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Hydrothermal Synthesis and Electrochemical Examination of Nanostructured Cobalt Sulfide for High Performance Energy Storage Devices

Samiyah Aloqayli
Pittsburg State University

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S. Aloqayli, C. Ranaweera, Ram K. Gupta

Department of Chemistry, Pittsburg State University

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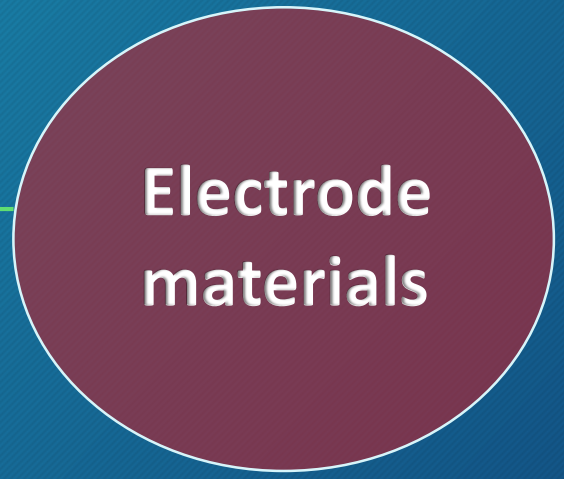
The importance of energy

- Energy, electricity, is a fundamental input in the modern world
- Energy has become a main focus of science and worldwide as a response to growing environmental concerns
- Energy demand will increase significantly in the future due to increase use of electronic devices

Materials for energy storage applications



Metal sulfide

- Richer redox chemistry
- Better electrical conductivity

Metal oxide

- Redox chemistry
- Controlled size and shape

The objective of the research

The main objective of the research is to synthesis nanostructured materials based on oxide and sulfide and compare their electrochemical properties, and then fabricate high performance energy storage devices which could be flexible as well as operate at high temperatures.

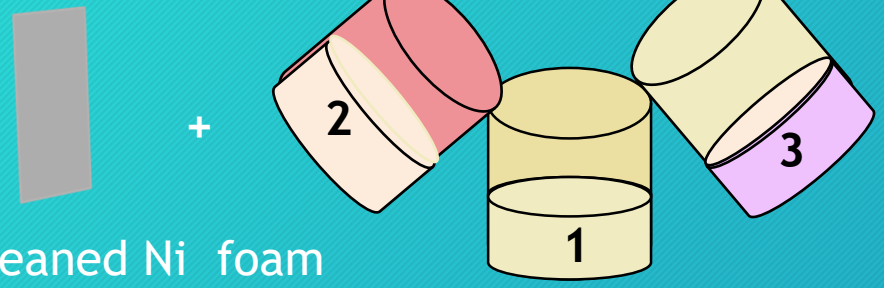
The research was carried out in two phases

The electrochemical performance evaluation of electrode materials:

- Cobalt oxide Co_3O_4
- Cobalt sulfide Co_9S_8

The fabrication and testing of the device using two **Co_9S_8** based electrodes.

Synthesis of cobalt oxide nanostructures



Cleaned Ni foam

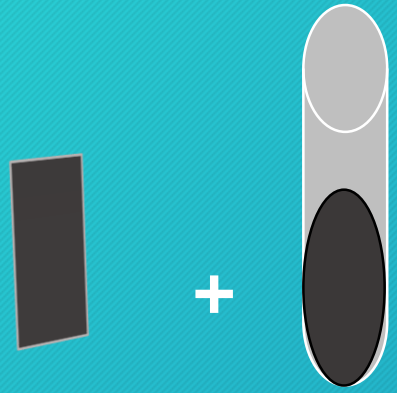
Help of bath sonication for 10 min

1+2+3

Transferred

Autoclave

Heating to 140 °C for 12 h

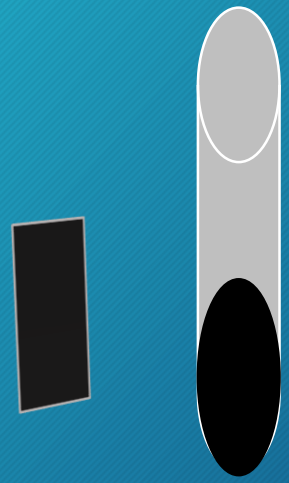


Washing with DI water and ethanol

Filtration + washing multi times.

Drying at 60 °C for 8 h in air

Following heating at 350 °C for 3 h.



(1) 3 millimoles of $Co(NO_3)_2 \cdot 6H_2O$ + 8 ml of DI water/ ethanol.

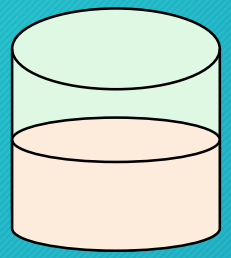
(2) 300 mg of PVP+ 10 ml DI water/ ethanol.

(3) 12 millimoles of urea +18 ml DI water /ethanol.

Synthesis of cobalt sulfide nanostructures

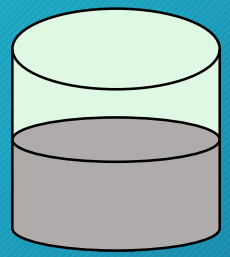
The synthesized cobalt oxide

+



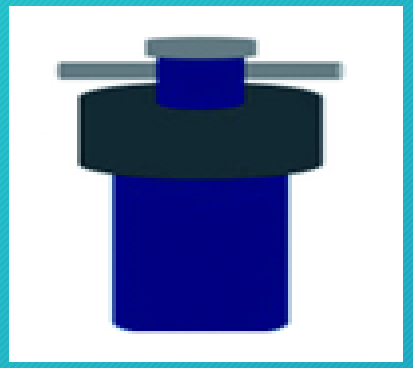
30 ml of 0.2M Na_2S solution

immersing



+

Transferring



Autoclave

Heating to 140 °C

for 24 h

washing with DI water and alcohol.

drying in vacuum at 60 °C

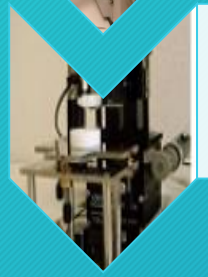
for 6 h.

