Battery Basics

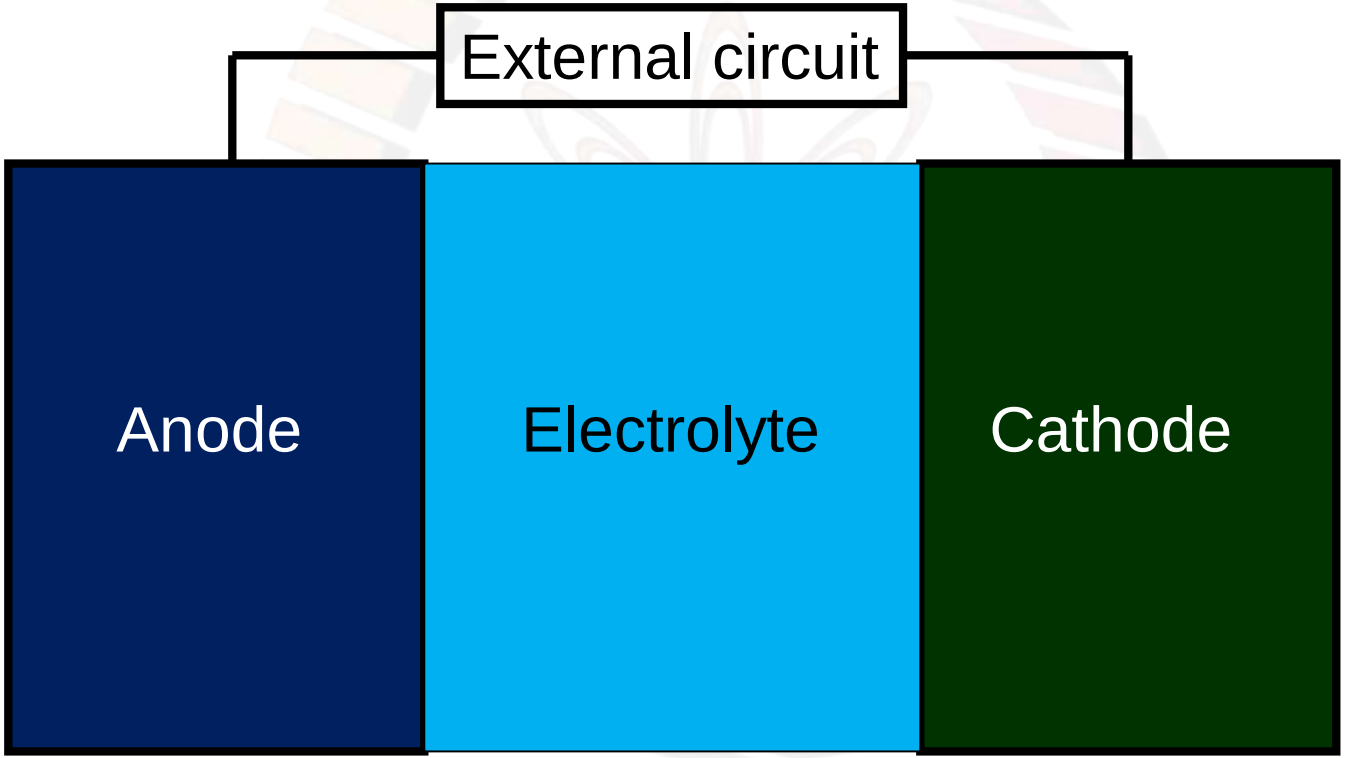
Learning Objectives

1) To state the various parts of the battery and their functions
2) To indicate the use of the electrochemical series
3) To distinguish between primary and secondary batteries
4) To indicate the meaning of terms used in the context of battery technology

- Electrochemical Device
  - Electrode phase
  - Electrolyte phase
  - Charge Transfer

- Energy Storage device

Electrochemical Device



Anode	**Oxidation**	**Loss of electrons**
Cathode	**Reduction**	**Gain of electrons**

