Baterías aplicadas a la movilidad eléctrica

Dra. Verónica Díaz

Plan de presentación

- Sistemas electroquímicos.
- Baterías
- Capacitores

Sistemas electroquímicos

- Sistemas espontáneos que proporcionan $W_{eléctrico}$ útil. Ej.: baterías, pilas, celdas de combustible.

Generan energía eléctrica útil a partir de una reacción electroquímica.

- Sistemas espontáneos que no proporcionan $W_{eléctrico}$ útil. Ej.: corrosión electroquímica
- Sistemas no espontáneos. Ej. electrolizadores

  Ocurre una reacción electroquímica a medida que son alimentados por energía eléctrica

Sistemas electroquímicos

Parámetro	*Celda galvánica*	*Celda electrolítica*
Transformación energética	química→eléctrica	eléctrica→química
Tendencia termodinámica	espontánea	No-espontánea
ΔG	< 0	> 0
E	> 0	< 0
Polaridad de electrodos		
ánodo	-	+
cátodo	+	-

Basic Similarities and Dissimilarities among the Three Types of Electrochemical Technologies

Electrochemical energy conversion (fuel cells)	Electrochemical energy storage			Electrochemical synthesis
	Batteries		Electrochemical capacitors	
•Spontaneous cell •Consumes fuel and oxidant •Generates electricity	Primary batteries •Spontaneous cell •Consumes chemicals •Generates electricity	Secondary batteries •Driven/spontaneous cell •Consumes electricity •Generates/consumes chemicals •Generates electricity	•Same as secondary batteries	•Driven cell •Consumes electricity •Generates chemicals
•Thermodynamic reversible potentials and overpotential losses determine efficiency for conversion of chemical to electrical energy •Activation overpotentials predominate at low current densities •Mass transport overpotentials at higher current densities	•Thermodynamic reversible potentials and ohmic overpotentials determine efficiency for energy conversion •Activation overpotentials significant in metal-air batteries		•Redox potentials for positive and negative electrode reactions determine efficiency of cells •Ohmic overpotentials could be significant	•Thermodynamic reversible potentials and overpotential losses determine efficiency of cell •Ohmic overpotential predominates
•Cathode → positive electrode •Anode → negative electrode	Primary batteries •Cathode → positive •Anode → negative	Secondary batteries Discharge: •Cathode → positive •Anode → negative Charge: •Cathode → negative •Anode → positive	•Same as secondary batteries	•Cathode → negative •Anode → positive
•High true surface area of electrocatalysts (i.e., high roughness factors) is essential	•Similar to fuel cells, more so for gas-consumption/gas-evolution electrode reactions		•Same as fuel cells	•Same as fuel cells, more so for gas-evolution reactions

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ALMACENAMIENTO ELECTROQUÍMICO DE ENERGÍA

- Dos tipos de tecnologías
  - Baterías
    - Primarias :Zn-MnO_2 , Zn- aire, Li-$SOCl_2$
    - Secundarias: Niquel (Ni-Cd) (Ni-hidruro metálico), plomo-ácido, Zn-MnO_2, ion litio
  - Capacitores electroquímicos

Baterías-Magnitudes características

- Capacidad: Cantidad de electricidad (carga eléctrica) que podrá suministrar durante su descarga.
  - $C=\int I dt$
  - Depende de cantidad de sustancia electroactiva (tamaño de electrodos y cantidad de electrolito- volumen y concentración): densidad de almacenamiento de electricidad Ah/kg

- Energía almacenada
  - Wh; Wh/kg
  - Energía = ∫EIdt
- Potencia: velocidad de entrega de energía almacenada
  - W=d(Energía almacenada)/dt= EI
  - W; W/kg (densidad de potencia)