Characterizations

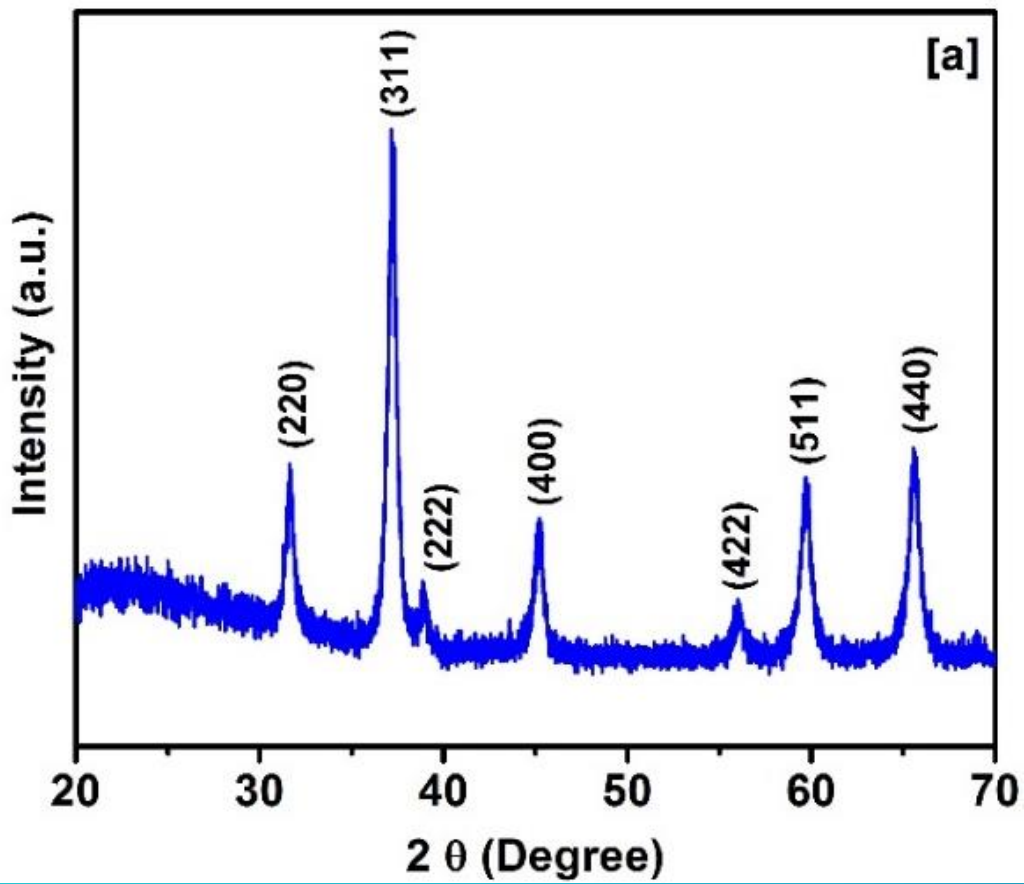
- X-ray diffraction

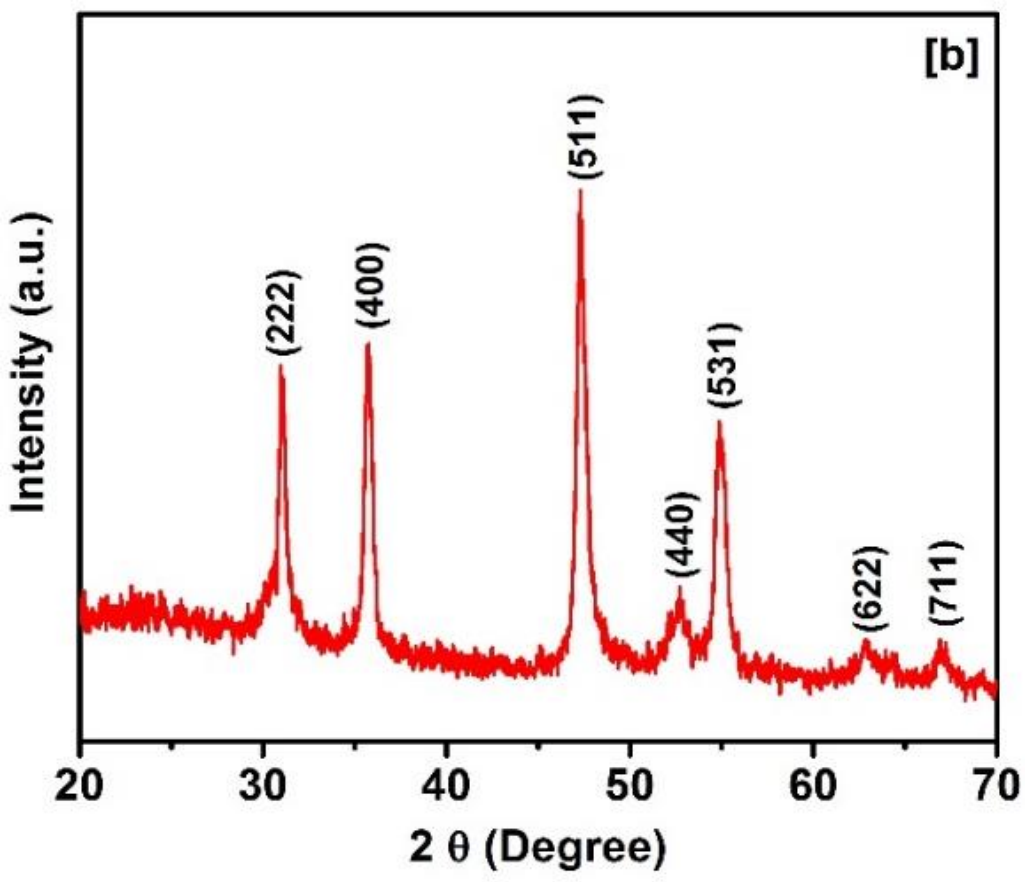
- Scanning electron microscopy

