Electric Car

By

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Outline

• Introduction to electric car
• History of electric car
• How electric cars work
• Batteries of electric cars
  - Lead Acid Battery
  - Lithium Ion Battery
  - Lithium Air Battery
• Advantages and Disadvantages of electric cars
Introduction to Electric cars

- Electric car is an alternative fuel automobile that uses electric motors and motor controllers for propulsion.
- Electric cars which store electrical energy in a capacitor or battery.
- Electric cars create less pollution than gasoline-powered cars, so they are environmentally friendly.
- Electric cars are zero emissions vehicles.
- Electric car did not have the vibration, smell, and noise associated with gasoline powered cars.
History of Electric Cars

- **1828** The first electric car was developed in Hungary.
- **1835** The first practical electric vehicle was built in America.
- **1859** France developed an electric car with a rechargeable lead-acid storage battery.
- **1891** The first successful electric automobile in the United States was produced.
- **1897** Electric cars were produced in New York city and used for taxis.
- **1902** Electric car has topped speed of over 14 mph, range of 18 miles/charging.
History of Electric cars

- **1974** Electric car has topped speed of over 30 mph, range of 40 miles/charging.
- **1997 - 2000** Electric cars are available for lease only.
- **2009** Few electric cars are available on the market such as Nissan LEAF, Chevrolet Volt, and Mitsubishi i MiEV with speed 70 mph, range of 300 miles/charging for lithium ion battery and 80 miles/charging for lead acid battery.
How Electric Cars Work

- The heart of an electric car is the combination of:
  + The electric motor
  + The motor's controller
  + The batteries

DC controlled motor may run on 96 to 192 volts.

AC controlled motor usually runs at 240 volts AC using a 300 volt battery pack.
Comparison of Energy Densities for Various Chemistries

More information on battery chemistry and battery pack design can be found at the Nexergy Web site.
# Lead-acid battery

![Lead-acid battery](image)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy/weight</td>
<td>30-40 Wh/kg</td>
</tr>
<tr>
<td>Energy/size</td>
<td>60-75 Wh/L</td>
</tr>
<tr>
<td>Power/weight</td>
<td>180 W/kg</td>
</tr>
<tr>
<td>Charge/discharge efficiency</td>
<td>50%-92% [1]</td>
</tr>
<tr>
<td>Self-discharge rate</td>
<td>3%-20%/month [3]</td>
</tr>
<tr>
<td>Cycle durability</td>
<td>500-800 cycles</td>
</tr>
<tr>
<td>Nominal Cell Voltage</td>
<td>2.105 V</td>
</tr>
</tbody>
</table>
Lead Acid Battery Reactions

- Chemical Reactions for charge & Discharge

At the negative terminal the charge and discharge reactions are:

\[ \text{Pb} + \text{SO}_4^{2-} \xrightleftharpoons{\text{charge}} \text{PbSO}_4 + 2e^- \]

At the positive terminal the charge and discharge reactions are:

\[ \text{PbO}_2 + \text{SO}_4^{2-} + 4H^+ + 2e^- \xrightleftharpoons{\text{charge}} \text{PbSO}_4 + 2H_2O \]

The overall chemical reaction is:

\[ \text{PbO}_2 + \text{Pb} + 2\text{H}_2\text{SO}_4 \xrightleftharpoons{\text{charge}} 2\text{PbSO}_4 + 2\text{H}_2\text{O} \]
Advantages & Disadvantages of Lead Acid Battery

• **Advantages of Lead Acid Battery**
  - Inexpensive.
  - Reliable.
  - Rechargeable battery systems.
  - Low maintenance requirements.

• **Disadvantages of Lead Acid Battery**
  - Low energy density.
  - Limited number of full discharge cycles.
  - Environmentally unfriendly.
  - Taking 12hr-16hr to recharge by standard outlet (110v).
## Lithium-ion battery

Varta Lithium-ion battery, Museum Autovision, Altlußheim, Germany

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy/weight</td>
<td>100-160 Wh/kg[^1]</td>
</tr>
<tr>
<td>Energy/size</td>
<td>250-360 Wh/L[^1]</td>
</tr>
<tr>
<td>Power/weight</td>
<td>~250-~340 W/kg[^2]</td>
</tr>
<tr>
<td>Charge/discharge efficiency</td>
<td>80-90%[^3]</td>
</tr>
<tr>
<td>Energy/consumer-price</td>
<td>2.8-5 Wh/US$[^4]</td>
</tr>
<tr>
<td>Self-discharge rate</td>
<td>5%-10%/month</td>
</tr>
<tr>
<td>Time durability</td>
<td>(24-36) months</td>
</tr>
<tr>
<td>Cycle durability</td>
<td>~1200 cycles</td>
</tr>
<tr>
<td>Nominal Cell Voltage</td>
<td>3.6 / 3.7 V</td>
</tr>
</tbody>
</table>