Baterías

Type of battery	Cell reaction	Standard thermodynamic reversible potential, V	Specific energy (attained), Wh/kg	Energy density (attained), Wh/l
		Primary		
$Zn\text{-}MnO_2$	$Zn + 2\ MnO_2 \rightarrow ZnO + Mn_2O_3$	1.5	145	400
Zn-Air	$Zn + \frac{1}{2}\ O_2 \rightarrow ZnO$	1.65	370	1300
$Li\text{-}SOCl_2$	$4\ Li + 2\ SOCl_2 \rightarrow 4\ LiCl + S + SO_2$	3.65	590	1300
		Secondary		
Lead Acid	$Pb + PbO_2 + 2\ H_2SO_4 \rightarrow 2\ PbSO_4 + 2\ H_2O$	2.1	35	70
$Ni\text{-}H_2$	$H_2 + 2\ NiOOH \rightarrow 2\ Ni(OH)_2$	1.5	55	60
Ni-Cd	$Cd + 2\ NiOOH \rightarrow 2\ Ni(OH)_2 + Cd(OH)_2$	1.35	35	100
Ni-MH	$MH + NiOOH \rightarrow M + Ni(OH)_2$	1.35	75	240
Lithium Ion	$Li_XC_6 + Li_{1\text{-}X}CoO_2 \rightarrow LiCoO_2 + C_6$	4.1	150	400

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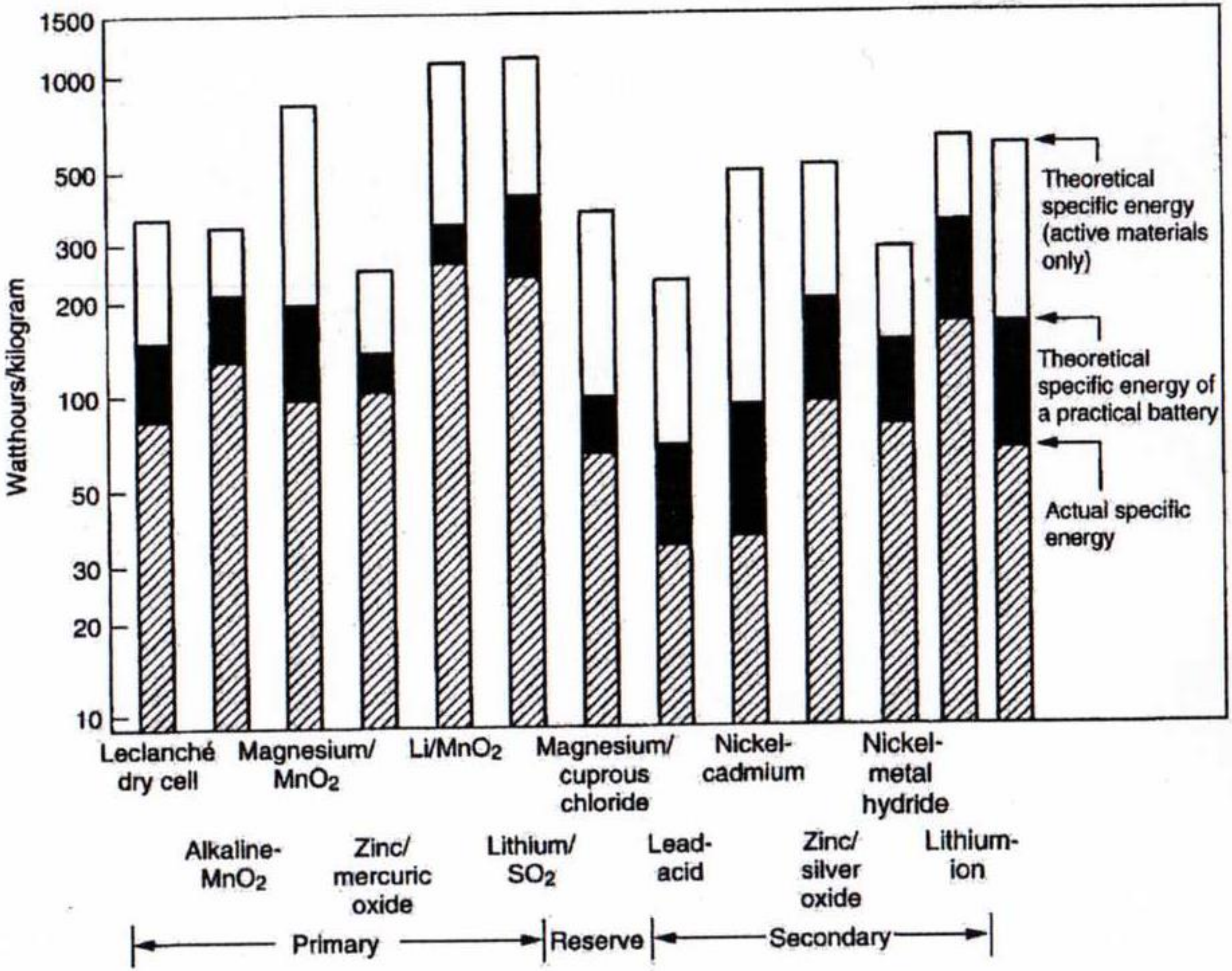