- Energy-dispersive X-ray spectrometer

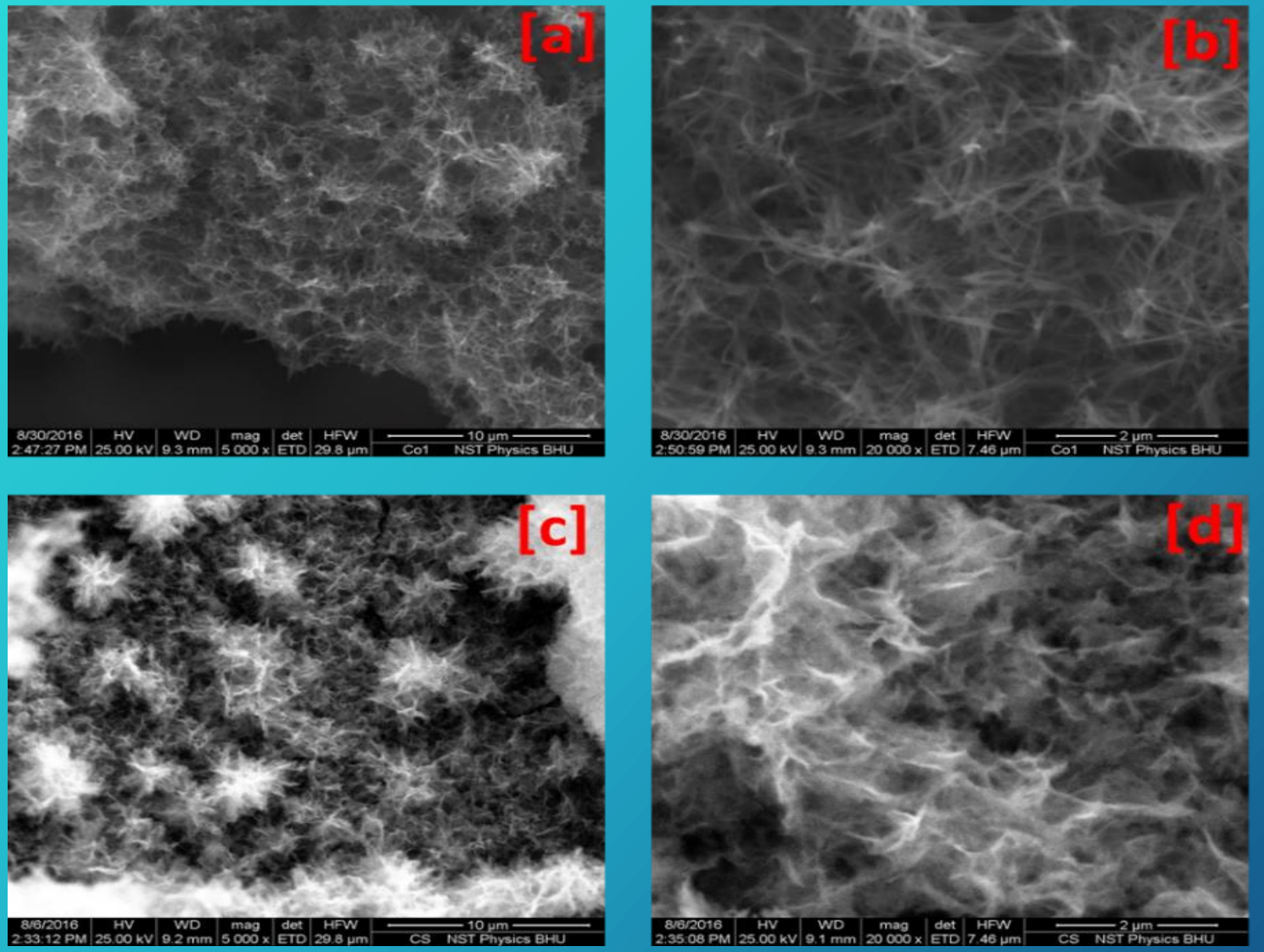


- Electrochemical techniques

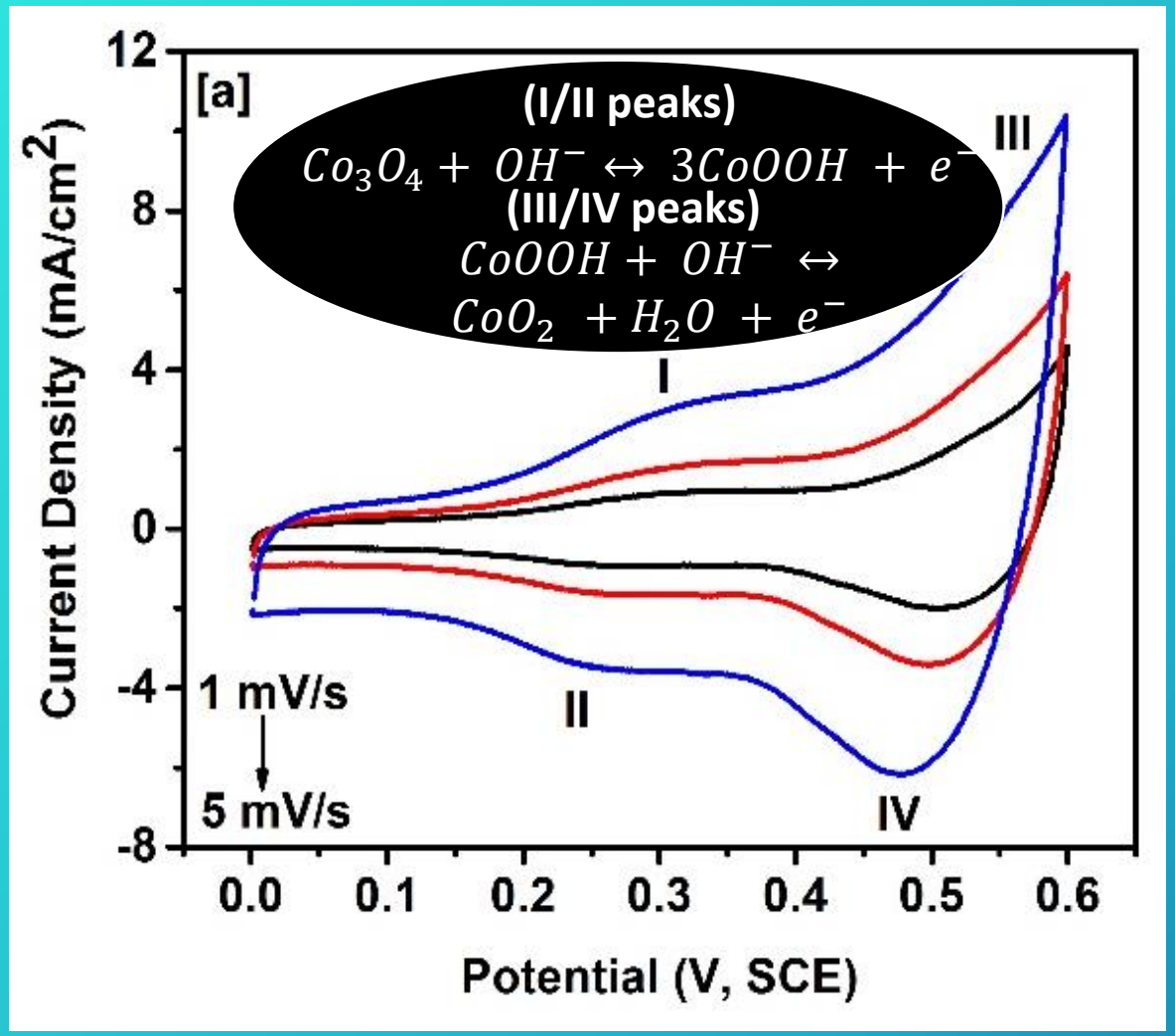


