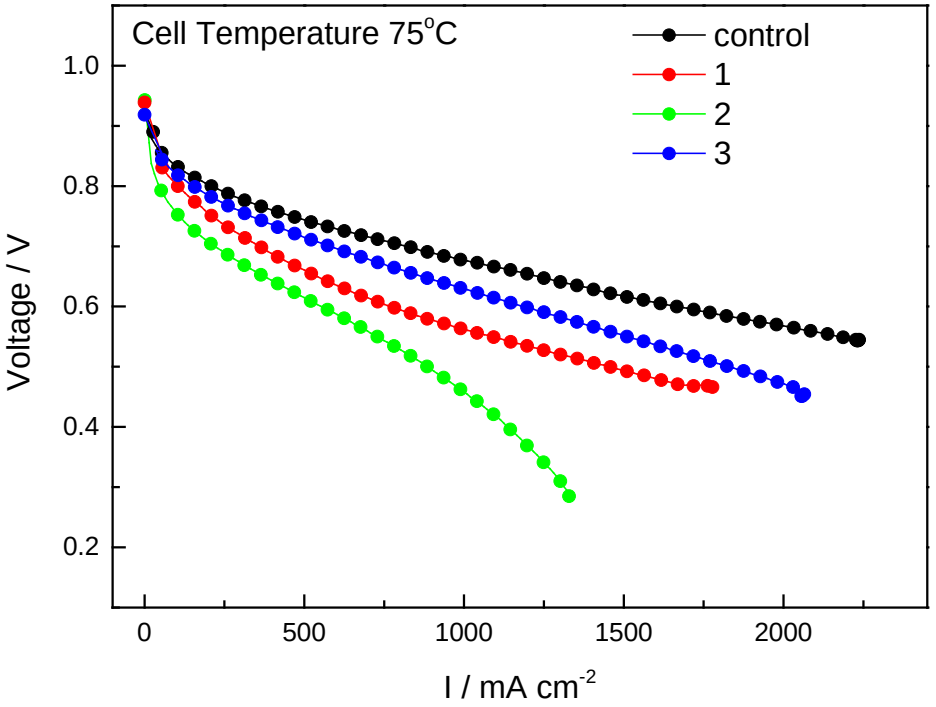
(Battery Mode: Pre-charged anode to 0 V)



PEMFC with Energy Storage Electrode

(Fuel Cell Mode)