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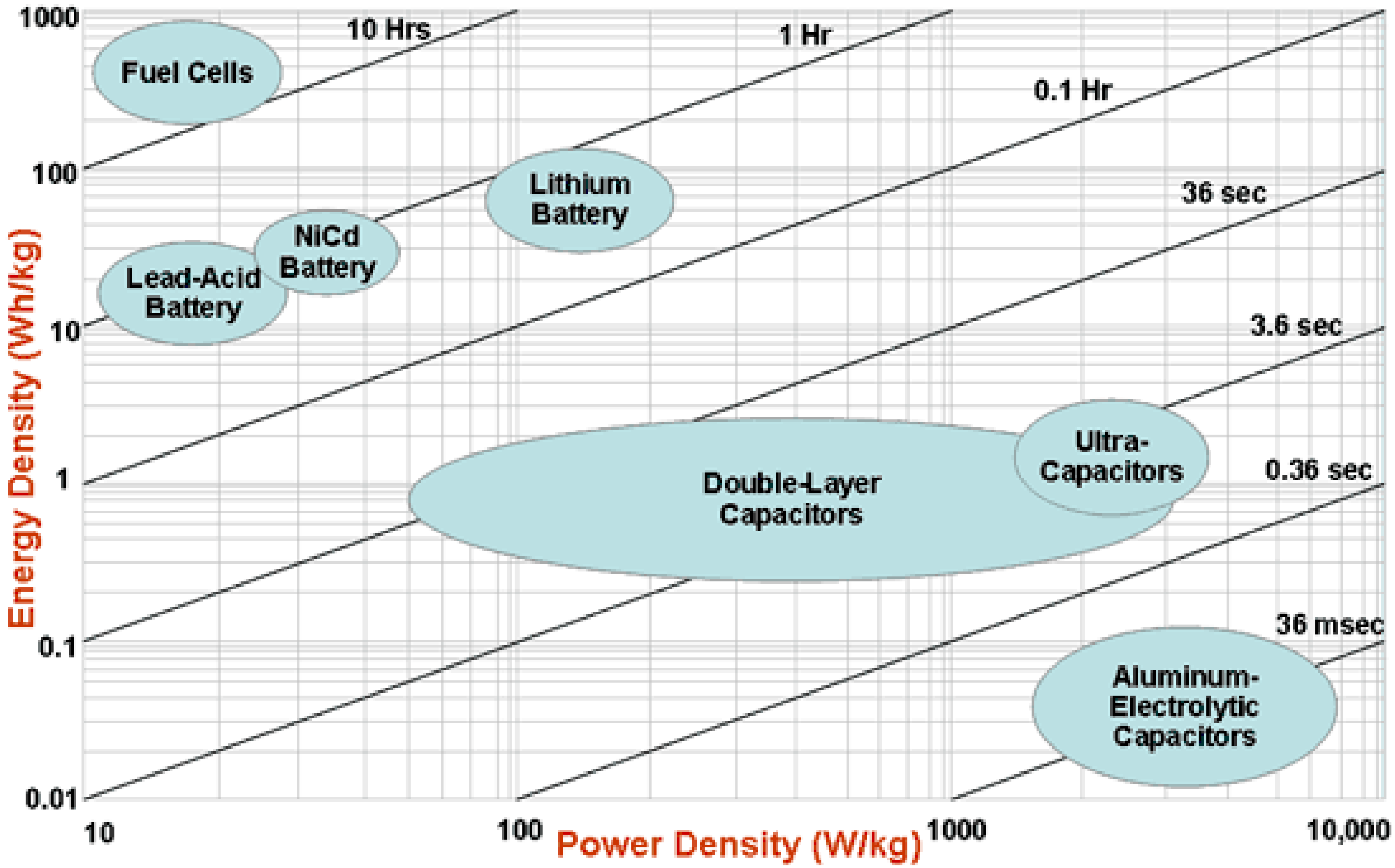

