An introduction to Batteries

N. Murer

Outline

1. Definition and principles

2. Technology

1. Characteristics

Outline

1. **Definition and principles**

2. Technology

1. Characteristics

Definition

An electrical battery is one or more electrochemical cells that convert stored chemical energy into electrical energy (= current).

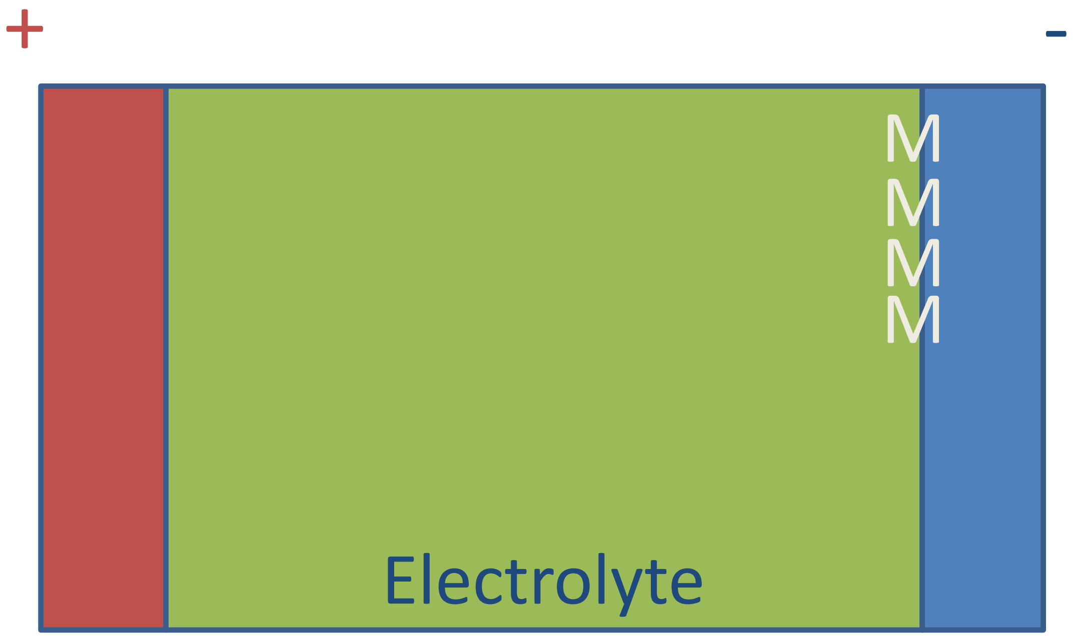
Primary batteries : cannot be recharged.

Secondary batteries : rechargeable batteries that involve reversible reactions (backward and forward)

