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### Effect of Chemical Treatment on the Electrochemical Properties of Carbon Nanotubes

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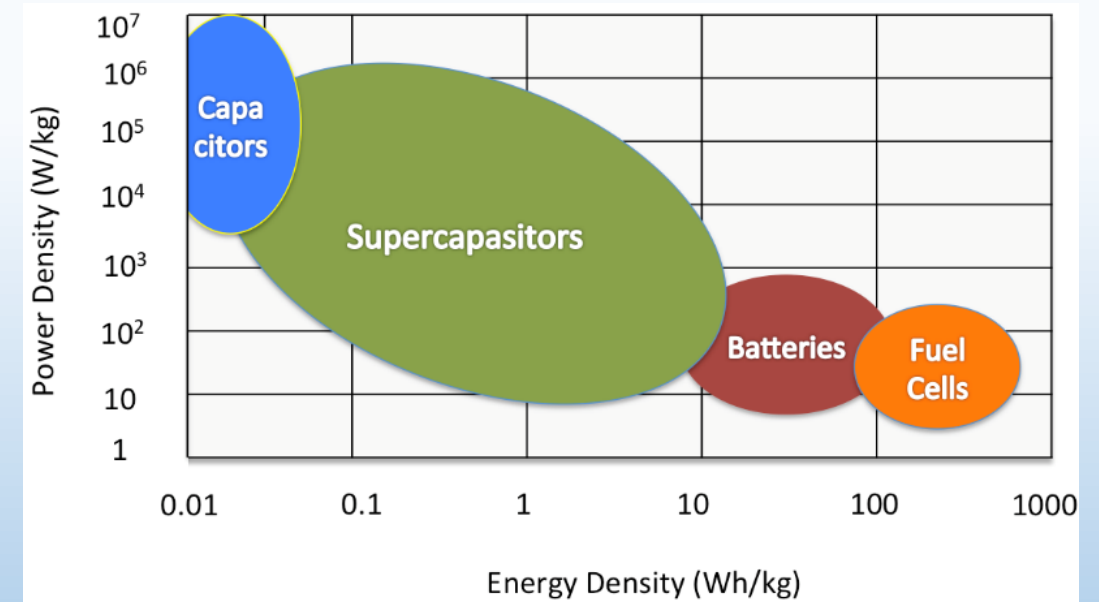
# The Effects of Chemical Treatment on the Electrochemical Properties of Carbon Nanotubes

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# Supercapacitors