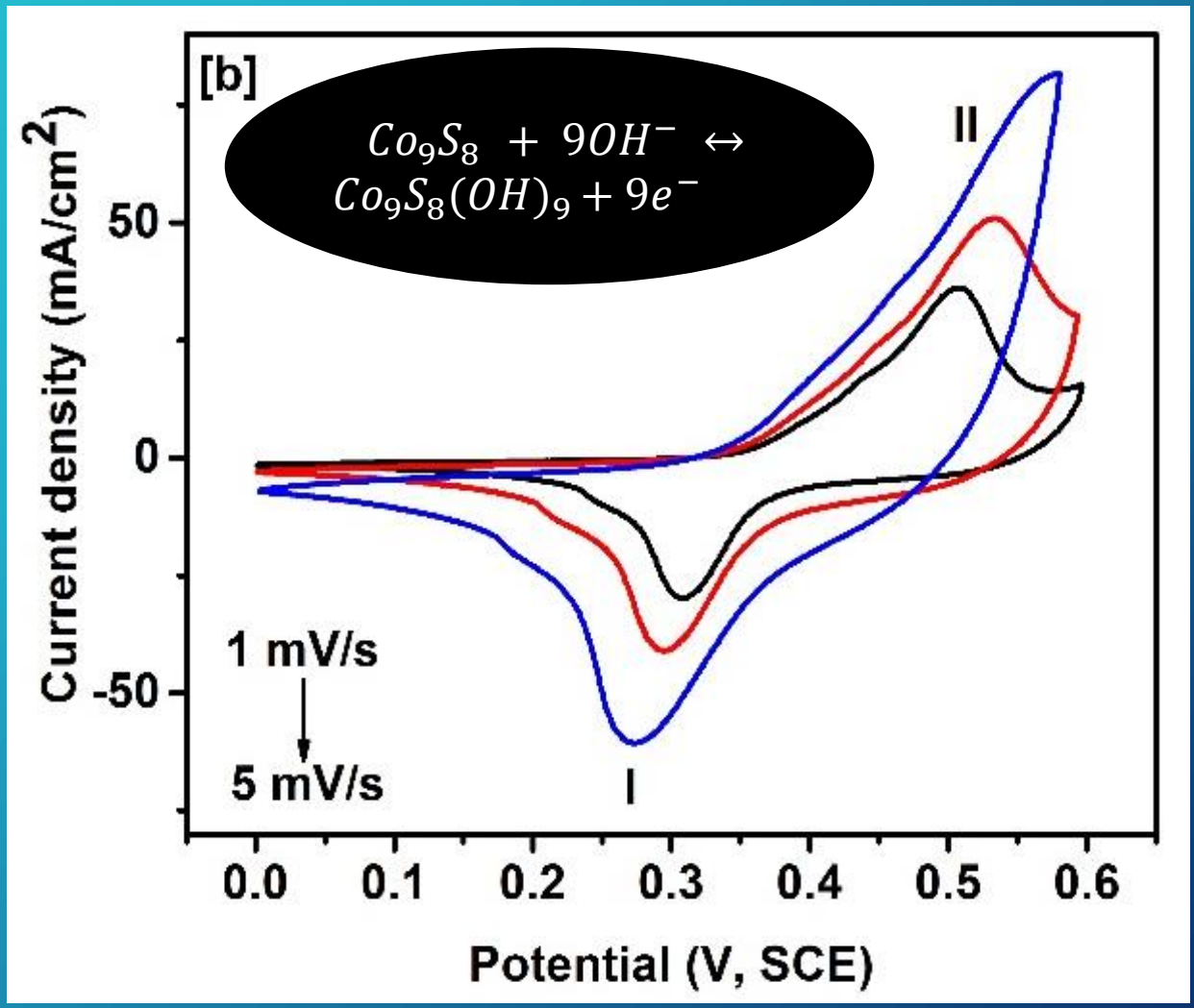


XRD patterns of (a) cobalt oxide (Co_3O_4) and (b) cobalt sulfide (Co_9S_8).