Source US Defence Logistics Agency

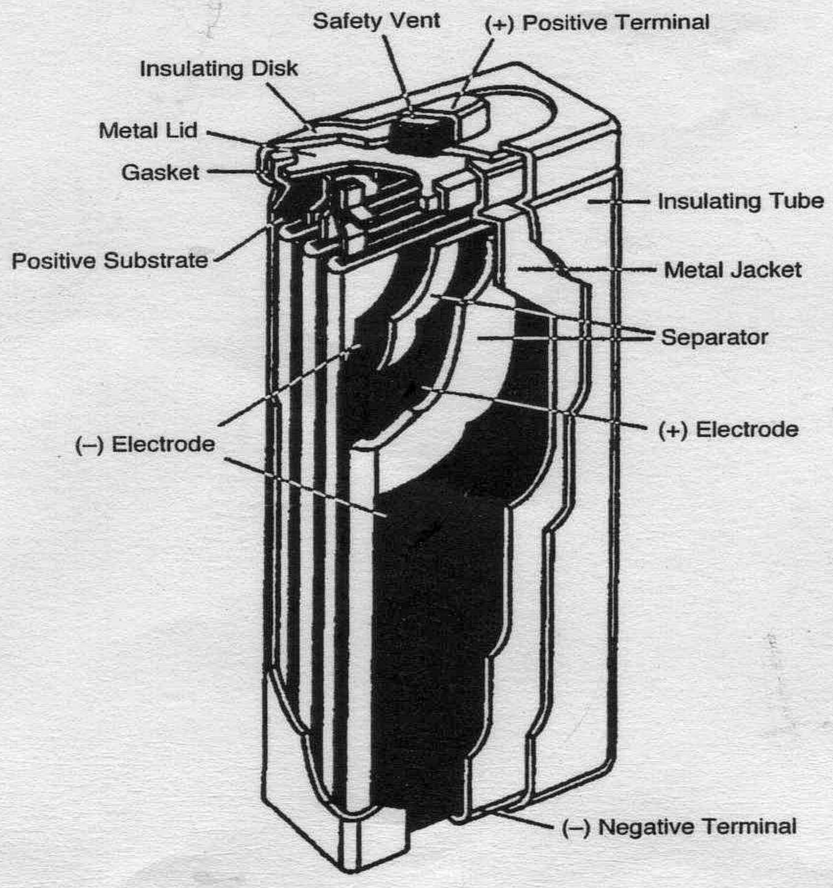

Figure 3.18. Schematics of a prismatic design for a battery. This design is similar for primary and secondary batteries. Reproduced from Reference 36, Copyright (2002), with permission of The McGraw-Hill Companies.