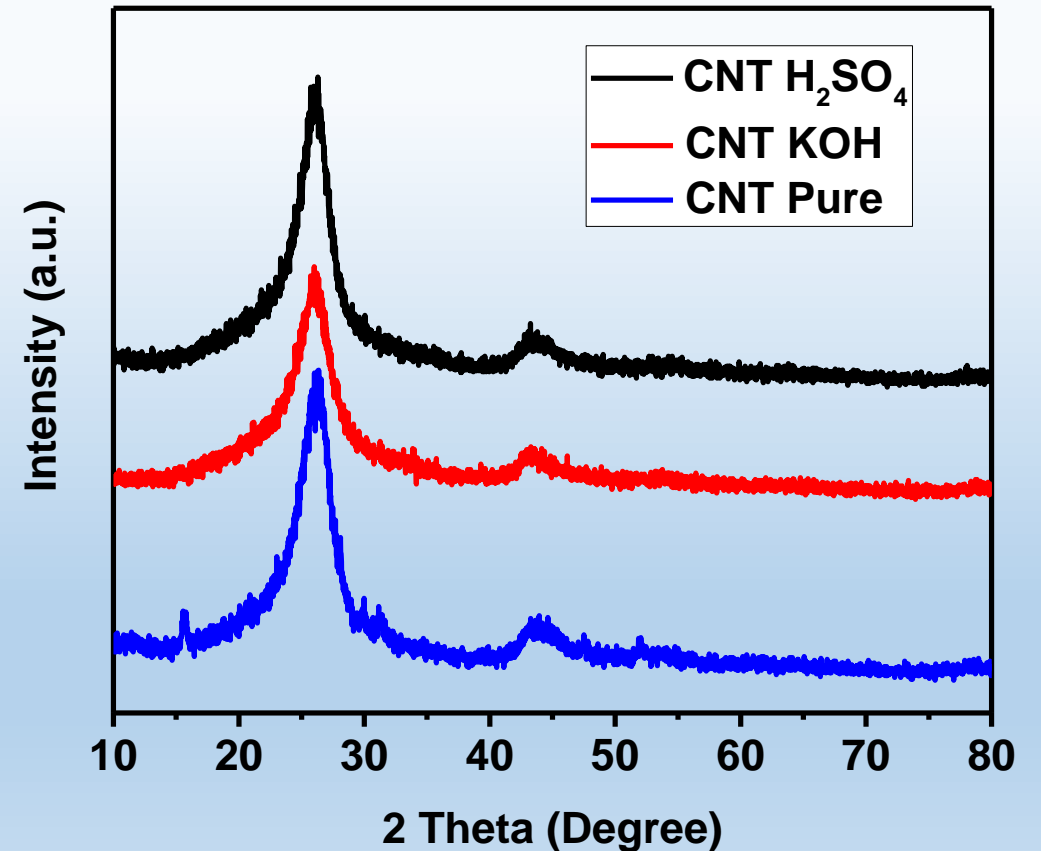
- Electrochemical energy storage device
- Bridge the gap between dielectric capacitors and batteries
- Types of Supercapacitors
  - Pseudo capacitors (metal oxides)
  - Electric Double Layer Capacitors
    - Activated carbon
    - Carbon aerogel
    - Graphene
    - Carbon nanotubes



