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AN OVERVIEW OF FUEL CELL TECHNOLOGY

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Abstract

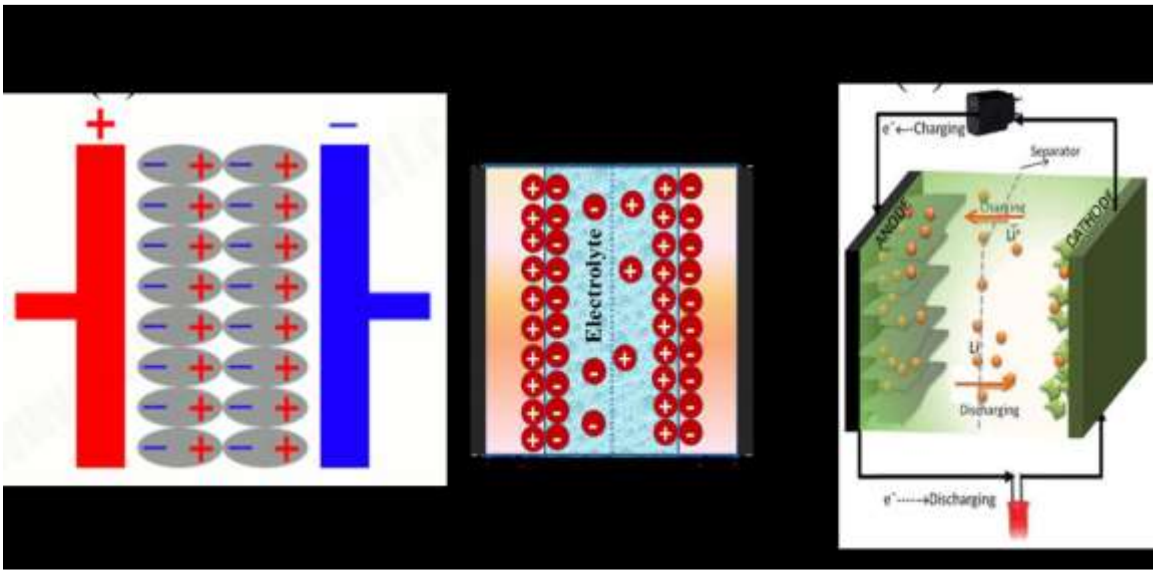
We are going through a age of drastic change in automobile sector. Over 70%of global energy demands are met by oil, natural gas and coal, while renewables account for almost all of the rest. However, excessive reliance on nonrenewable fossil fuel leads to a harmful effect on the environment and society. Hence it is important to use renewable energy as well as store this energy efficiently. Nowadays, the world is moving towards cleaner and safer sources for energy production like solar, hydro, wind, nuclear, fuel cell, and compressed natural gas, but the production rates are not fast enough to sustain global energy demands. Fuel cell systems are used for stationary applications, such as heat-power cogeneration for household/residential use and uninterruptable power supply (UPS). They also find applications as back-up power supply devices in banks, hospitals, and telecom companies for maintaining their business operations during unexpected power breakdowns. The analysis is focused to develop various fuel cells with direct application in stationary powers and transportation.

Keywords: *Nonrenewable, Fossil fuel, Li-ion battery, Electro catalysts.*

Discussion and Results: In a capacitor, two or more conducting plates are separated by a dielectric. When we introduce an electric current to the capacitor, the flow of dielectric stops and charge builds up. This built-up charge is then stored in form of an electric field among the plates. Each capacitor is designed to have a certain capacitance. The current discharged rapidly as soon as it connected to an external circuit. In a super capacitor, dielectric is absent between the plates; instead, there is an electrolyte and a thin separator. Once we introduce current to the super capacitor, ions build on either side of the separator to generate a double layer of charge. Super capacitor can‘t withstand high voltage as high voltage would break down the electrolyte, however, they have very high capacitance. Batteries work similar to that of super capacitors. It contains four major parts; a positive terminal (cathode), negative terminal (anode), a separator and an electrolyte. Its charging/discharging process takes place through a chemical reaction, which generates a voltage. The battery provides a consistent DC voltage. In a reaction principle, Li-ions (in Li-ion battery) that move from the cathode to anode during charging process are absorbed back during the discharge process. In rechargeable batteries, the charge can be restored by reversing the electrical energy into chemical energy using outside electrical.

Because of the large fluctuations in the generation of electricity from the above renewable energy sources, it must be efficiently stored and supplied to the world on demand. There are many different storage techniques that have been developed over the last few years. These are super capacitors, batteries, flywheels, compressed air, pumped hydro-power and thermal. Among the various energy-storage technologies, batteries and super capacitors are the most appealing and promising devices to offer and to store energy for automotives, residential and portable electronic applications. The performance of batteries and super capacitors depends largely upon the properties of the nano structured materials that they are composed of. Both super capacitors and batteries are analogous to each other, where negative electrodes and positive electrodes are separated by separators that are soaked with electrolytes. Normally, super capacitors formed a bridge between the battery and the conventional dielectric capacitor. On another side, fuel cells which convert chemical energy into electrical energy owing to their high energy density have received much attention in recent years. A fuel cell generates electrical energy by a chemical reaction between a fuel (hydrogen or hydrocarbons) and oxidant (oxygen) in an environmentally friendly manner. Super capacitors, batteries and fuel cells consist of two electrodes in contact with an electrolyte solution. In all cases, electro catalysts play a major role by promoting the progress of electrochemical reactions. In fuel cells, Pt is still considered as one of the best electro catalysts up to today. Both super capacitors and fuel cells development aim to either compete with or even in some cases replace battery-related applications.