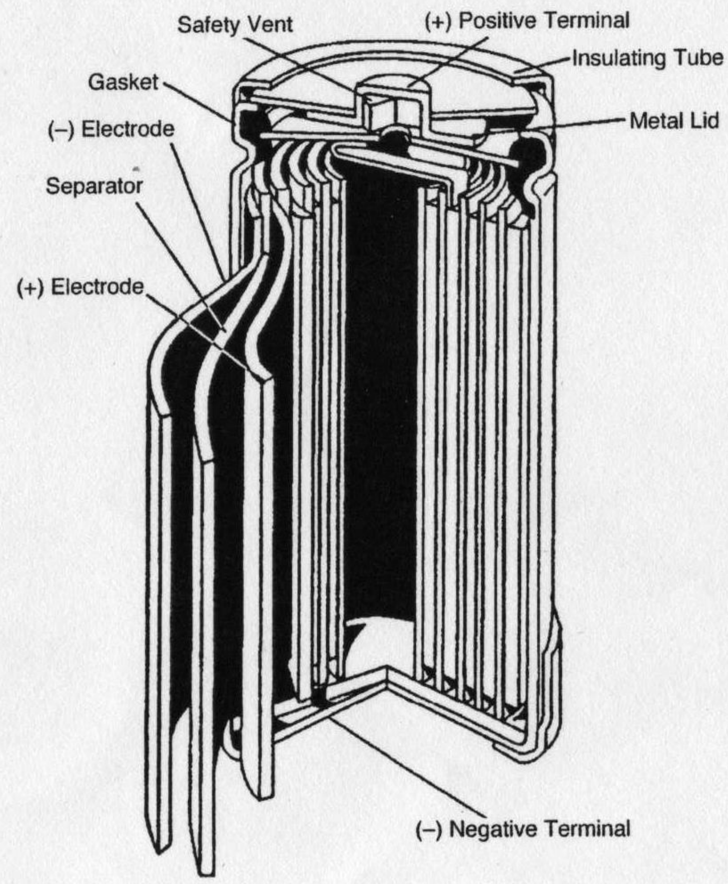

Figure 3.17. Schematic of a cylindrical design for a battery; this design is similar for primary and secondary batteries. Reprinted from Reference 36, Copyright (2002) with permission from The McGraw-Hill Companies.

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Reserve Batteries

- Tipos
  - Activada con agua
  - Por inyección de electrolito
  - Activada con gas
  - Activada por calor

- Especificaciones
  - Autodescarga baja
  - Alta energía especifica y alta densidad de potencia

- Aplicaciones
  - Torpedos
  - Misiles
  - Equipos de emergencia en botes salvavidas

Thermal batteries

- Ventajas
  - Alta confiabilidad
  - Amplio rango de temp de operación
  - Pico de potencia de 10W/cm2
  - Larga vida sin degradación y autodescarga
  - Respuesta inicial de milisegundos (start up time)
- Desventajas
  - Cortos tiempos de generación de potencia
  - Baja a moderada energía específica y densidad de energía
  - Temperaturas superficiales alcanzan 200°C
  - Se usan una sola vez

Capacitores electroquímicos

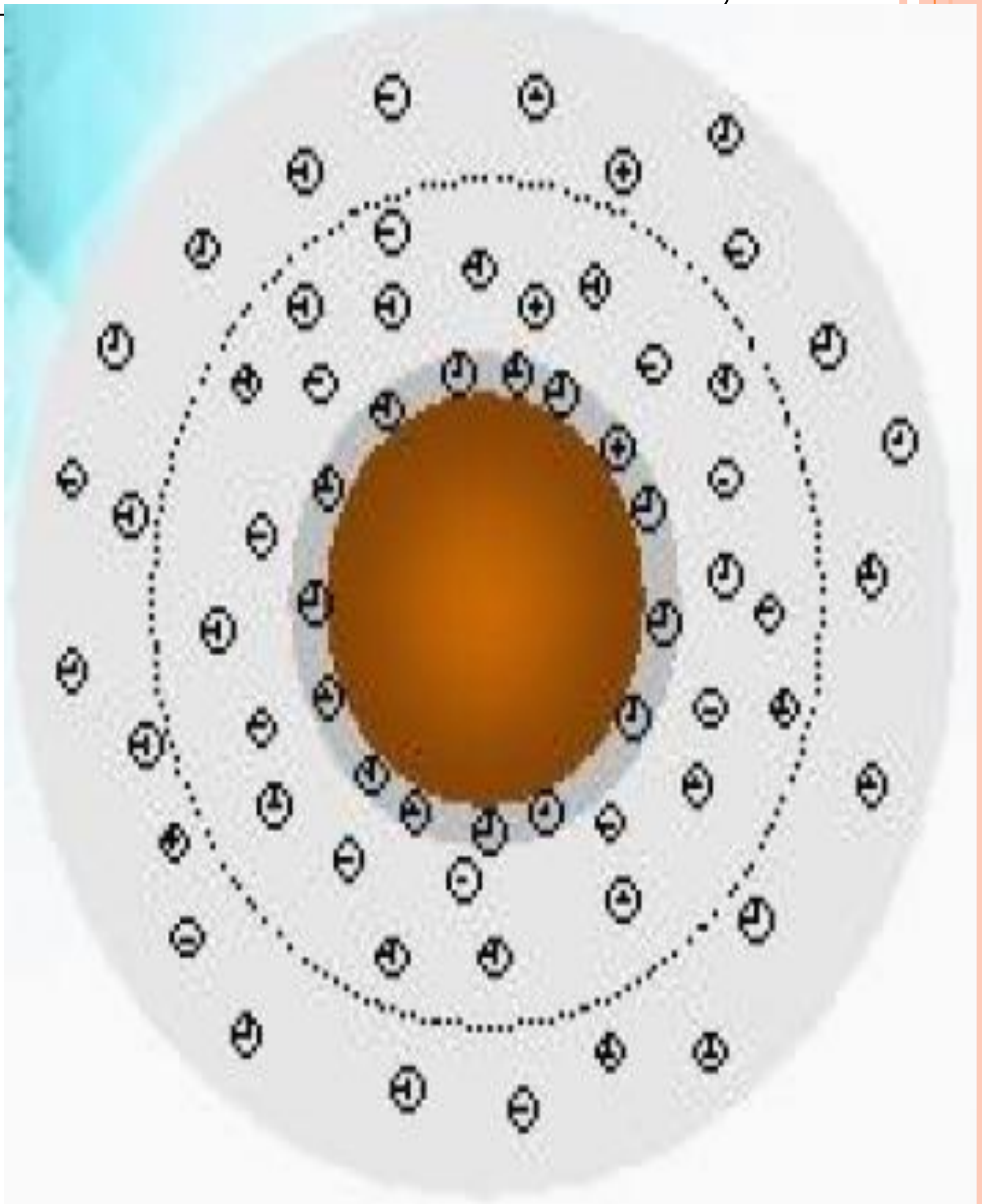
- Capacidades 20-200 veces mayores que capacitores convencionales de estado sólido
- $C=A\varepsilon\varepsilon_0/d$
- *Energía almacenada:*
  - $G=CV^2/2$