Ragone Plot

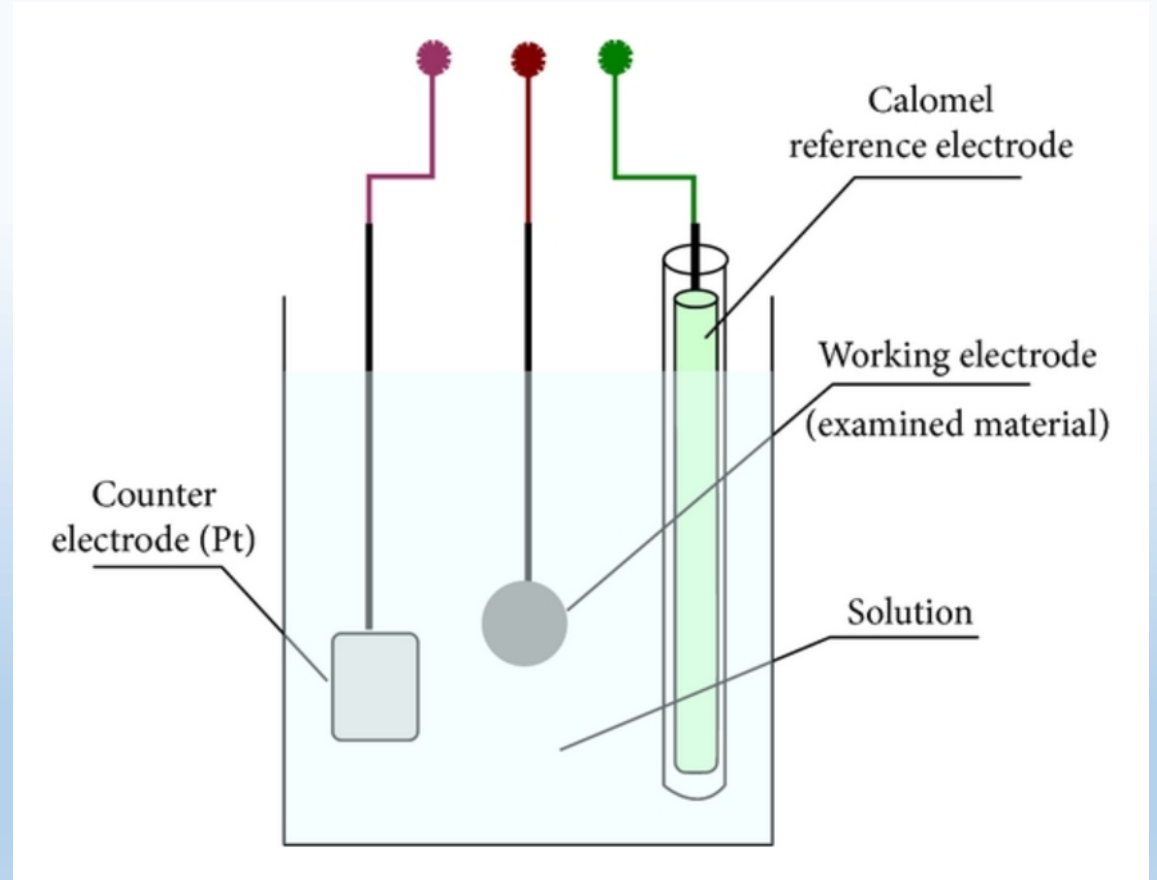
# Structural Characterization

- X-ray diffraction
- Pure CNT was most graphitic (conductive phase of carbon)
- $6 \text{ KOH} + \text{C} \rightarrow 2\text{K} + 3\text{H}_2 + 2\text{K CO}_2$
- Nano pores caused by KOH activation
  - EDL formed inside porous carbon
  - Increase surface area increases ion absorption and therefore capacitance
