Review on Batteries for Electric Vehicles

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Abstract: Electric Vehicles, being clean & green mobility, are the solution to negative environmental impact of conventional vehicles. Energy storage is a fundamental component for the EVs, as performance & range factor are major drawbacks. And, variety of energy storage options are available to power the EVs. Therefore, this paper reviews on different type of batteries (specially on Li-ion batteries) to select one as per requirements.

Index Terms **– Electric vehicles, Batteries, Li-ion Batteries.**

INTRODUCTION

The In order to compete with greenhouse gases emissions & their contribution to global warming, automotive industry is turning electric. EVs are the revolution of transportation as well as in technology. EVs are around 75% efficient in turning input energy as output whereas, ICE vehicles only about 15%. EVs have high performance & smooth control. And, can be charged from renewable energy like solar. Even when EVs are recharged from dirtiest coal dominated grid, EVs still produce less global warming pollution. Many other environmental issues like air pollution, depletion of ozone layer due to exhausted chemicals, drilling for oil can be eliminated by application of EVs.

Even after being such as great gift to human health & wildlife. EVs have to face problems like limited range driving per charge, charging & discharging process causes depreciation in its performance. Now the role of energy storage comes in play to power EVs with high performance over high range & long period of time. Depending on the power source, EVs can be generally categorised as solely battery-powered electric vehicles (BEVs), hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), as well as photovoltaic electric vehicles (PEVs) and fuel cell vehicles (FCVs).[1] Since advance technology of rechargeable batteries have been adopted as major power source for reliable performance & reasonable cost, BEVs will be on focus for discussion.

BATTERY

Batteries are key component of performance & energy storage.

In order of selection of battery, following factors have to be considered.

- Energy Density (W-h/Kg)
- Power Density (W/Kg)
- Nominal Voltage
- Operating Temperature
- Cycle Life
- Overcharge Tolerance
- Self-Discharge

Some different types of batteries for EVs are

- Valve Regulated Lead Acid (VRLA)
- Nickel Cadmium (Ni- Cd)
- Nickel Metal hydride (Ni- MH)
- Lithium Ion (Li-Ion)

From Table 1, Li-Ion batteries are considered to be more reliable & best option for overall requirements. Some other worth noticing features of Li-Ion batteries are light & small size & weight, rapid charge capability, no memory effect.[2]

These features help Li-Ion battery to dominate electronics market as power source in many portable devices like laptops, smartphones, camera, power tools and many more.

Table 1: Technical Specifications of batteries

Battery Type	**Lead Acid**	**Ni-Cd**	**Ni-MH**	**Li-ion**
Energy Density	30-50	45-80	60-120	110-160
Power Density	180	150	250-1000	1800
Nominal Voltage	2V	1.25V	1.25V	3.6V
Overcharge Tolerance	High	Moderate	Low	Very Low
Self-Discharge	Low	Moderate	High	Very Low
Cycle Life	200-300	1500	300-500	500-1000
Operating Temp. (in Celsius)	-20-60	-40-60	-20-60	-20-60

LI-ION BATTERY

Four primary components: Cathode, Anode, Electrolyte, Separator

Table 2: depicts those essential components with their functions in lithium-ion batteries. Also, a detailed electrochemical process occurred in a lithium-ion cell is schematically represented in Fig.1 [3].

Materials of electrodes in Li-ion Batteries-

ANODE – Lithiated graphite, which have a layered structure on copper current collector

CATHODE – Lithium metal oxide, which either have a layer or tunnelled structure on aluminium current collector [4].

In Fig. (3), In the discharge process, lithium in the anode is ionised and emitted to the electrolyte. Lithium ions move through a porous plastic separator and then insert into atomic-sized holes in the lithium metal oxide cathode. At the same time, electrons are released from the anode. This becomes electric current travelling to an external load. During charging cycle, lithium ions go from the cathode to the anode through the separator. Therefore, lithium-ion cells can be recharged based on this reversible electrochemical reaction [5].

Table 2: Essential Components of Li-ion Battery

COMPONENTS	OPERATION
CATHODE	Li-ions enters the cathode when the battery discharges & leaves when the battery charges
ANODE	Li-ions enters the anode when the battery discharges & leaves when the battery charges
ELECTROLYTE	The electrolyte allows transport of Li-ion between cathode & anode but not electrons
SEPERATOR	The separator prevents short-circuit between cathode & anode & only pass Li-ion through pores