Categorías

- Capacitores de doble capa

  1^{ero}: carbono activado en ácido sulfúrico (oxidación, alta resistencia equivalente, alta resistencia iónica en microporos)
- Capacitores basados en pseudocapacitancias

Doble capa electroquímica



La doble capa eléctrica describe la variación del potencial eléctrico próximo a una superficie.

La doble capa es un término que describe el arreglo que presentan los iones y las moléculas de solvente en disolución al aproximarse a la superficie de un electrodo cargado eléctricamente, de tal forma que se presentan dos capas con polaridad distinta separadas por una distancia de orden molecular.

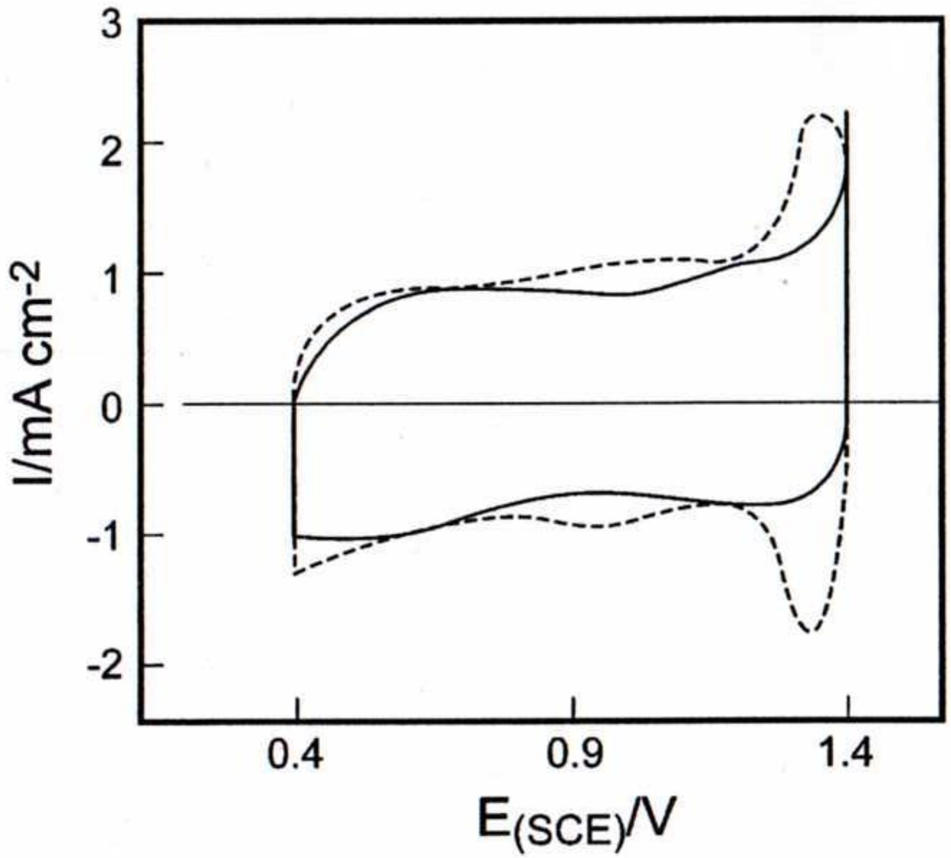


Figure 3.33. Cyclic voltammogram of a ruthenium oxide in acid and alkaline media, exhibiting pseudocapacitance behavoir. Reprinted from Reference 45, Copyright (1990) with permission from Elsevier.