The Electrochemical Cell

Standard Electrochemical Series

	Standard Electrode Potential
$Au^{3+} + 3e^- \rightarrow Au$	$+ 1.420\ V$
$Pt^{2+} + 2e^- \rightarrow Pt$	$+ 1.200\ V$
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	$+ 1.229\ V$
$Ag^+ + e^- \rightarrow Ag$	$+ 0.800\ V$
$Cu^{2+} + 2e^- \rightarrow Cu$	$+ 0.340\ V$
$2H^+ + 2e^- \rightarrow H_2$	$0.000\ V$
$Pb^{2+} + 2e^- \rightarrow Pb$	$- 0.126\ V$
$Ni^{2+} + 2e^- \rightarrow Ni$	$- 0.250\ V$
$Cd^{2+} + 2e^- \rightarrow Cd$	$- 0.403\ V$
$Zn^{2+} + 2e^- \rightarrow Zn$	$- 0.763\ V$
$Li^+ + e^- \rightarrow Li$	$- 3.401\ V$

Energy Storage Device:

Fuel and oxidant are stored within the device.

Energy Conversion Device:

Fuel and oxidant are stored external to the device

Cell:

A single electrochemical unit; i.e. one anode, one cathode, and the electrolyte

Battery:

A collection of cells in series or parallel

Primary Cell:

Single use power source

Secondary Cell:

Can be recharged

Thermodynamics

Thermodynamics Cell Voltage

Thermodynamics Cell Voltage

Kinetics

Thermodynamics

Kinetics

Cell Voltage

Cell Current

Cell characteristics:

Capacity: Total charge in cell
Coulombs or Ah

Voltage

Current

Power = V * I
Watts

Time

Energy: Power * Time
Joules or Wh

Conclusions

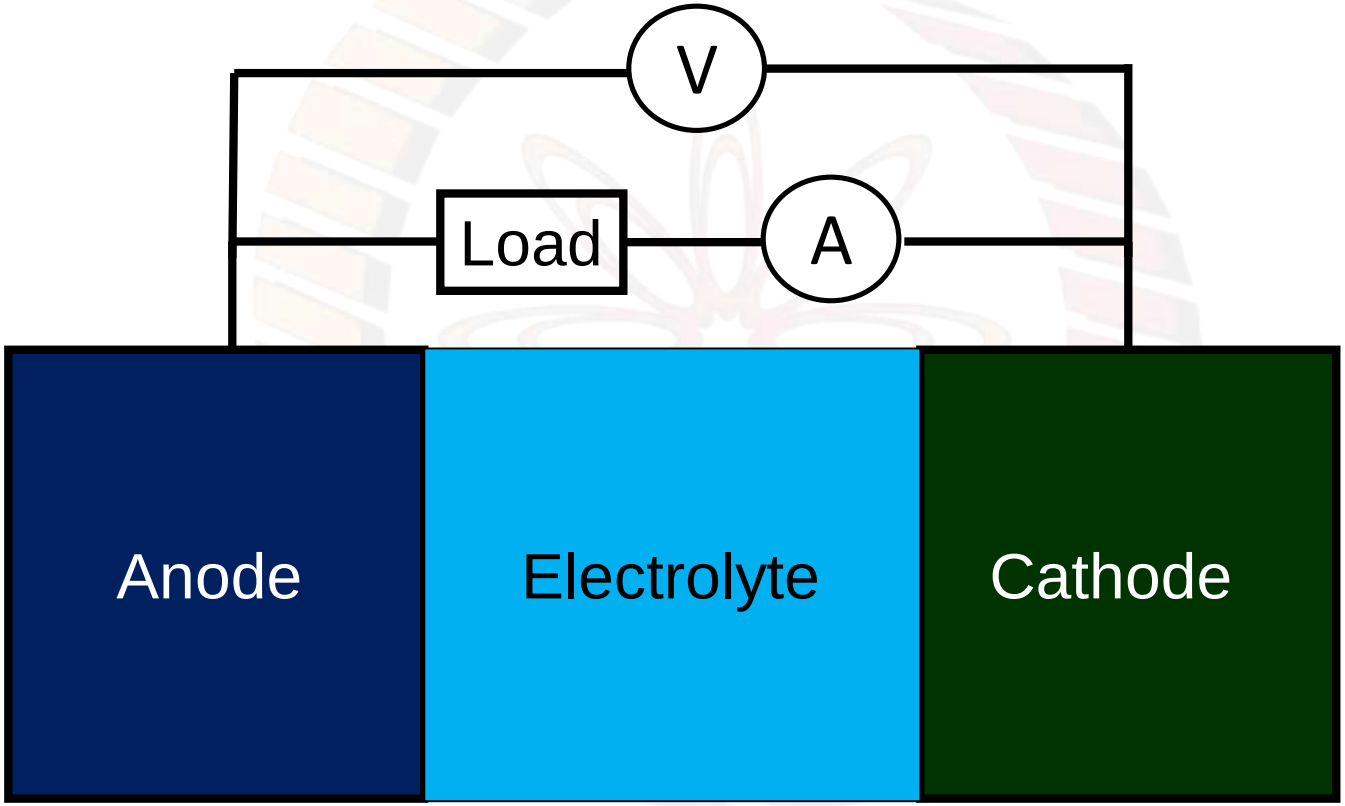
1) Batteries have specific parts that can have dramatically opposite functions
2) The electrochemical series is the starting point to understand Battery voltages
3) Primary and secondary batteries are both commonly used