- Brunauer-Emmett-Teller absorption method
  - Pure CNT =  $210 \text{ m}^2/\text{g}$
  - KOH activated =  $239 \text{ m}^2/\text{g}$
  - $\text{H}_2\text{SO}_4$  treated =  $236 \text{ m}^2/\text{g}$



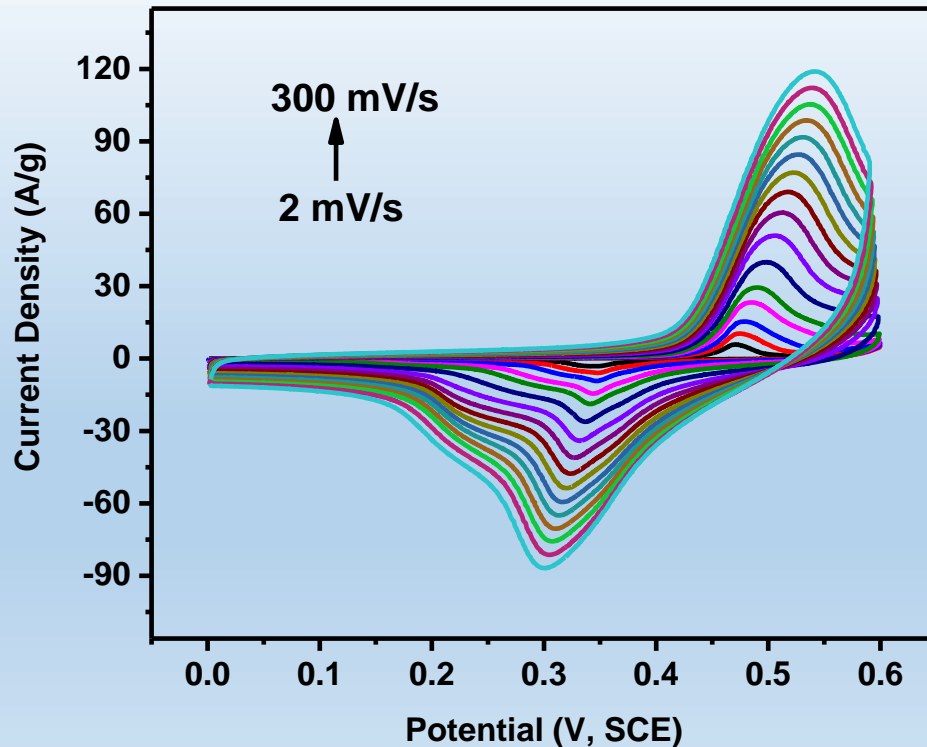
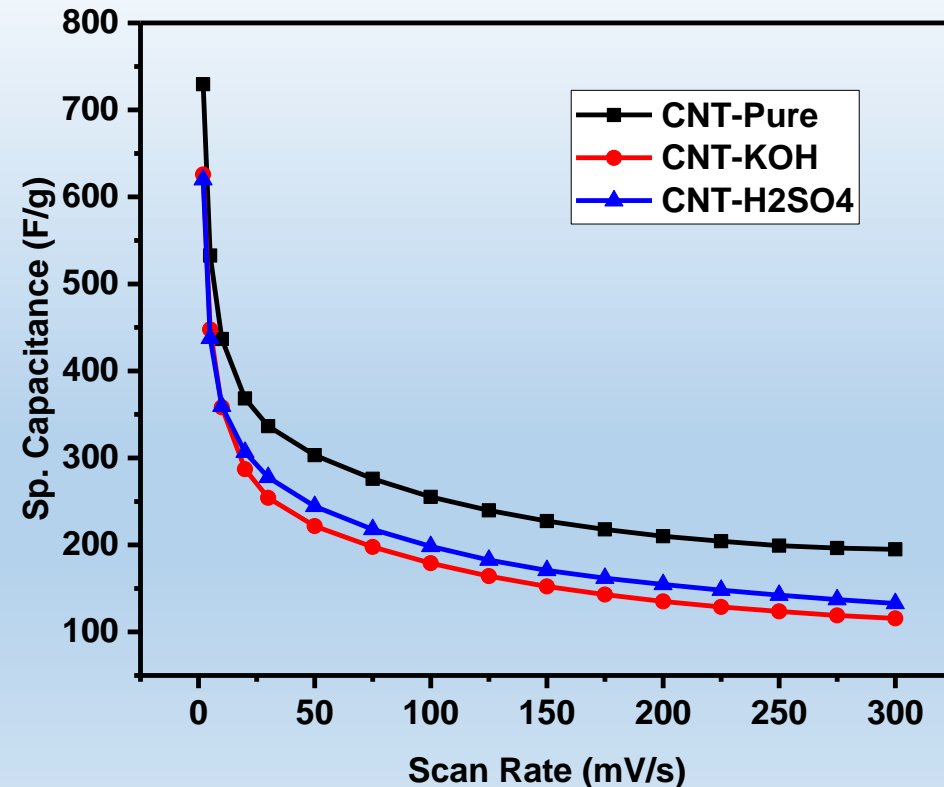
# Electrochemical Characterization