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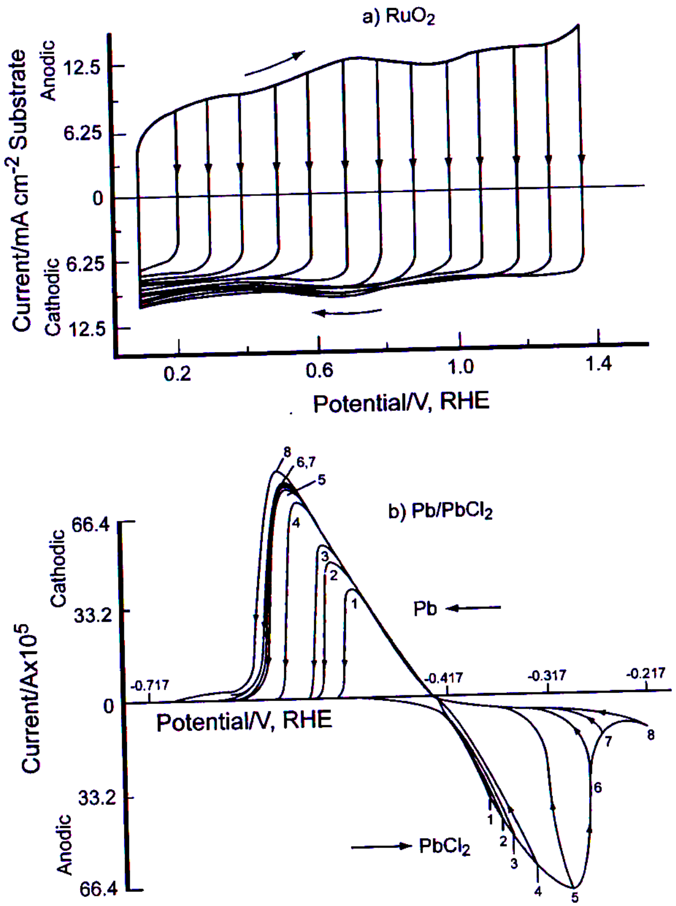

Figure 3.35. Cyclic voltammograms illustrating the reversible behavior of a ruthenium oxide electrode and the irreversible behavior of a lead/lead dichloride electrode. Reproduced by permission of the author.[50]