Battery Testing and Performance

Learning Objectives

1) To draw a schematic of the typical battery test process
2) To indicate the significance of C-Rate
3) To be familiar with the typical discharge and charge curves
4) To indicate the effect of the C-Rate on the charge-discharge curve
5) To indicate the significance of the polarization curve

Battery Testing



The C-Rate

The rate at which the battery is discharge or charged, relative to its capacity

The C-Rate

The rate at which the battery is discharge or charged, relative to its capacity

1 C Rate => Discharge or Charge in 1 hour
2 C Rate => Discharge or Charge in ½ hour
5 C Rate => Discharge or Charge in 12 minutes

0.1 C Rate => Discharge or Charge in 10 hours

Terminology associated with use

State of charge: % of maximum capacity that is remaining unused

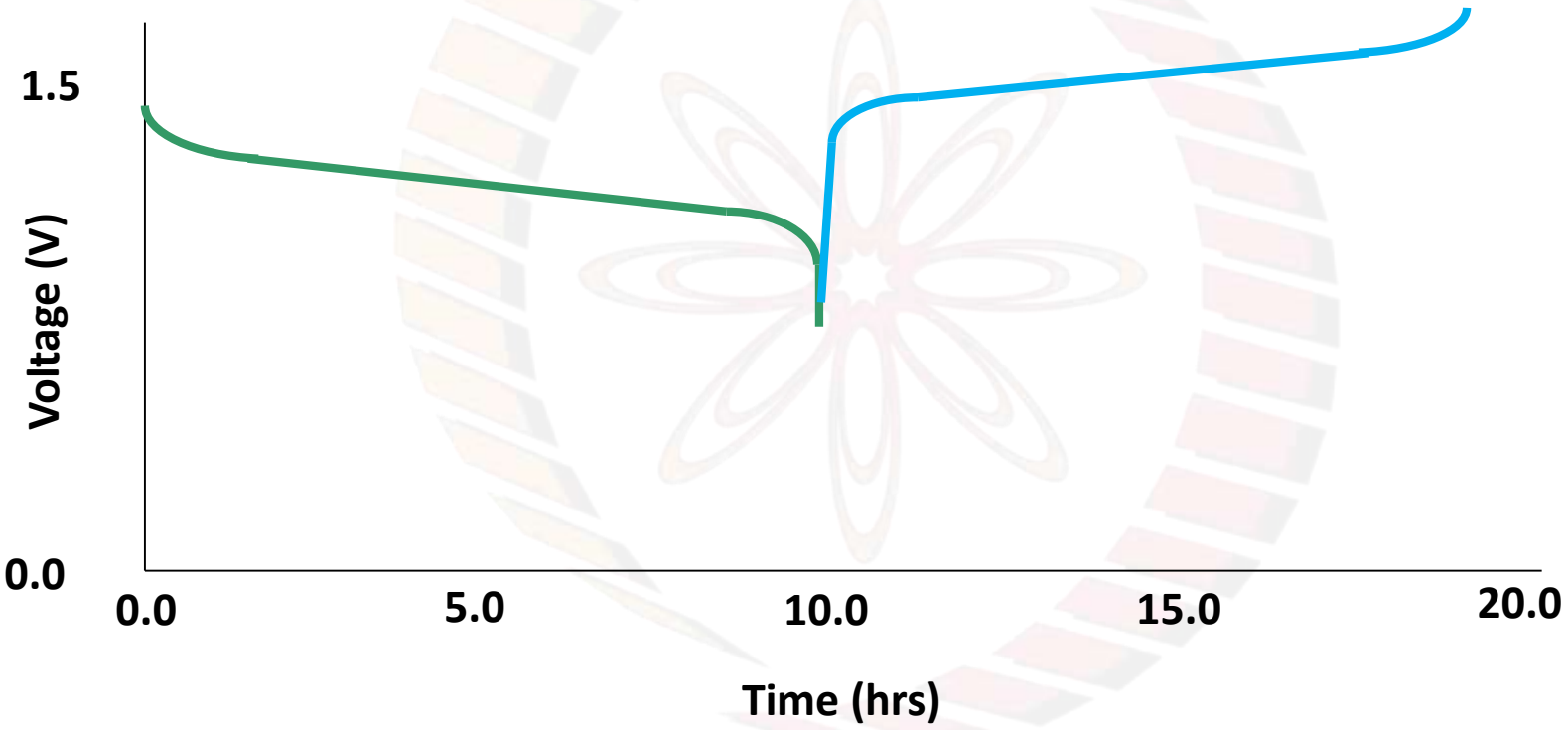
Depth of Discharge: % of maximum capacity that has been discharged

Cycle life: Number of cycles before the battery fails to meet performance specifications. Affected by Depth of Discharge