- Working Electrode Preparation:
  - Mixed 80 wt.% CNT, 10 wt.% acetylene black, 10 wt.% polyvinylidene difluoride (PVdF) in N-methyl pyrrolidinone (NMP).
  - Slurry was pasted on nickel foam
- Charge storage capacity was measured using both cyclic voltammetry (CV) and galvanostatic charge-discharge (CD)



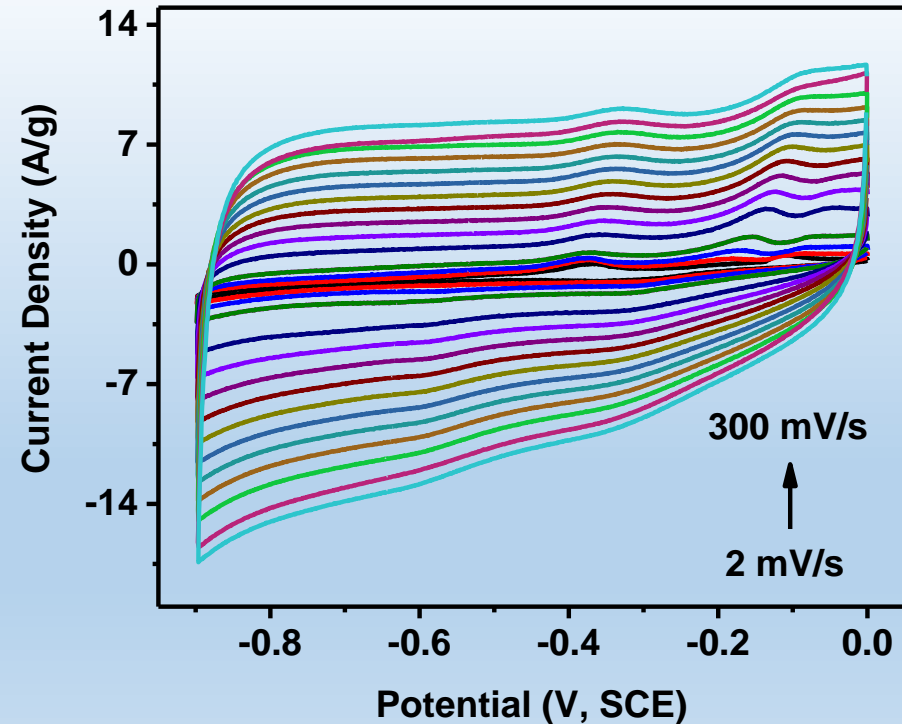
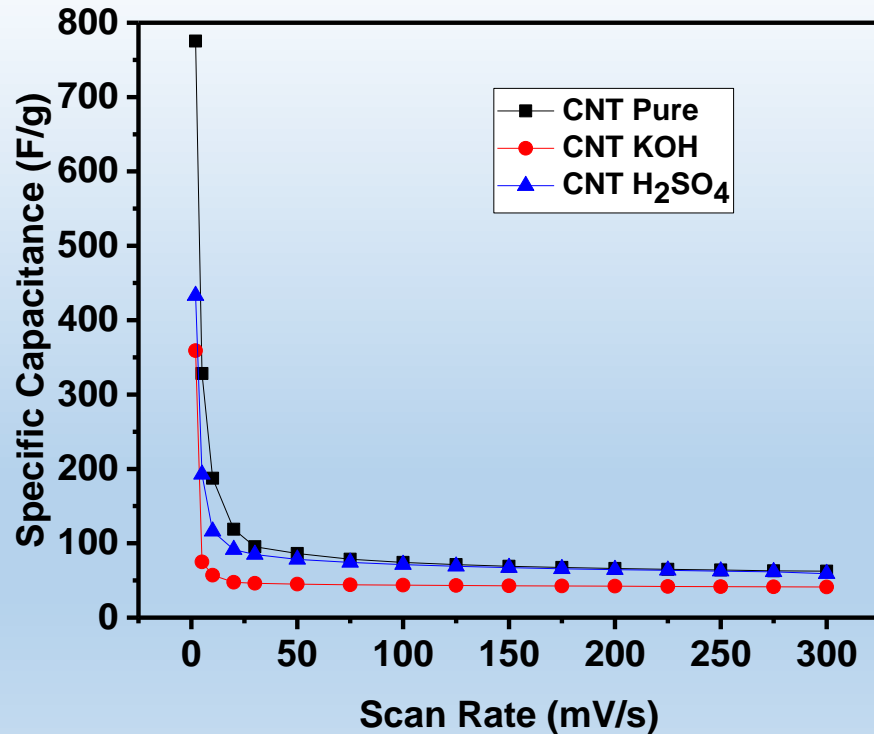
# Cyclic Voltammetry (Positive Potential)

- Peaks represent the transfer of electrons
- Specific Capacitance decreases with increasing scan rates
  - Insufficient time for electrolyte to absorb and desorb from electrode surface