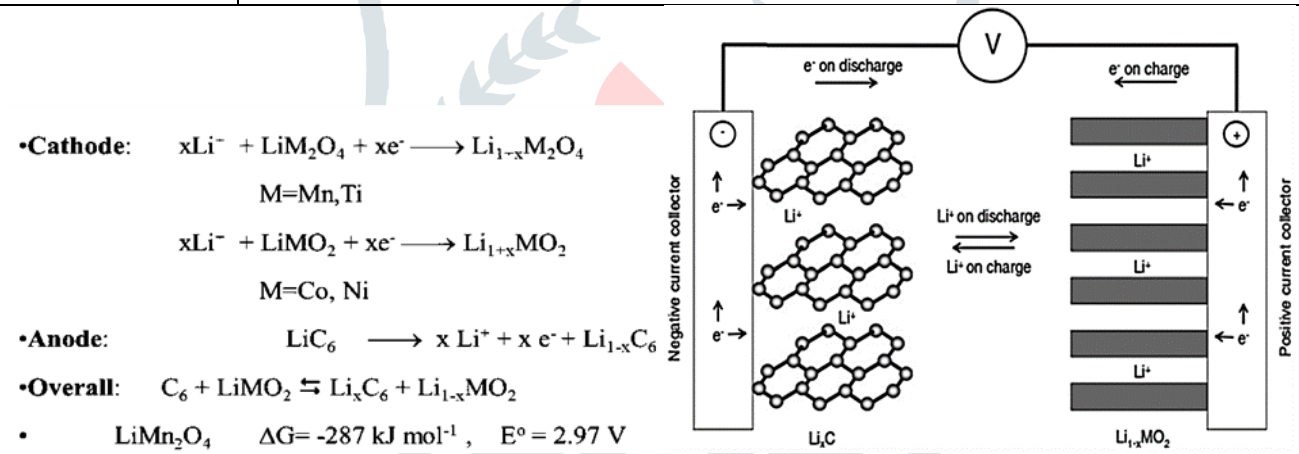

Fig. 1: Electrochemical Reaction in Li-Ion Battery

To fulfil the specific energy & power requirement, Li-ion batteries must be assembled in modules & further composed into battery packs in which cells are connected in series-parallel arrangement.[9] Fig 2.

Fig.2: Li-ion Battery Cell, Battery module & Battery pack [9]

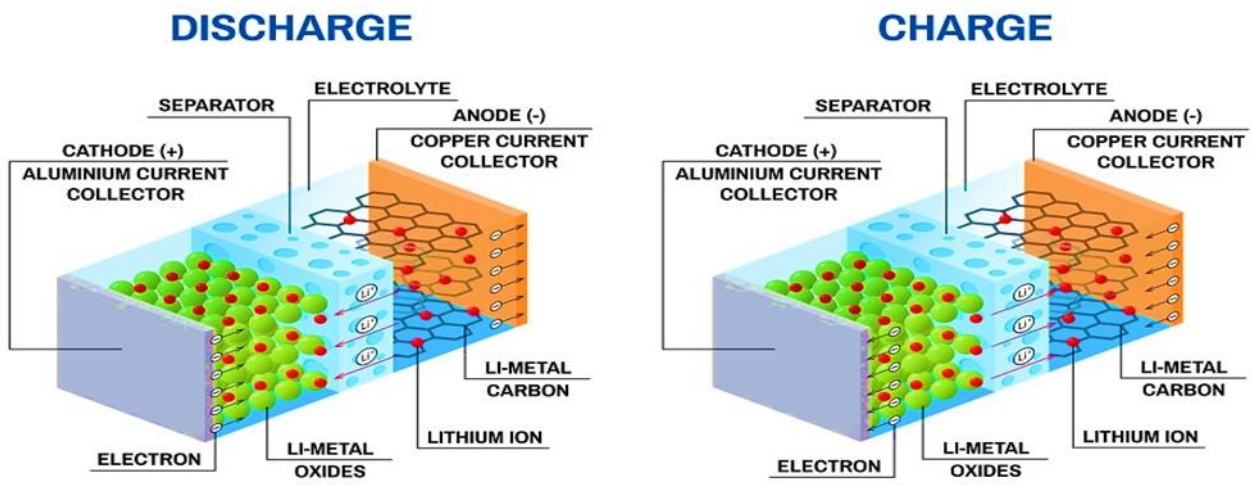

Fig.3: Charging & Discharging in Li-ion Battery

DIFFERENT TYPES OF LI-ION BATTERIES

- The Lithium Cobalt Oxide (LCO)
- Lithium Manganese Oxide (LMO)
- Lithium Iron Phosphate (LFP)
- Lithium Nickel Manganese Cobalt Oxide (NMC)

All above mentioned batteries are currently being used by EVs developers in several models. TABLE (3)
Other than these 4, many are being researched

- Lithium Titanate (LTO)
- Lithium Sulphur (Li/S)

LMO is commonly mixed with NMC to improve performance. The combination is chosen for most EVs. One of the most popular types of PHEV "Chevrolet Volt" uses this combined type of Li-ion battery, which has a total energy of 16 kWh, also capable of providing driving range of 40 miles.

The USABC has been contributed the development of performance targets and specified testing procedures for batteries in EVs [7]. It also presented the spider chart in Fig. 4 where the 100% solid line equals the USABC optimal targets of EV batteries and the grey area represents the status of typical lithium-ion batteries in EVs [8].