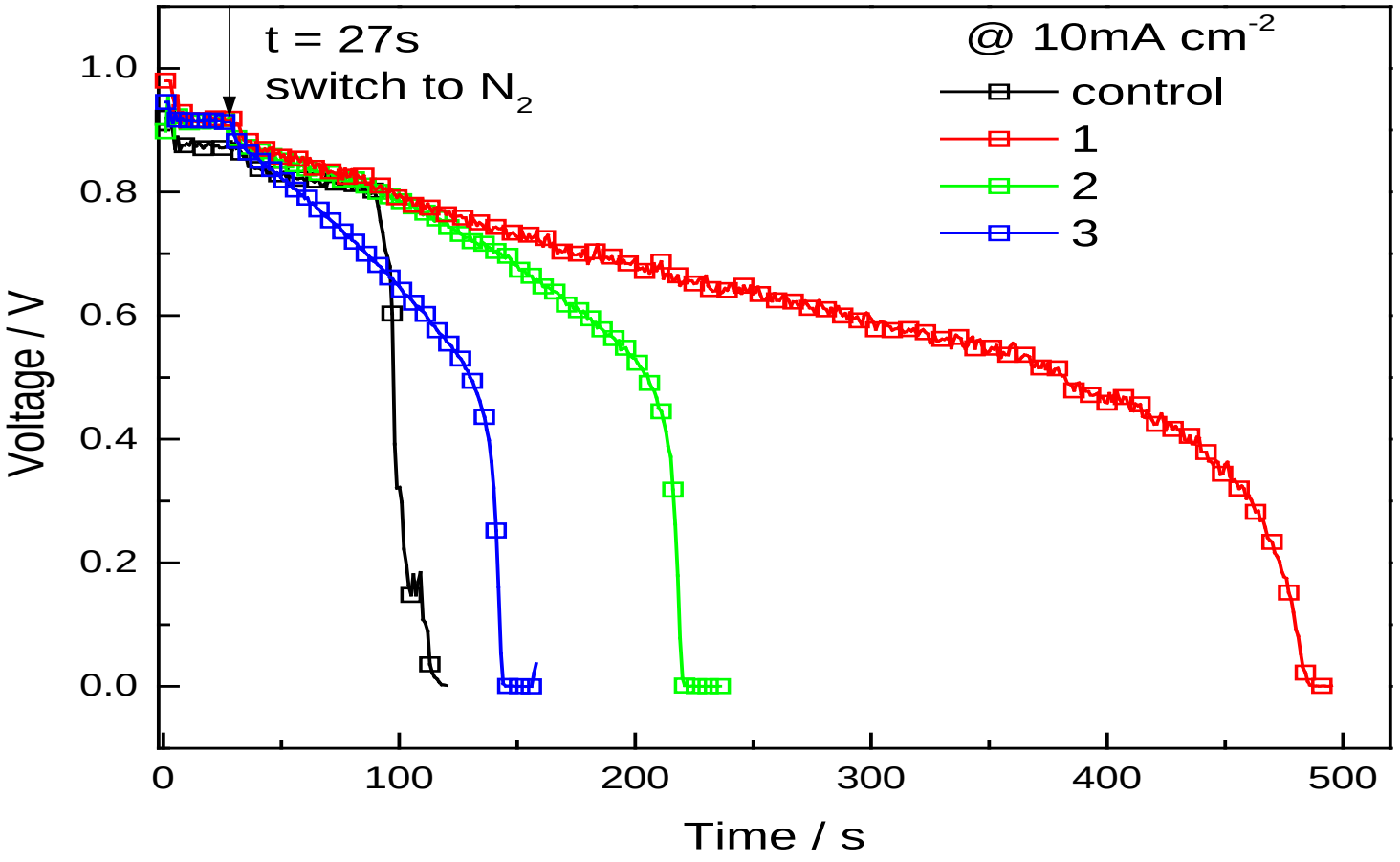




Working PEMFC but with deteriorated performance

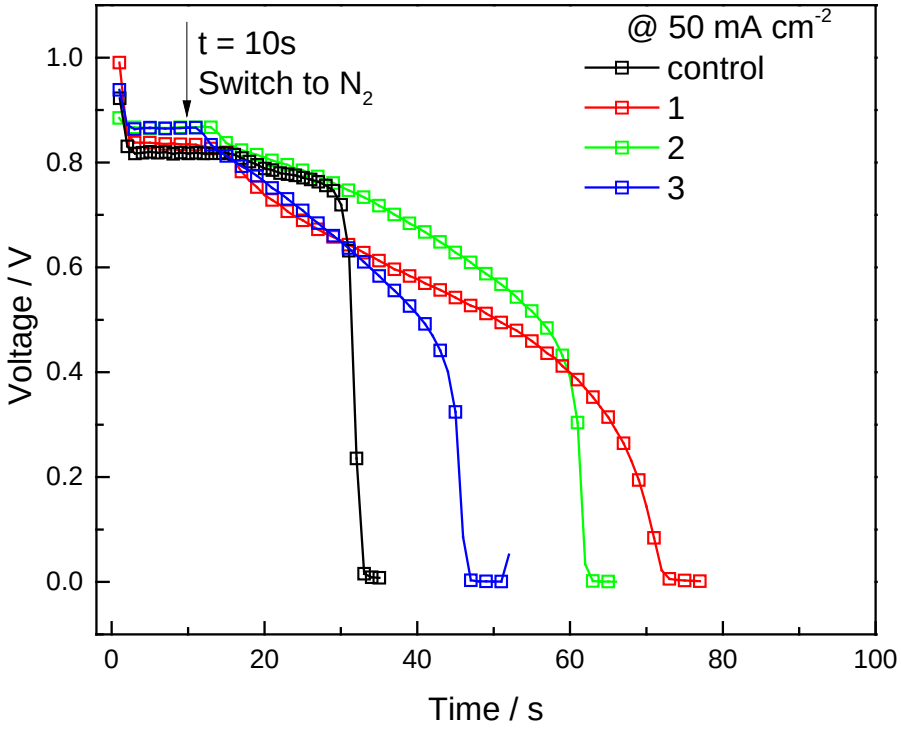
Structure optimization to reduce the resistance will be conducted

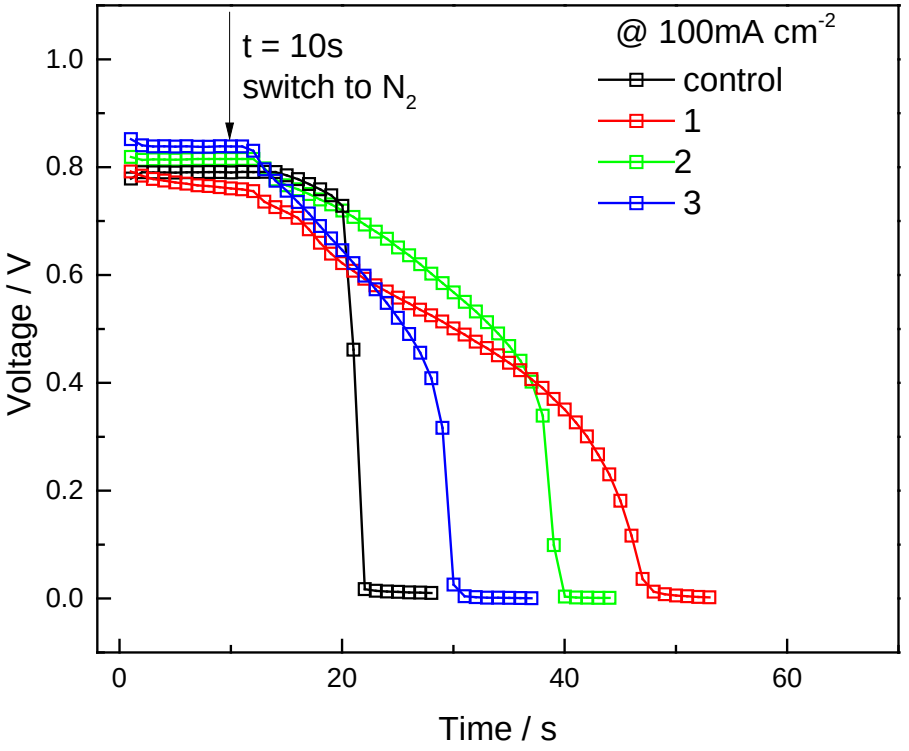
Responsive PEMFC based on the Energy Storage Electrode (H_2 Starvation Mode)