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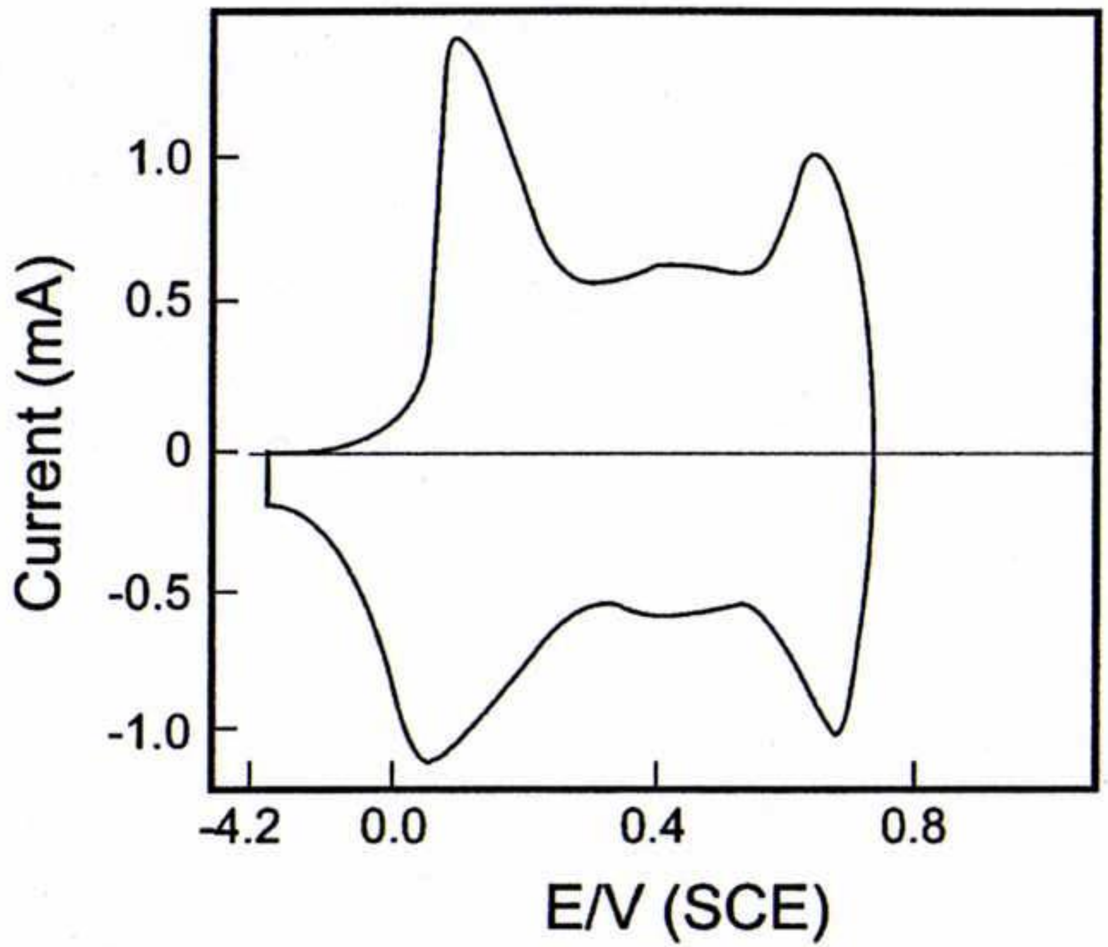

Figure 3.34. Cyclic voltammogram of a polyaniline electrode exhibiting pseudocapacitance behavior.[42]

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Performance characteristics and economic applications	Electrochemical energy conversion (fuel cells)	Electrochemical energy storage		Electrochemical synthesis
		Batteries	Electrochemical capacitors	
Thermodynamic reversible potential (E_r), V	1.2–1.35	1–6	1–1.5	1–6
Stack design	Mostly bipolar	Mostly monopolar, some bipolar	Mostly monopolar	Monopolar/bipolar
Operating temperature range (T), ^{0}C	0–1,000	(–30)–550	0–100	1–1,000
Overpotential losses:				
Activation	High for low-intermediate temperature	Low for most batteries	Low	High for gas-evolution/gas-consumption reaction
Ohmic	High in intermediate and high c.d. range	High for metal-air batteries	Low to high	Could be high
Mass transport	High in high c.d. range	Not significant	Not significant	Not significant
Voltage efficiency, %	30–60	60–70	60–70	40–80
Power density (output or input) based on geometric area of electrodes, mW/cm^2	0.1–600	< 0.1	2–10	100–500

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Performance characteristics and economic applications	Electrochemical energy conversion (fuel cells)	Electrochemical energy storage		Electrochemical synthesis
		Batteries	Electrochemical capacitors	
Specific power for system, W/kg	100–500	1–1,000	100–1,000	100–500
Power density for system, W/l	10–600	200–300	Could be as high as 10 kW/l	N/A
Specific energy for system, Wh/kg	10–600	10–200	10–50	N/A
Lifetime of electrochemical stack, years	0.5–5	0.1–10	0.1–1	1–10
Capital cost, $	50–10,000/kW	10–1,000/kWh	100–1,000/kWh	2,000–5,000/kW
Operating and maintenance cost, $/kWh	0.1–1	~0	~0	0.1–1
Commercialized/demonstrated applications	Auxiliary power for space vehicles since 1961 Power generation, co-generation, portable power, power range from 10W–10MW	Electric-utility energy storage, standby/emergency Starter batteries for transportation vehicles Power source for tools, computers, cell phones, pacemakers, defibrillators	Peak power	Aluminum and chlor-alkali production Electrowinning of metals Electroorganic synthesis Water electrolysis Corrosion protection/passivation Bioelectrochemistry

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