How it works

Example of a Li-ion battery

1. Initial state (charged) : $E_{cell} = E_{OC}$

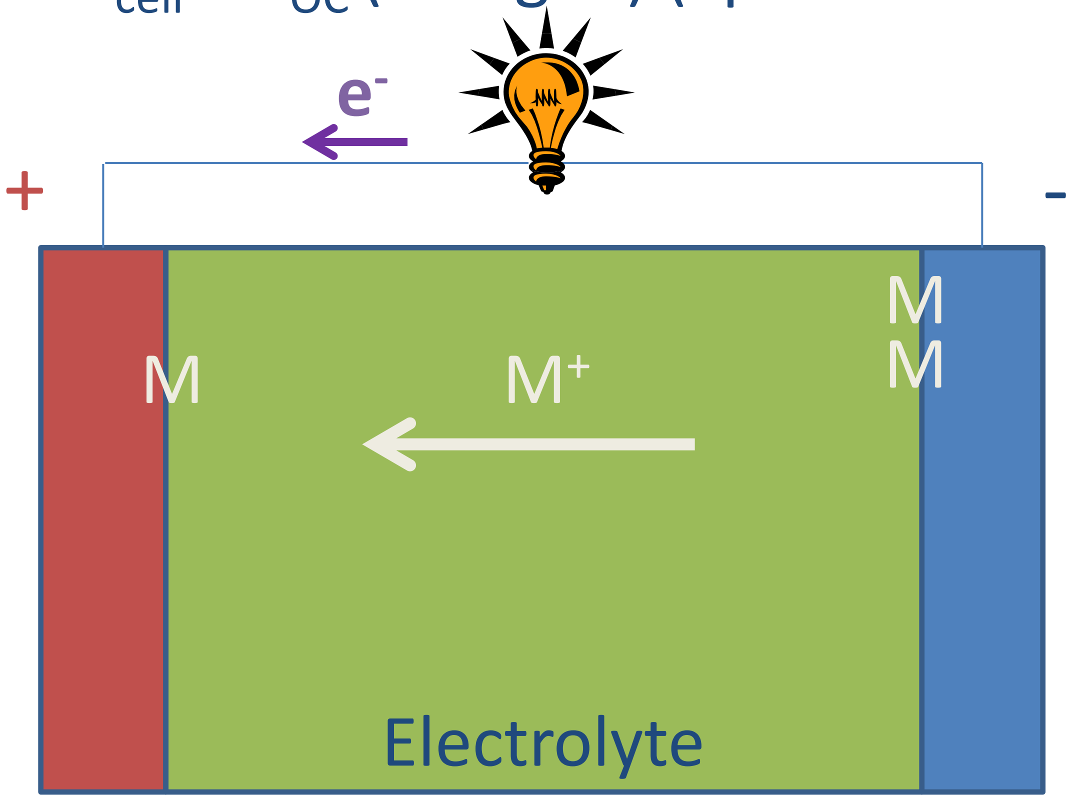


E_{cell} = Cell voltage = potential difference between the positive electrode and the negative electrode.

How it works

Example of a Li-ion battery

2. Discharge : $E_{cell} < E_{OC}$ (charged) (Spontaneous reactions)



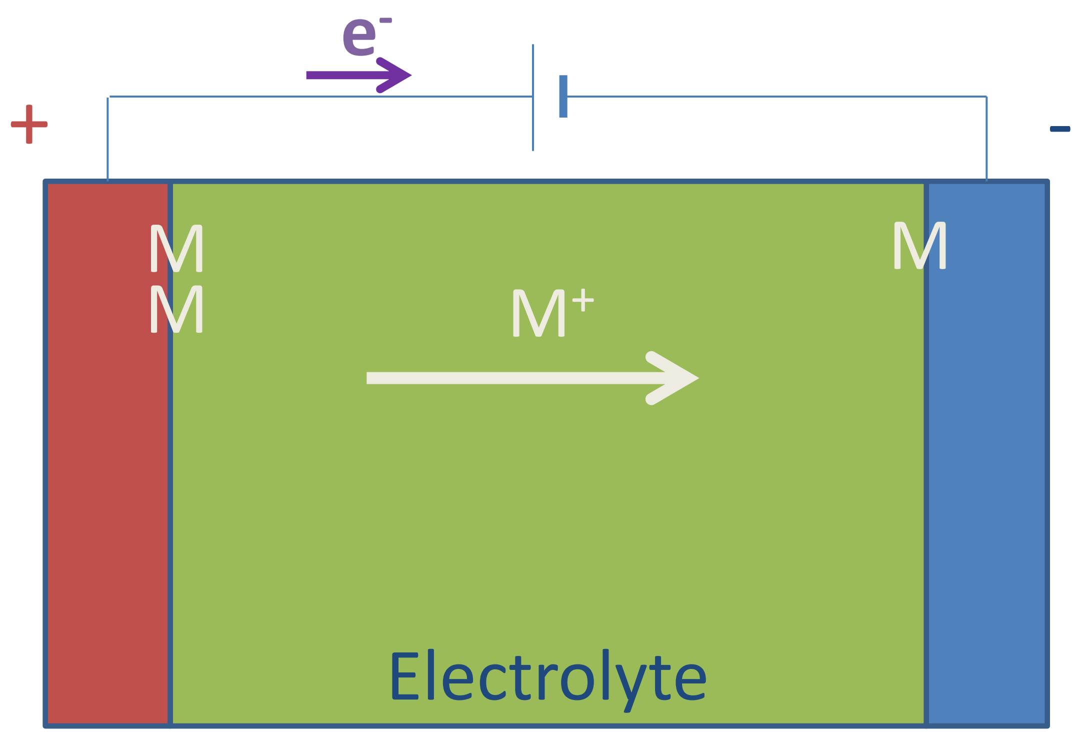
Cathode/Reduction
(Insertion)