Among, energy storage devices, lithium-ion batteries are commonly used electronic equipment in everyday life due to their high energy density. However, it was found that due to slow electron/ion transport, it suffers a variety of resistive losses, which creates heat and generates dendrite formation while operating at high power, which ultimately leads to significant security issues. This lead to the failure of electric car made by Tesla and the Dreamliner airplane made by Boeing. Therefore, a device needs to be developed with proper literature audit and coherent plan, to, eliminate the safety issues and enhance the stability and efficiency. All these advancements will increase their feasibility to use them commercially in energy related technologies.



(a) an electrostatic capacitor (b) a supercapacitor, and (c) a battery

OVERVIEW OF FUEL CELLS

First time Swiss scientist Christian Friedrich Schönbein gave a basic idea about fuel cell in the year 1838. In the next year in 1839, Sir William Grove developed the first fuel cell based on reversing the electrolysis of water by an accident. Grove stated that by immersing one end of two platinum electrodes in sulphuric acid solution and the other two ends separately sealed in containers of oxygen and hydrogen, a constant current is flowing between the electrodes.

In 1896, William W. Jacques developed the first fuel cell with practical applications. Later in the year 1933, Francis Bacon developed the first fuel cell made up of hydrogen and oxygen and in the year 1958, he developed a 5 kW alkaline fuel cell which was used in Apollo spacecraft. In 1955, Thomas Grubb modified the fuel cell design by using membrane made of ion exchange polystyrene sulfated as an electrolyte. Three years later, Leonard Niedrach, designed a way of depositing platinum on the membrane, so that it can act as a catalyst for oxidation and reduction reactions of hydrogen and oxygen, respectively. In 1959, a team led by Harry Ihrig built a 15 kW fuel cell for a tractor from Allis-Chalmers. This fuel cell was made of 1008 cells having 1 V per cell and potassium hydroxide as electrolyte. The device used a mixture of propane and compressed hydrogen gases as fuel, and oxygen as an oxidizing agent. In 1960, scientists G.H.J. Broers and J. A. A. Ketelaar developed a fuel cell using an electrolyte composed of a mixture of lithium carbonate, sodium and/or potassium, impregnated on magnesia sintered porous disk, whose operating temperature reached 650 °C.

In 1961, G. V. Elmore and H. A. Tanner made phosphoric acid fuel cell by using a mixture of 35% phosphoric acid and 65% of silicon dust stuck to the teflon as an electrolyte. After that, the research work was focused to develop various fuel cells with direct application in stationary powers and transportation.

PRINCIPLES OF FUEL CELL TECHNOLOGY

A fuel cell (FC) is a promising power generation technology which converts the chemical energy stored in a fuel directly into electrical energy, heat, and reaction products through an electrochemical reaction with little or no pollution. An electric current is produced by a pair of redox reactions that occur at anode/cathode, which are separated by an electrolyte membrane. At the anode, the fuel is oxidized generating electrons and positive ions, while oxidant is reduced at the cathode side. The electrolyte membrane is specifically designed in such a way that it permits only positive ions to flow from anode to cathode and restricts the flow of electrons. These free electrons flow through an external circuit to the cathode side to maintain global electrical neutrality. The recombination of the positive and negative ions with oxidant takes place at the cathode to form pure water.

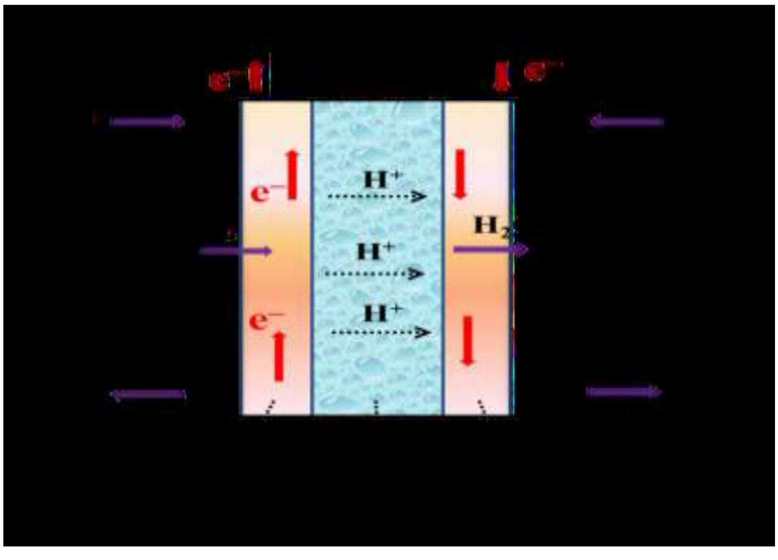
The relevant chemical reactions involved in the anode and cathode and it's overall reactions are given as -