[^1]: Reference to energy and power density
[^2]: Reference to specific energy
[^3]: Reference to efficiency
[^4]: Reference to cost of energy storage
Lithium Ion Battery Reactions

- Chemical Reactions for charge & Discharge
Advantages & Disadvantages of Lithium Ion Battery

• Advantages of Lithium Ion Battery
  - Higher energy density.
  - Operate at higher voltages than other rechargeable.
  - Lower self discharge rate than other rechargeable.
  - Low Maintenance - no periodic discharge is needed; there is no memory.
  - Specialty cells can provide very high current to applications such as power tools.

• Disadvantages of Lithium Ion Battery
  - More expensive than other rechargeable ($10,000/battery).
  - Lithium Ion Batteries are not available in standard cell size.
  - Damage due to overcharging or undercharging.
  - Highway speed, max 70 mph, taking 8 hours to complete recharge
# Lead Acid vs Lithium Ion

<table>
<thead>
<tr>
<th>Lead-acid battery</th>
<th>Lithium-ion battery</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Lead-acid battery" /></td>
<td><img src="image" alt="Lithium-ion battery" /></td>
</tr>
</tbody>
</table>

## Lead-acid Battery

- **Energy/weight**: 30-40 Wh/kg
- **Energy/size**: 60-75 Wh/L
- **Power/weight**: 180 W/kg
- **Charge/discharge efficiency**: 50%-92% [1][5]
- **Energy/consumer-price**: 7 (sid) - 18 (fd) Wh/US$ [2]
- **Self-discharge rate**: 3%-20%/month [3][5]
- **Cycle durability**: 500-600 cycles
- **Nominal Cell Voltage**: 2.105 V

## Lithium-ion Battery

- **Energy/weight**: 100-160 Wh/kg[1]
- **Energy/size**: 250-360 Wh/L[1]
- **Power/weight**: ~250-~340 W/kg[2]
- **Charge/discharge efficiency**: 80-90%[3]
- **Energy/consumer-price**: 2.8-5 Wh/US$[4]
- **Self-discharge rate**: 5%-10%/month
- **Time durability**: (24-36) months
- **Cycle durability**: ~1200 cycles [citation needed]
- **Nominal Cell Voltage**: 3.6 / 3.7 V
Lithium Air Battery Reactions

Li-air batteries hold the promise of increasing the energy density of Li-ion batteries by as much as five to 10 times. But that potential will not be realized until critical scientific challenges have been addressed.

The possible discharge cell reactions are:

1. \[2Li + O_2 \rightarrow Li_2O_2\]  \((E_0 = 3.1 \text{ V})\)
2. \[4Li + O_2 \rightarrow 2Li_2O\]  \((E_0 = 2.91 \text{ V})\)
Advantages & Disadvantages of Lithium Air Battery

• Advantages of Lithium Air Battery
  - Ten folds increase in energy capacity compared to lithium ion battery cell.
  - Operate at higher voltages than other rechargeable.
  - Lower self discharge rate than other rechargeable.
  - Low maintenance requirements.

• Disadvantages of Lithium Air Battery
  - It is easy to explode in contact with water.
  - More expensive than other rechargeable.
Advantages & Disadvantages

• **Advantages of the electric car**
  - Zero emission vehicle
  - Lower cost of fuel (43 miles/dollar)
  - Rechargeable batteries are recycle well
  - Smooth running, No vibration
  - Less maintenance

• **Disadvantages of the electric car**
  - Takes time to charge battery (several hours)
  - Low speed (max speed, 70 mph)
  - Heavy battery (Lithium battery is 1000 pounds)
  - Costly to replace new battery ($10,000/battery)
Electric Cars

• References:
  - http://auto.howstuffworks.com/electric-car.htm
  - http://www.pbs.org/now/shows/223/electric-car-timeline.html
  - http://www.roadandtrack.com/article.asp?section_id=6&amp;article_id=6393
  - http://earth2tech.com/2008/06/19/epyon-10-minute-electric-car-charging/
  - http://www.asecert.org/Template.cfm?Section=Clean_Fuels_Clean_Vehicle_Technology1&amp;Template=/ContentManagement/ContentDisplay.cfm&amp;ContentFileID=609
  - http://www.transportation.anl.gov/features/2009_Li-air_batteries.html
  - http://www.natureforus.com
Thank you

Green Technology