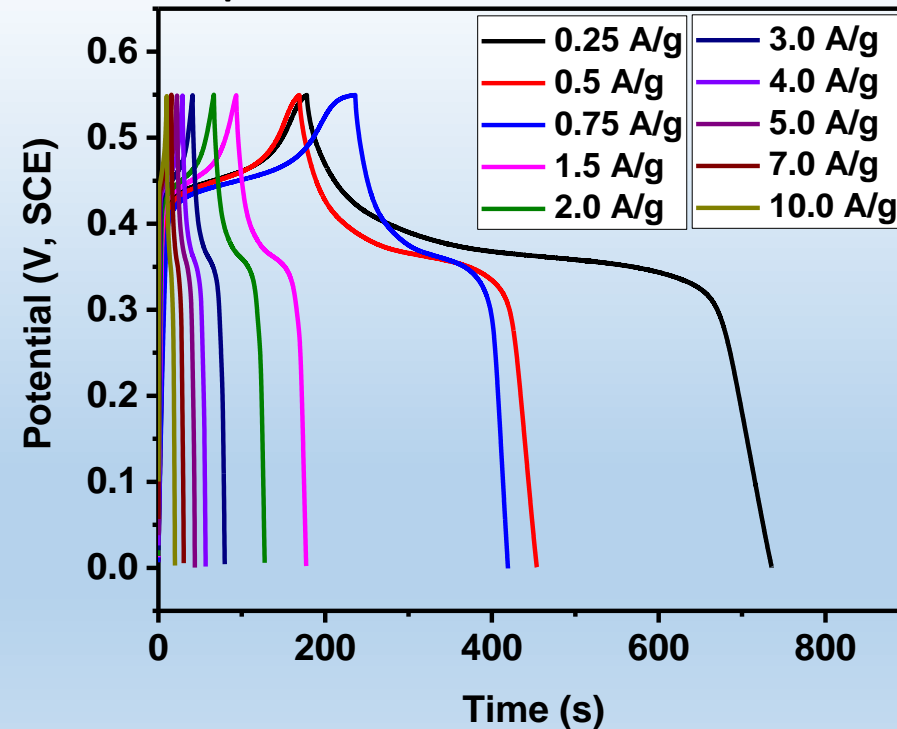
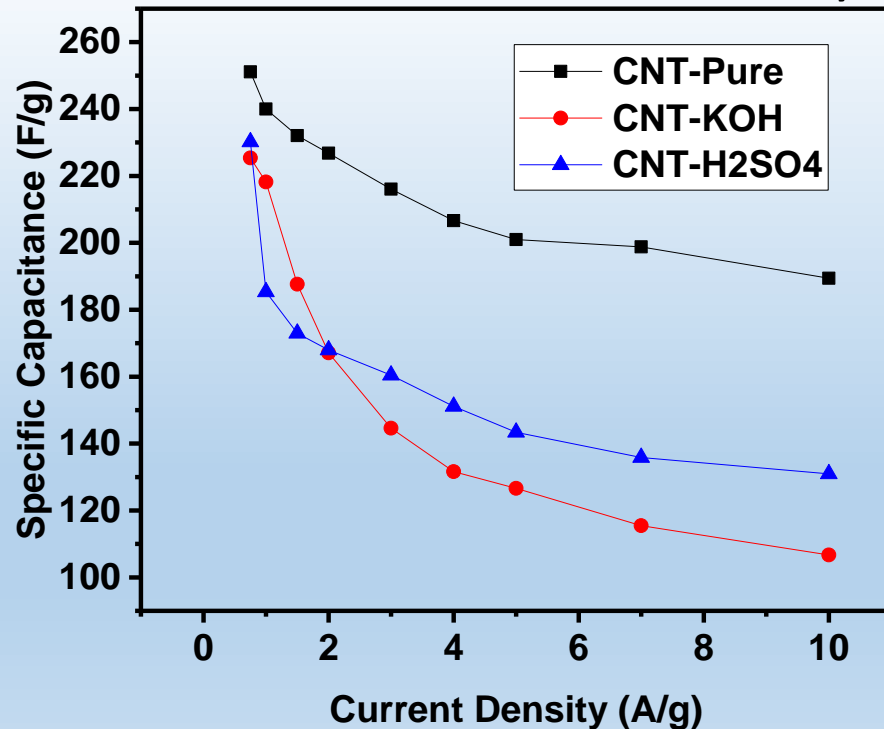
# Cyclic Voltammetry (Negative Potential)

- The shape of the graph confirms the electrochemical double layer
- Similar shape over various scan rates shows electrochemical stability of electrode