SEM images of Co_3O_4 (a,b) and Co_9S_8 (c,d) at various magnifications.

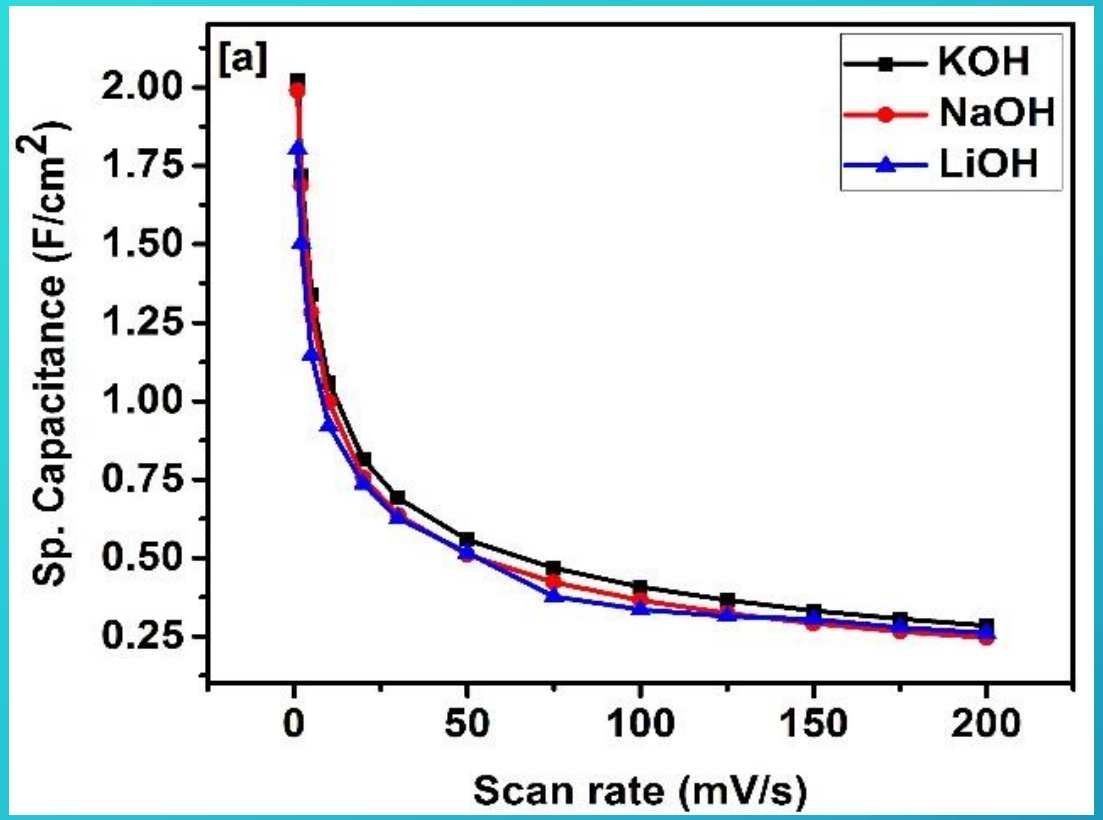


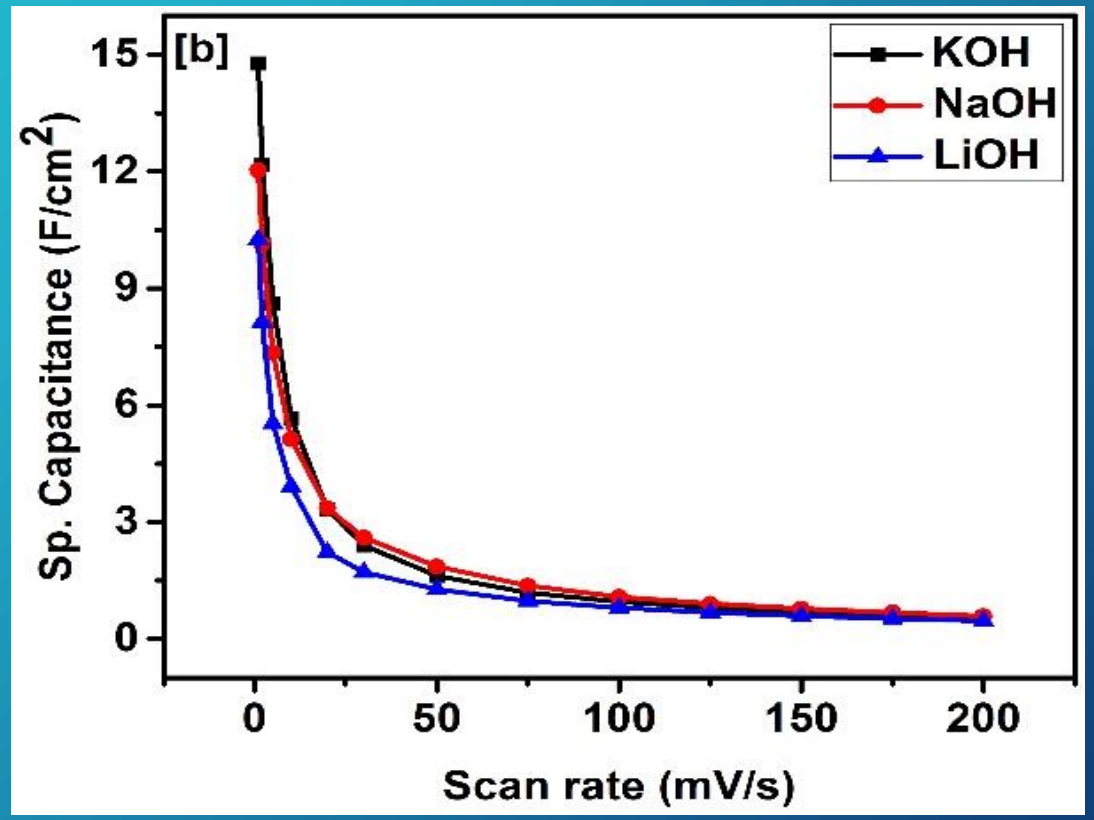


CV curves of (a) Co_3O_4 and (b) Co_9S_8 at various scan rates in 3M KOH electrolyte.