Table 3: Various EVs manufacturer & their users

Cathode Material Type	EVs Battery Packs Manufacturers	EVs Developers & EV models	Battery Packs Usable Capacity (KW H)	Approx. Range under Normal Driving Conditions (Miles)
Lithium Cobalt Oxide (LCO)	Panasonic	Tesla- Roadster	56	245
	Tesla	Daimler Benz-Smart EV	16.5	84
Lithium Manganese Oxide (LMO)	AESC, EnerDel	Think-Think EV	23	99.4
	Toshiba, LG chem, Hitachi, GS Yuasa	Nissan-Leaf EV	24	105
Lithium Iron Phosphate (LFP)	A123, BYD, GS	BYD-E6	57	249
	Yuasa, Lishem, Valence	Mitsubishi-iMiEV	16	99.4
Lithium Nickel Manganese Cobalt Oxide	Hitachi, LG chem, Samsung	BMW – Mini E	35	150

Now, we should compare these batteries with each other to select as per our requirements in Table :4

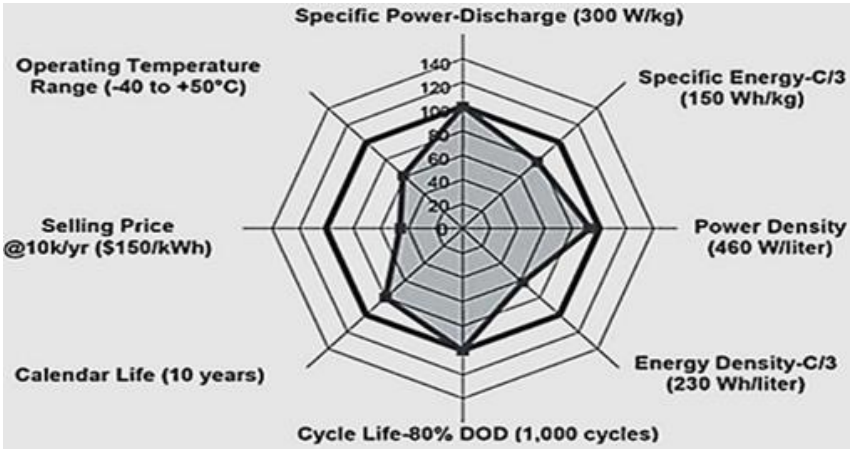

Fig:4 Comparison between USABC minimum goals and typical status of lithium-ion battery technology in EV applications

Table: 4 Comparison Between various Li-ion Batteries

Specification	**LCO**	**LMO**	**LFP**	**NMC**
Nominal Voltage	3.90V	3.70V	3.40V	3.60-3.70V
Charge Limit	4.20V	4.20V	3.60V	4.20V
Cycle Life	500	500-1000	1000-2000	1000-2000
Operating Temp.	Average	Average	Good	Good
Specific Energy	155	100-120	160	200
Specific Power	1C	10C,40C	35C	10C
Thermal Runaway	150	250	270	210
Safety	Poor	Average	Very Good	Good
Cost	High	Low	Moderate	Moderate

RESULT & DISCUSSION

Different types of batteries have different energy capacity, which is one of a major factor to determine potential & suitability for EVs. Four type of Li-ion batteries are highly used in EVs.LCO batteries have been the leading technology for a long term because of its high performance, high energy & power density. But, due to safety reasons & high price of cobalt, many EVs manufactures like BMW, Nissan & leading battery makers like LG, Samsung have opted safer & cheaper options like LMO, LFP, NMC. Still researches are being done to maximize their limits & others newly Li-based batteries are under development for betterment of EVs & pollution free future.

REFERENCES

[1] M. Anderman, “Status and trends in the HEV/PHEC/EV battery industry,” Rocky Mountain Institute, 2008.
[2] K.E. Aifantis, S.A. Hackney, and R.V. Kumar, “High Energy Density Lithium Batteries, Materials, Engineering, Applications,” Wiley-Vch Verlag GmbH & Co. KGaA, Weinheim, 2010
[3] H.A. Kiehne, “Battery Technology Handbook,” Expert Verlag, New York, 2nd edition, 2003
[4] T.B. Reddy, “Linden’s Handbook of Batteries,” McGraw Hall, 4th edition, 2011
[5] P. Lyman, “Battery Basics: a primer for battery technology,” CECOM LRC Power Sources Team, 2002
[6] M. Yilmaz and P. Krein, "Review of the impact of vehicle to grid technologies on distribution systems and utility interfaces." IEEE Transactions on Power Electronics, vol. 28(12), pp. 5673-5689, 2013.
[7] “USABC Electric Vehicle Battery Test Procedures Manual,” U.S. Department of Energy Contract DE-AC07-94ID13223, Report Number DOE/ID-10479, Revision 2, January 1996.
[8] K. Snyder, “U.S. Advanced Battery Consortium,” 2009 DOE Hydrogen Program and Vehicle Technologies Program Annual Merit Review and Peer Evaluation Meeting, U.S. Department of Energy, Arlington, VA, May 2009
[9] M. Lowe, S. Tokuoka, T. Trigg and G. Gereffi, “Lithium-ion Batteries for Electric Vehicles: The U.S. Value Chain,” Center on Globalization, Governance & Competitiveness, Duke University, October, 2010.