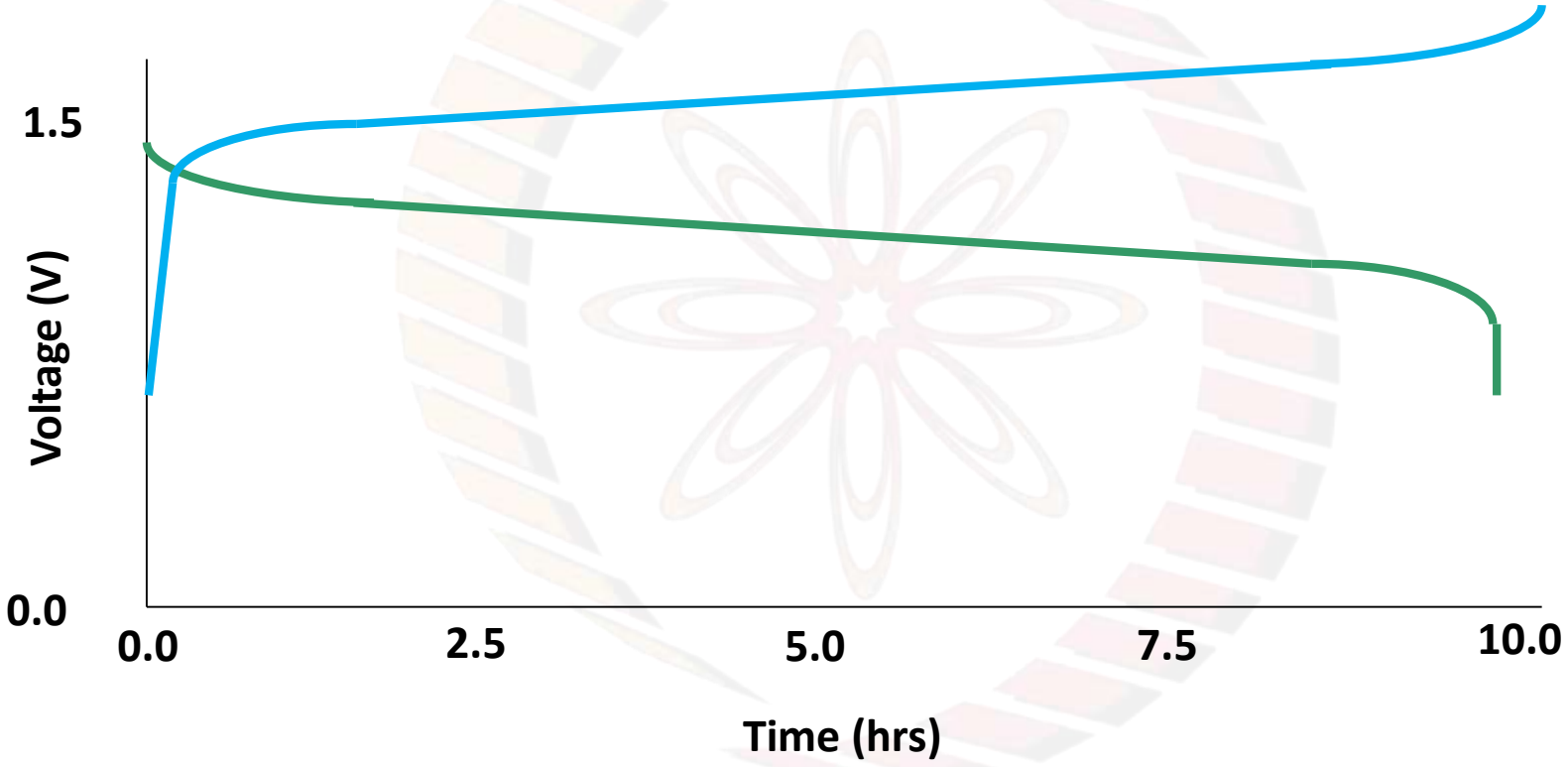
Discharge – Charge curves

Discharge – Charge curves

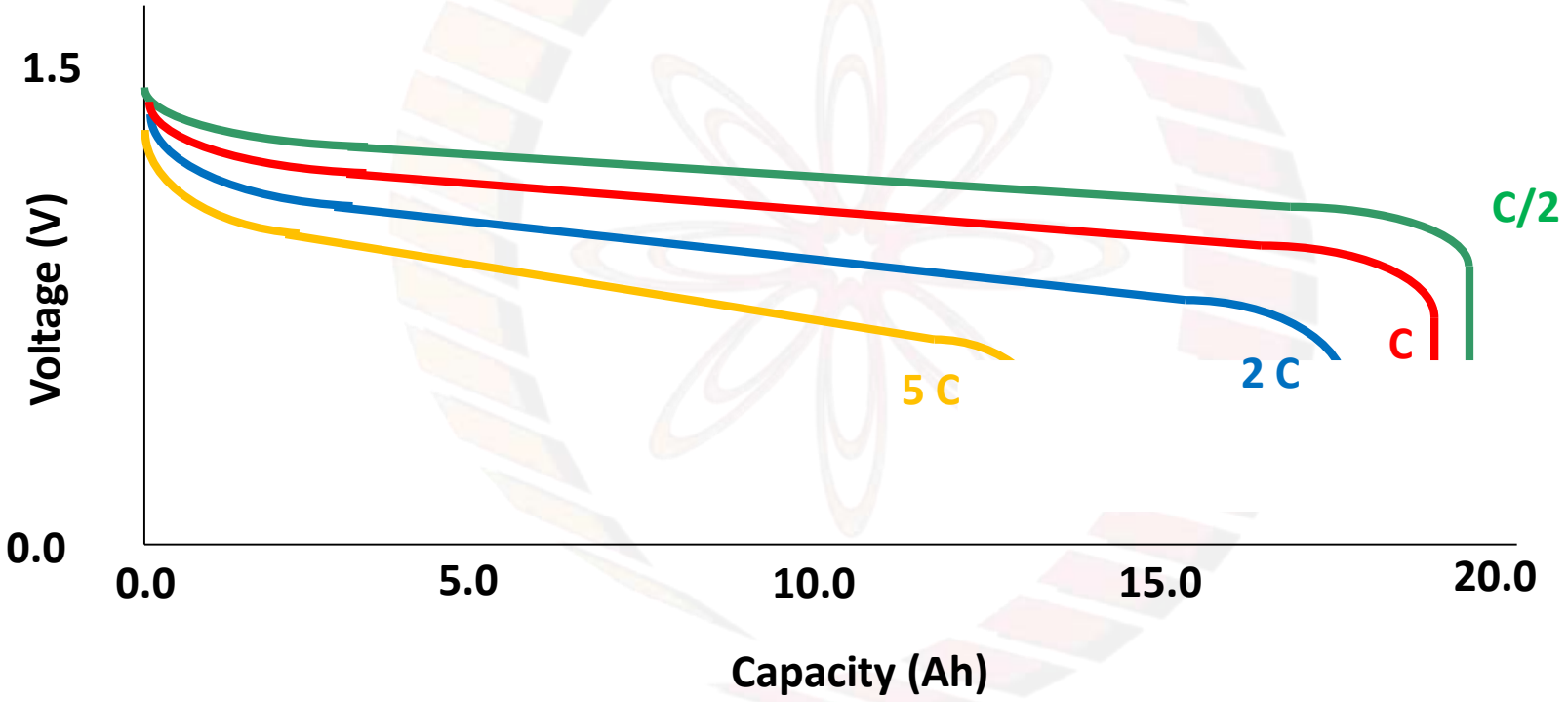
Discharge – Charge curves



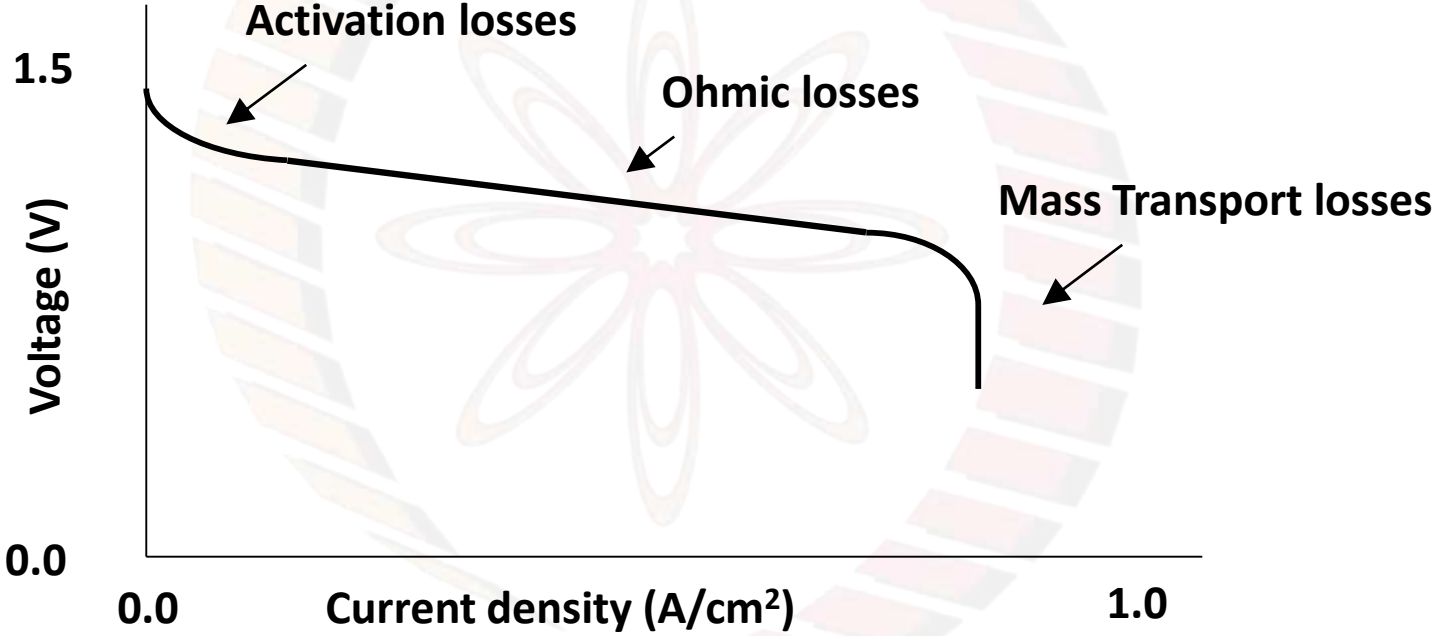