Anode/Oxidation
(Desinsertion)

How it works

Example of a Li-ion battery

3. Charge : $E_{cell} > E_{OC}$ (discharged) (Forced reactions)



Anode/Oxidation
(Desinsertion)

Cathode/Reduction
(Re-Insertion)

Outline

1. Definition and principles
2. **Technology**
3. Characteristics

Technology

Various materials are used for the positive and negative electrodes and the electrolyte

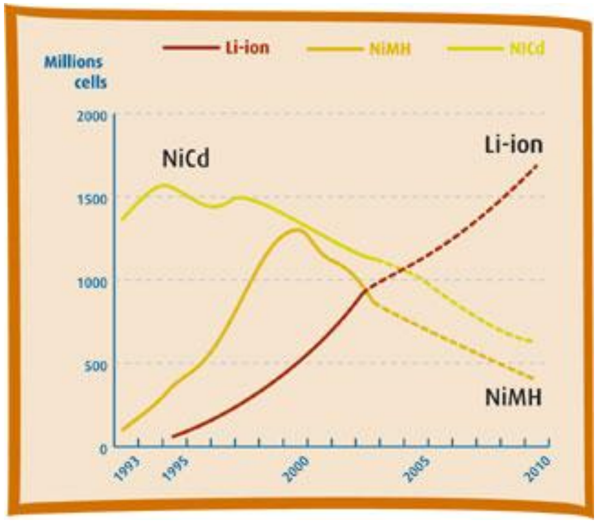
- Lead acid batteries (PbO_2-Pb)
- Alkaline batteries (Ni-MH and Ni-Cd)
- Lithium-ion batteries ($LiCoO_2$-, $LiMn_2O_4$-,$LiFePO_4$-C_6)
- Lithium Metal Polymer, Lithium-Air, …

Technology

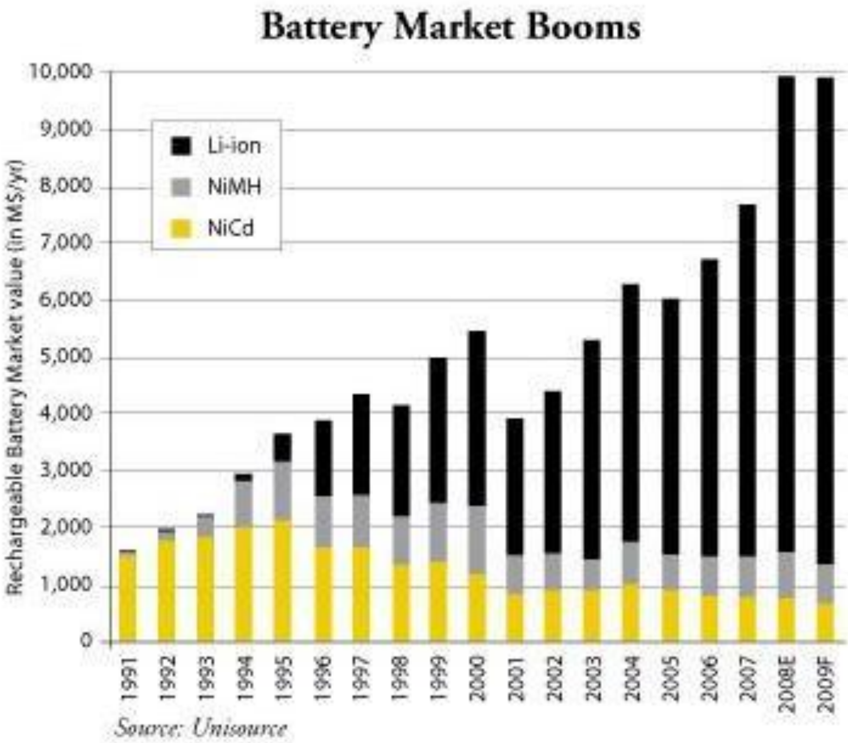
Name	Initial Charged State		After discharge		Electrolyte	Main application
	+	-	+	-		
Lead Acid	PbO_2	Pb	$PbSO_4$	$PbSO_4$	H_2SO_4	Automobile starter, PV
Nickel Cadmium	NiO(OH)	Cd	$Ni(OH)_2$	$Cd(OH)_2$	KOH	Electronics
Nickel-Metal Hydride	NiO(OH)	MH	$Ni(OH)_2$	M		
Li-ion	$Li_{1-x}CoO_2$	Li_xC_6	$LiCoO_2$	C_6	$LiPF_6$ in organic solvent	
	$Li_{1-x}FePO_4$	Li_xC_6	$LiFePO_4$	C_6		
Li-Metal	Li	$Li_xV_3O_8$	Li	V_2O_5	Polymer	Electronics, transportation