❖ **The specific capacitance calculated by using data from CV measurements :**

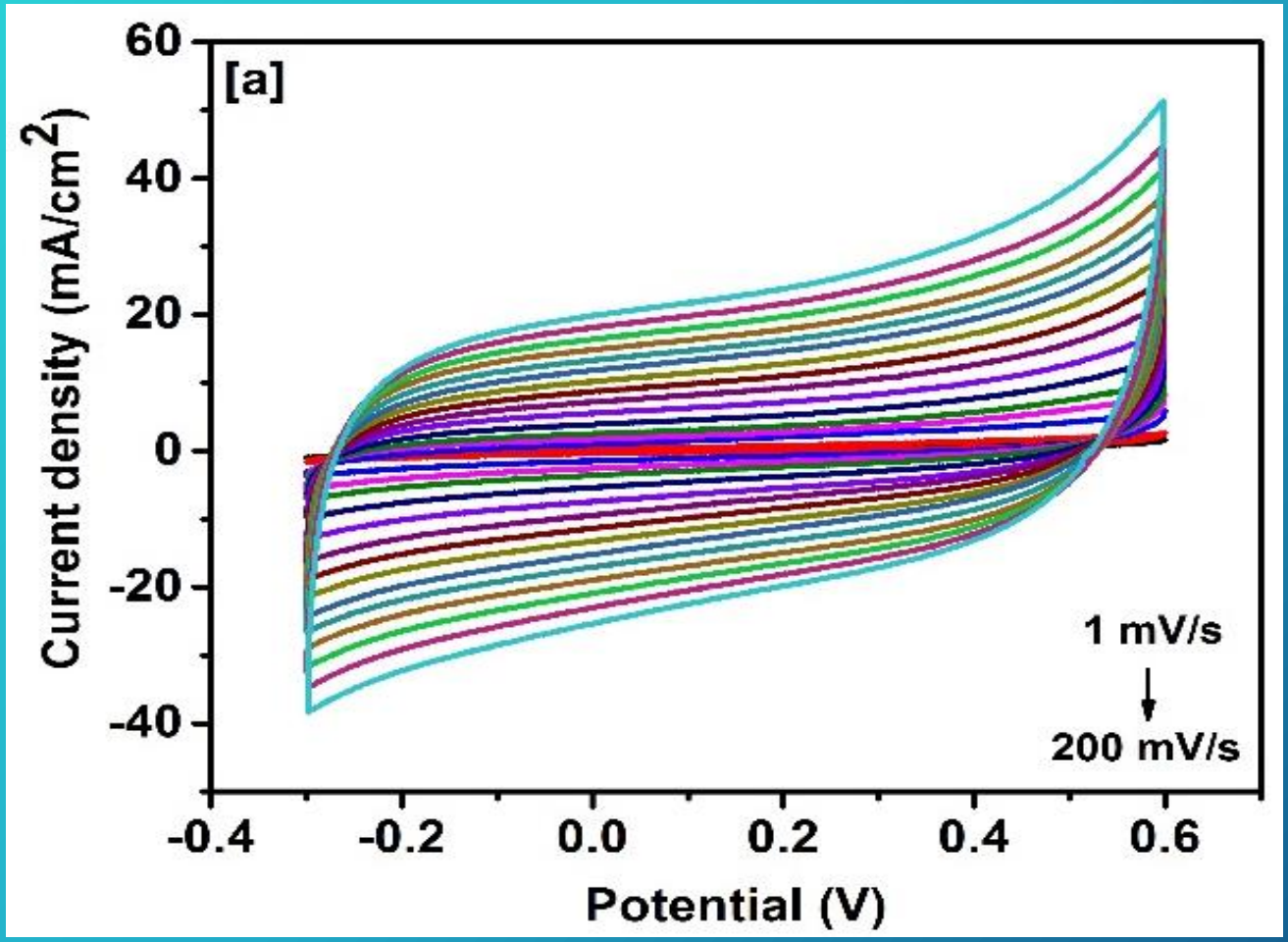
$$C_{sp} = \frac{Q}{\Delta V \times \left(\frac{\partial v}{\partial t}\right) \times A}$$