# Galvanostatic Charge-Discharge (Positive Potential)

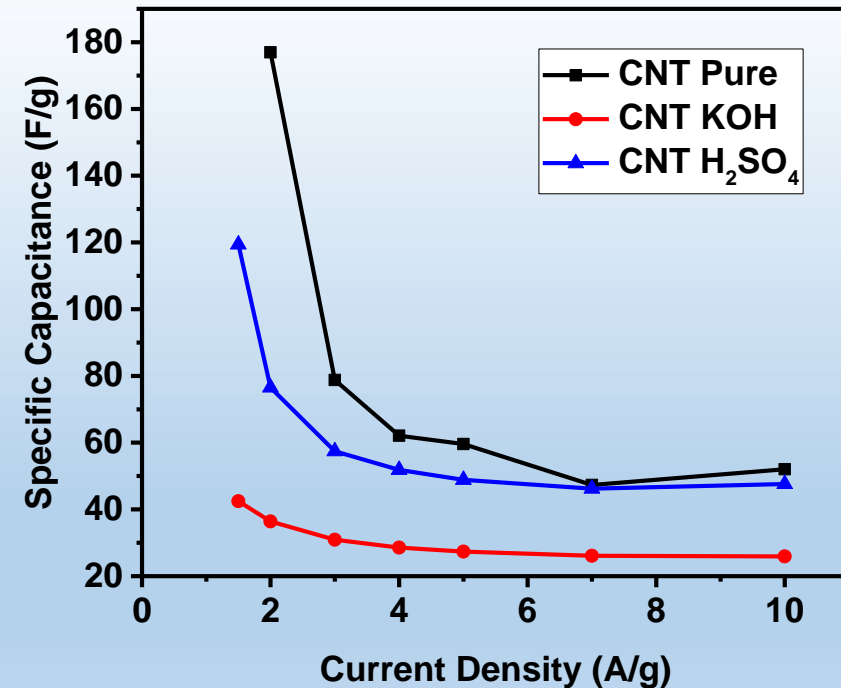
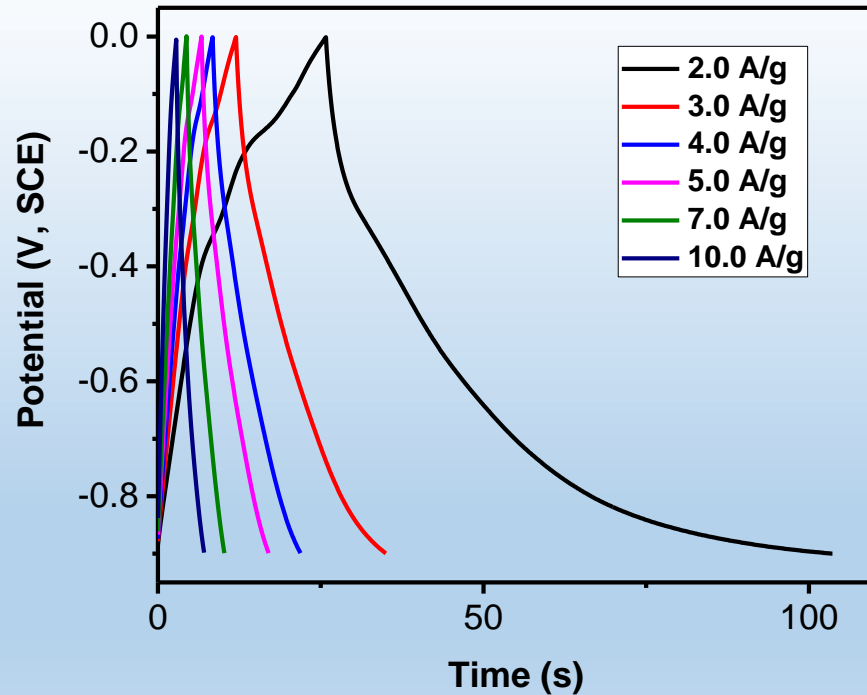
- $C_{sp} = \frac{I \times \Delta t}{\Delta V \times m}$
- Specific Capacitance decreases with increasing current densities
  - Insufficient time for electrolyte to diffuse into pores





# Galvanostatic Charge-Discharge (Negative Potential)

- Symmetrical and linear curves at high current densities
  - Suggests the stability of the electrode
- Specific capacitance decreased with increasing current densities



# Summary

- Pure carbon nanotube had the highest specific capacitance of 769 F/g at 2 mV/s
- The reduced capacitance of the sulfuric acid and KOH treated samples was likely due to the creation of functional groups that would increase resistivity
- Carbon nanotubes are still a promising material for supercapacitors given their relatively high surface area and crystalline graphitic structure