Technology

Lithium batteries represent now the largest share of the market



Source : www.umicore.com



Outline

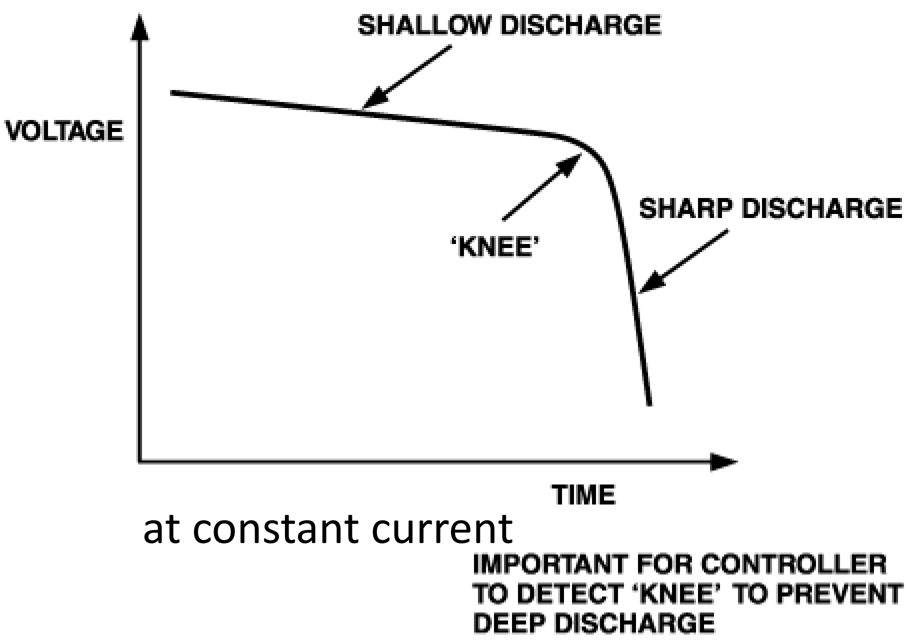
1. Definition and principles
2. Technology
3. **Characteristics**

Characteristics

Nominal Potential

constant potential value of the battery during the discharge in **V**

One cell voltage : Pb = 2 V, Ni-MH = 1.2 V, Li-ion = 3.6 V



at constant current

Deep discharge or deep charge can lead to potentially dangerous unwanted non-reversible reactions.
Ex : H_2 production for Ni-Cd battery.