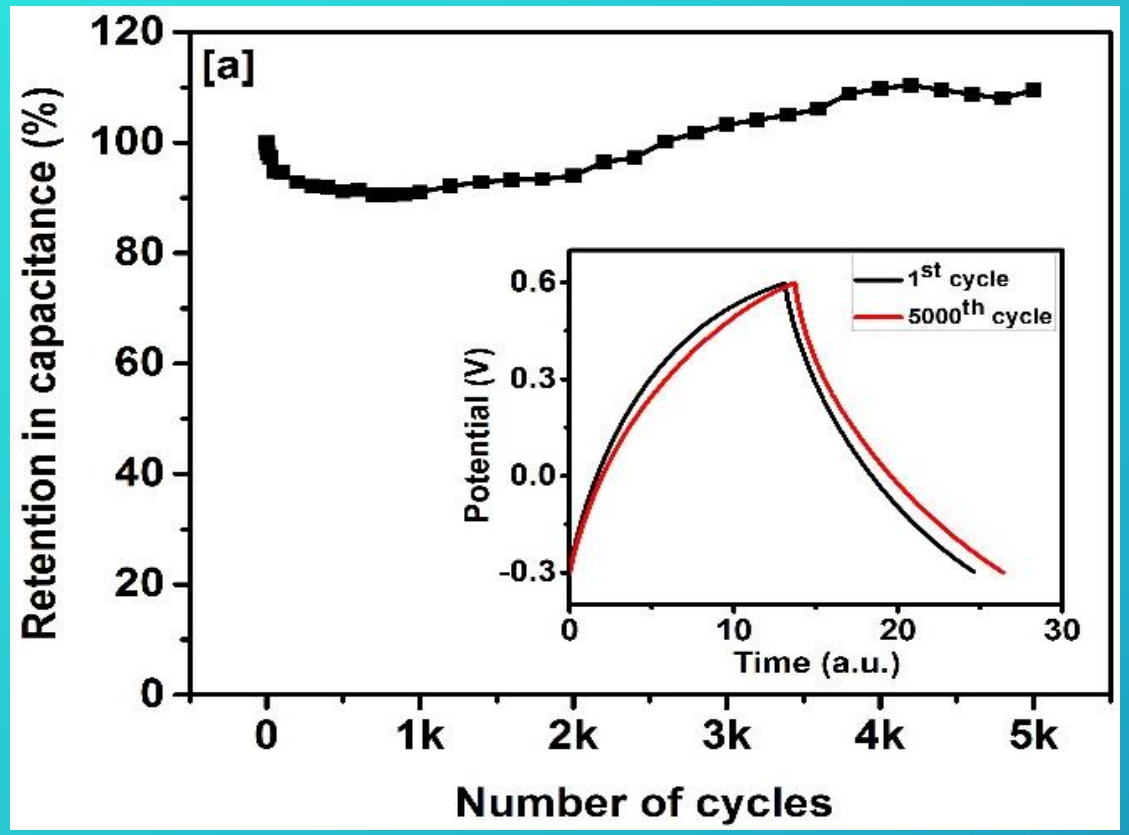
Effect of scan rate on specific capacitance of (a) Co_3O_4 and (b) Co_9S_8 in various electrolytes.

Cyclic voltammetry of the device

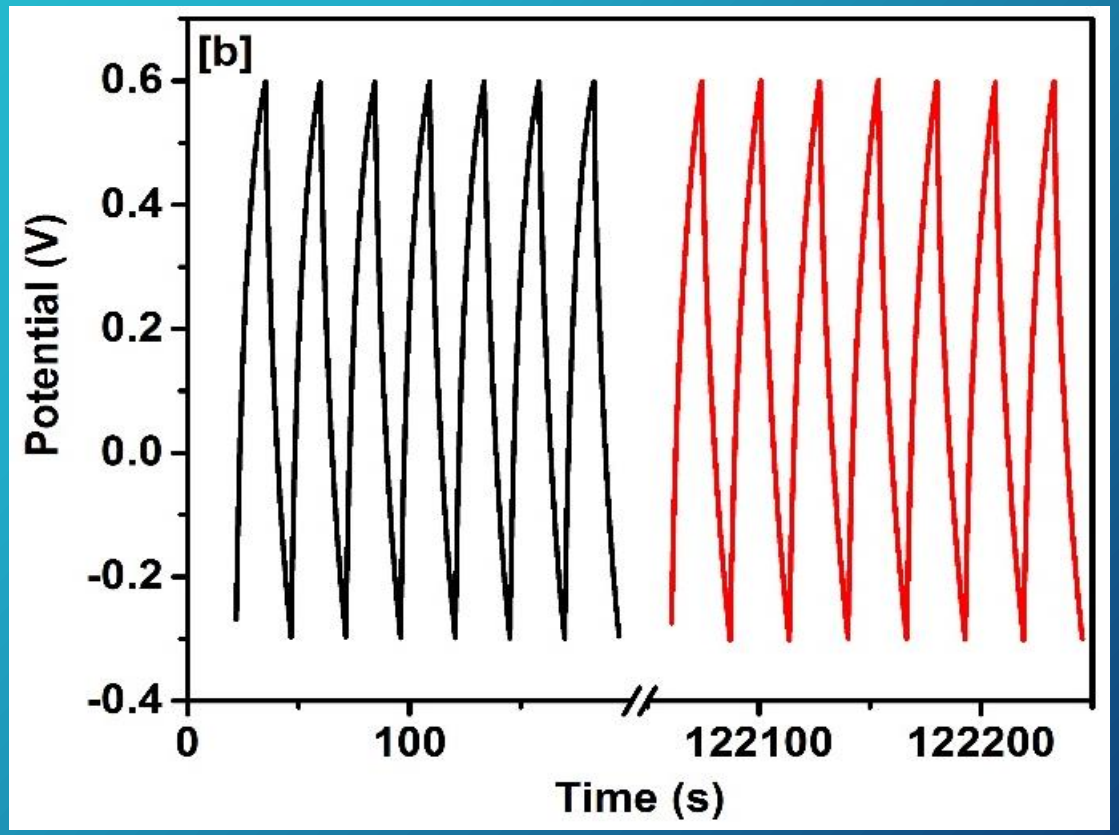


Cyclic voltammograms of the device at room temperature in various scan rates.