Working PEMFC with responsive capability demonstrated

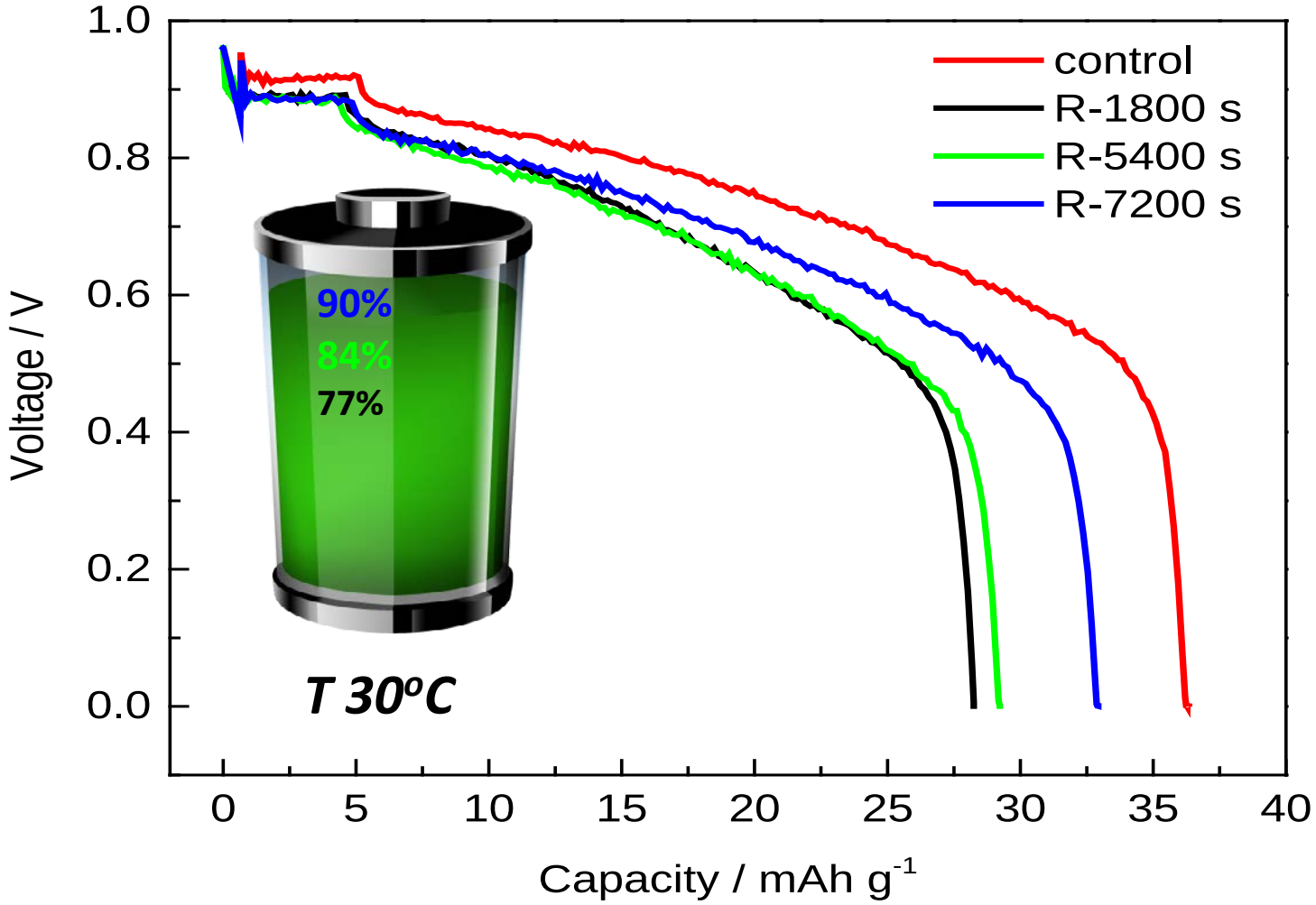
Responsive PEMFC based on the Energy Storage Electrode (H_2 Starvation Mode)





In Situ Charging of The Storage Electrode

Fuel cells operated under a current density of 10 mA cm^{-2}



Summary

- *Fuel cells with responsive capability demonstrated.*
- *Structure optimization is required to achieve high performance.*
- *Design will be extended to solid acid fuel cells for intermediate temperature operation*