Characteristics

Capacity

electrical charge that can be stored in a reversible way in **A.h**

1 mol of electrons (6.10^{23} e^-) = 1 Faraday = 96 500 C = 26.81 A.h

Energy = Voltage x Capacity in **W.h or V.A.h**

Power = Voltage x Current in **W**

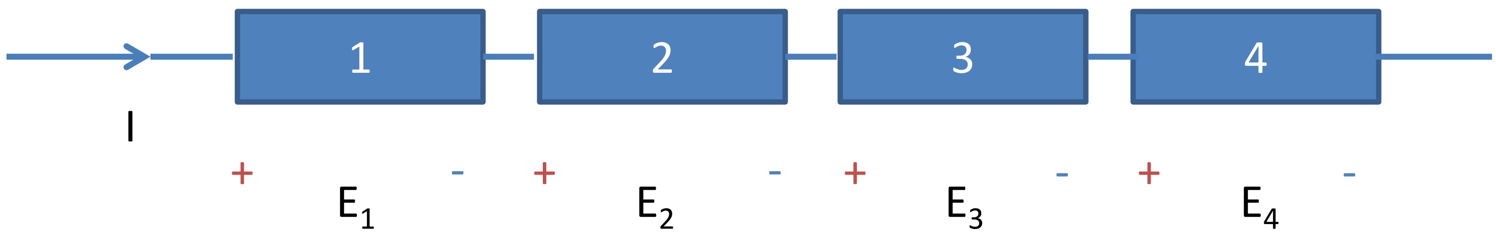
Discharge rate (or charge): current discharge value (galvanostatic mode) expressed as a function of the theoretical capacity.

C/n cycling rate: C (theoretical capacity)/n (number of hours).

Capacity, Energy and Power are usually expressed by unit of mass or volume for comparison purpose.

Stack : several batteries in series or parallel

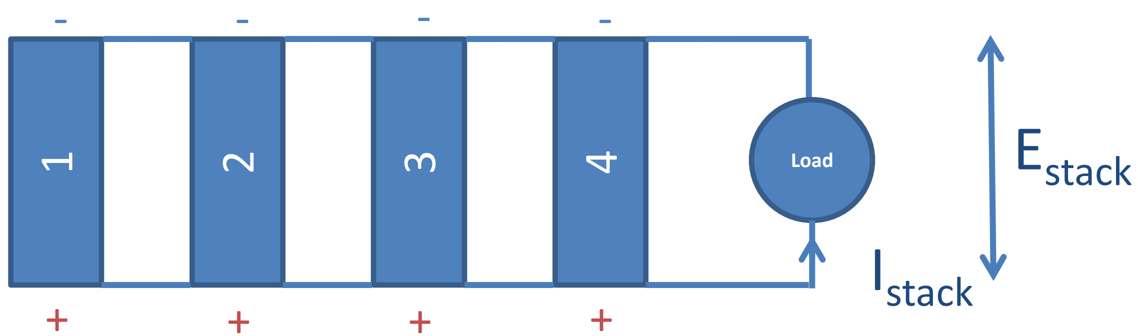
Series



$E_{stack} = E_1 + E_2 + E_3 + E_4$

$I_{stack} = I_1 = I_2 = I_3 = I_4$ (same current in all four elements)

Parallel



$E_{stack} = E_1 = E_2 = E_3 = E_4$

$I_{stack} = I_1 + I_2 + I_3 + I_4$

Comparison

Battery type	Lead-acid	Ni-MH	Ni-Cd	Li-ion	Rechargeable alkaline
Nominal Potential per cell (V)	2	1.2	1.2	3.6	1.5
Advantages	Cheap	Higher capacity than NiCd Less sensitive than NiCd to overcharging, memory effect and deep unloading	Rather cheap High currents allowed	Highest capacity	High capacity (ca. 2 times higher than Ni-MH)
Drawbacks	Heavy	More expensive than NiCd	Toxic Memory effect Degrades when overcharged Unusable after too deep unloading	Expensive Capacity decreases, even when not used Explosion risk at overheating, over-voltage or polarity reversal	Capacity reduced after each cycle (e.g. 50% after 15 cycles)

Thank you for your attention