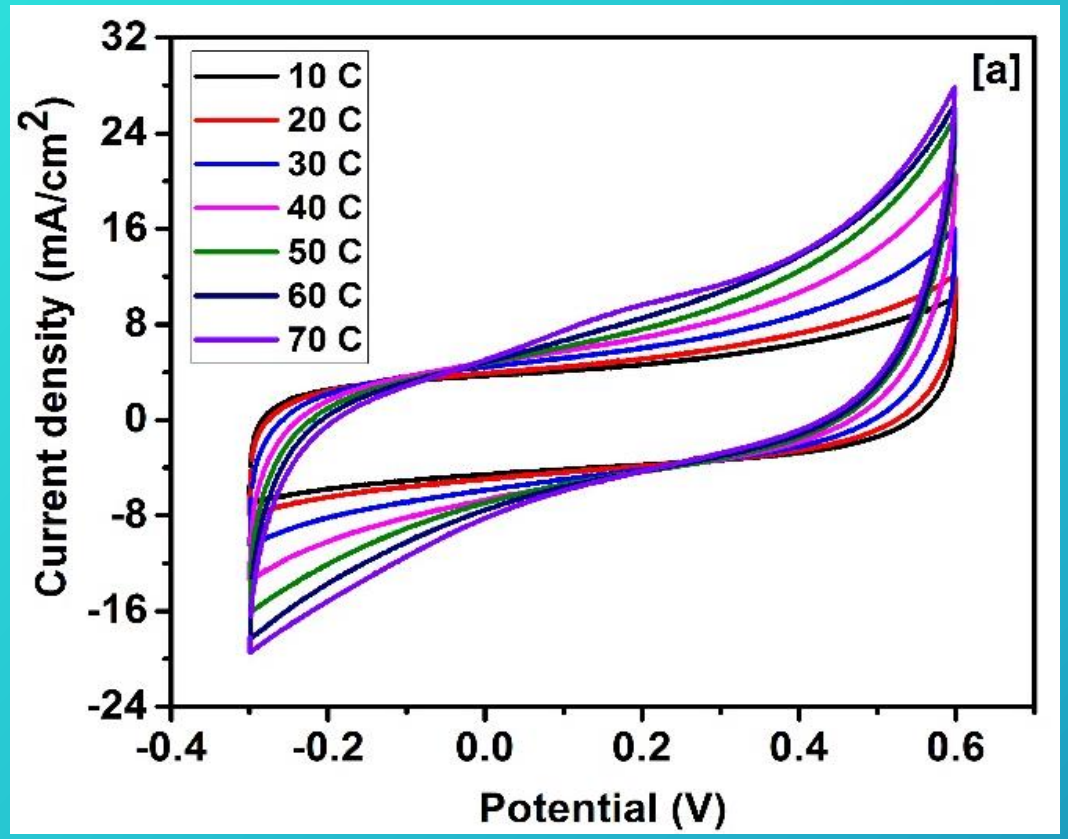
Stability Test



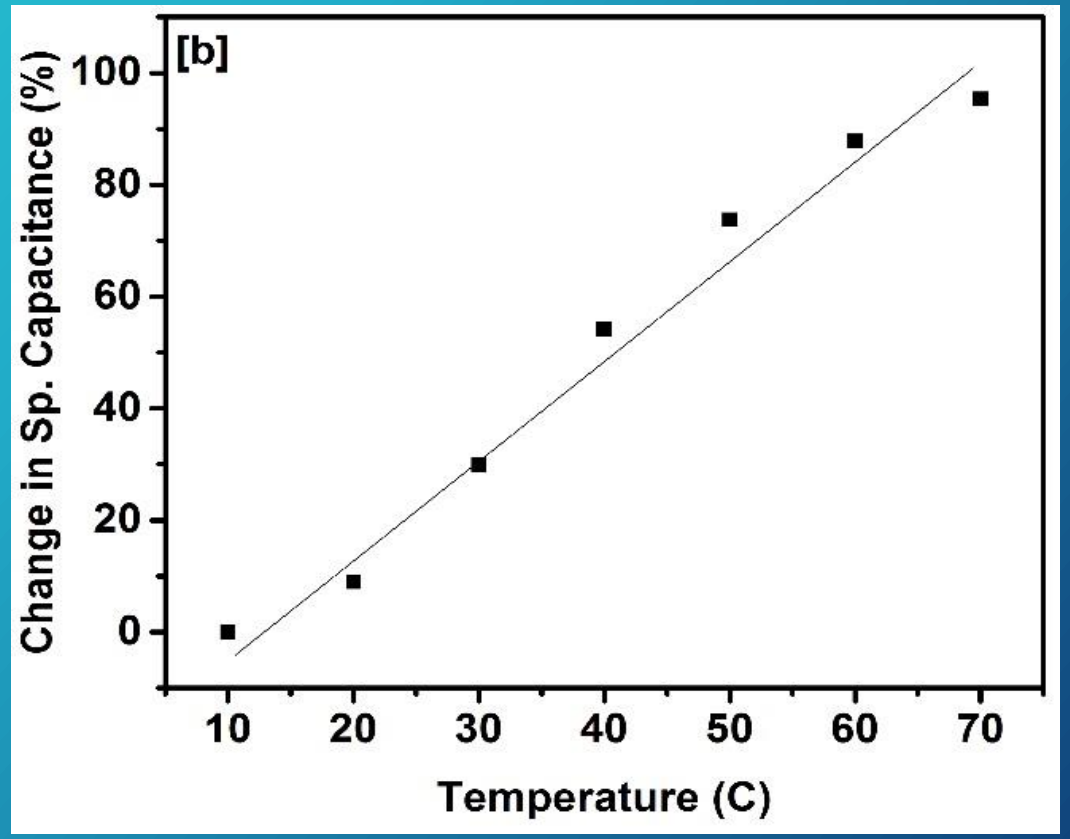
Capacitance retention versus number of charge-discharge cycles for the device (inset figure-potential vs. time plot for 1st and 5000th cycle of charge discharge).



First few and last few cycles of charge discharge profile of the device.



Cyclic voltammograms of the device at various temperatures.



% change in specific capacitance of the device versus temperatures.

CONCLUSION

- Phase pure Co_8S_9 was synthesized from Co_3O_4 using hydrothermal method.
- Cobalt oxide and cobalt sulfide showed specific capacitance of 983 and 7358 mF/cm^2 at 2 mA/cm^2, respectively with outstanding flexibility and stability.
- About 100% improvement in the charge storage capacity of the device was observed by increasing temperature from 10 to 70 ^oC.
- Our results suggest that cobalt sulfide could be used as an appropriate material for flexible energy storage devices.