Discharge – Charge curves

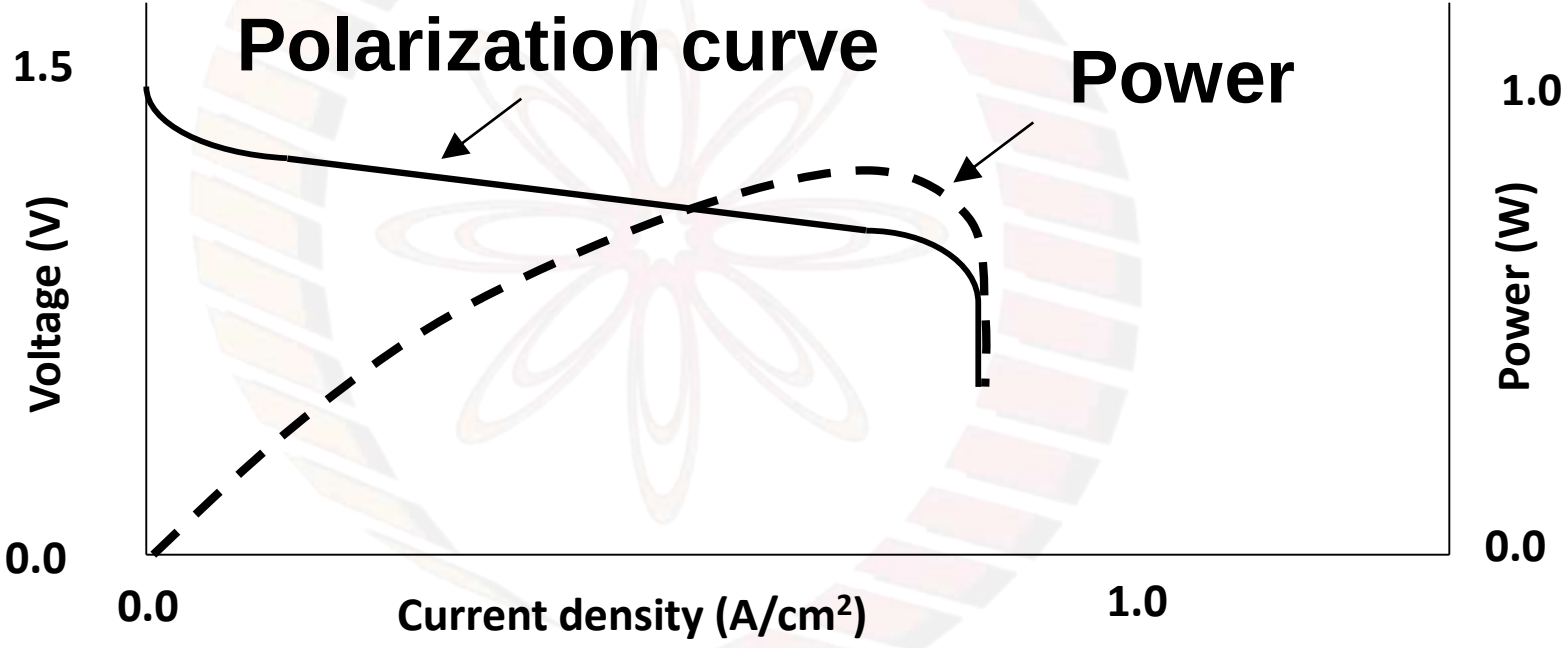


Effect of C-Rate on Discharge

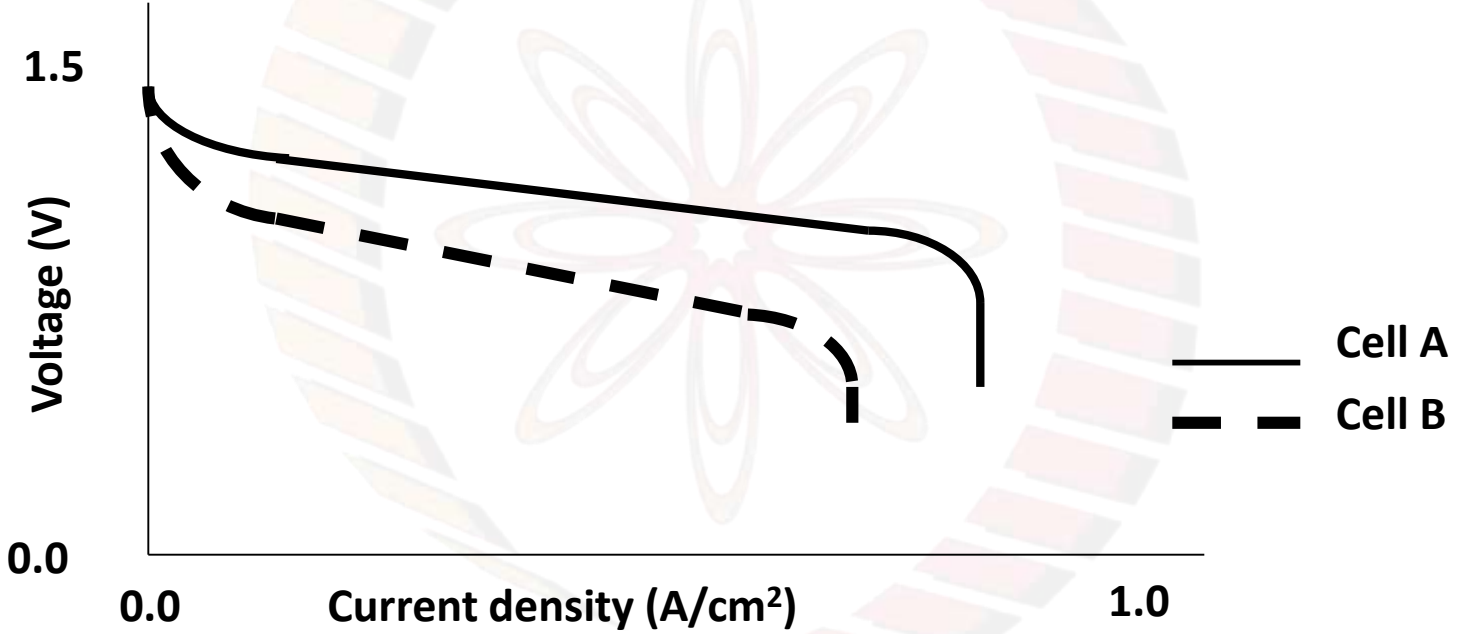


Polarization curve




Polarization curve
Power
1.5
0.0
Voltage (V)
1.0
0.0
Power (W)
0.0
Current density (A/cm²)
1.0

A comparison between two cells



Conclusions

1) C-Rate indicates the rate at which the battery is being charged or discharged relative to its capacity
2) Charge – discharge curves typically show steady performance of the batteries excepting close to the fully charged and fully discharged conditions
3) The polarization curve enables comparison between batteries from the perspective of power delivery

Common Battery Types

Different battery structures

Prismatic cell

Lithium ion Batteries