Anode : $H_2 = 2H^+ + 2e^-$ E = 0 V/SHE

Cathode : $1/2O_2 + 2H^+ + 2e^- = H_2O$ E = 1.23 V/SHE

Overall reaction : $H_2 + 1/2O_2 = H_2O$ E = 1.23 V/SHE

Unlike conventional batteries, fuel cells require the fuel and the oxidant to be supplied continuously to sustain the electrochemical reactions.



CLASSIFICATION OF FUEL CELLS

The fuel cells are classified mainly according to the choice of electrolyte, type of fuel and the operating temperature range. The schematic representation of various fuel cells with fuel types, electrolytes and their operating temperatures.. Currently, six major different types of fuel cells are available. These are

i. Proton exchange membrane fuel cell (PEMFC)

(a) Direct formic acid fuel cell (DFAFC)

(b) Direct Ethanol Fuel Cell (DEFC)

ii. Alkaline fuel cell (AFC)

(a) Proton ceramic fuel cell (PCFC)

(b) Direct borohydride fuel cell (DBFC)

iii. Phosphoric acid fuel cell (PAFC)

iv. Molten carbonate fuel cell (MCFC)

v. Solid oxide fuel cell (SOFC)

vi. Direct methanol fuel cell (DMFC)

MATERIALS FOR FUEL CELLS

In order to improve the methanol electro-oxidation kinetics, CO tolerance and cost reduction, various Pt based bi/multi-metallic alloys such as Pt-Ru, Pt-Rh, Pt-Pd, Pt-Ag, Pt-Au, Pt-Ni, Pt- Co, and Pt-Cu have been aimed and studied for methanol oxidation. Here the role of the second element is to provide sufficient site for OH adsorption at lower potentials and reduce the adsorption strength of the poisoning intermediates residues (e.g., CO) on Pt sites. Gasteiger and coworkers reported that in Pt-Ru catalyst, the water activation on Ru sites occurs at lower potentials (0.2−0.3 V) than that on the pure Pt surface. In addition, alloys with various nanostructures, such as nanowires, nanocages, nanodendrites, nanoframes, or core−shell structures have also been employed to reduce Pt loading and improve the electrocatalytic activity for alcohol oxidation. Ternary catalysts like Pt-Ru-Cu and quaternary catalysts like Pt-Ru-Os-Ir alloys with the adjustable composition are studied to further improve their electrocatalytic activity. However, the high cost of this noble metal has restricted its commercialization. Therefore, as alternate to these, economical transition metal oxides/carbides, such as MoO2, MoO3, TiO2, V2O5, Nb2O5, MnO2, CeO2, TiC, WC/W2C, MoC/Mo2C, NbC, VC and ZrC have been developed as electrocatalysts in the recent years.

Metal carbides have unique properties, such as high surface area, good chemical and thermal stability, outstanding anti-corrosion ability and low electrical resistivity, and are mostly used as supporting materials. Levy and Boudart first reported tungsten carbide (WC) which showed catalytic properties similar to platinum.This pioneering work opened up the utilization of carbide materials in DMFCs, heterogeneous catalysis, photocatalysis, solar energy conversion, and hydrogen production. The origin of MOR and ORR activity of the carbide materials stems from the fact that carbides have similar electronic states at the Fermi level as that of Pt metal. Carbides of W (WC/W2C), Ti, V, Mo (MoC/ Mo2C) can reduce the cost of the DMFC anode and promote both COads and MeOH electrooxidation. These transition metal carbides are strongly interacted with small Pt crystallites and allow activation of water at low potentials and show immense promise in promoting Pt/C for alcohol electro-oxidation. Last but not least; metal carbides can help to reduce the cost of DMFC. Therefore, they are promising additives for Pt catalysts.

Conclusion:

Fuel cells are mostly used in transportation, stationary and portable power generation devices. In the past few years, the fuel cell light-weight vehicle market has been led by Honda, General Motors, and others. In 1998, General Motors Corporation (GMC) with its German subsidiary, Opel, introduced a methanol fuel-cell-powered car called ―Zafira‖. In 2000, Ballard Power Systems Inc. (BPSI, Canada) in alliance with Daimler-Chrysler, established a 6 kW DMFC system for a one-person vehicle. In this system, both the anode and cathode catalysts were impregnated over an oxidized carbon substrate. In 2003, Yamaha (Japan) developed the FC06 prototype DMFC-powered motorcycle with an output power of 500 W.

In 2007, a better-quality DMFC-powered two-wheeler (FC-Dii) was introduced with an output power of 1 kW. A number of fuel cell buses have been initiated in the years from 1984 through 2008 by several government-funded procurement plans, such as the US National Fuel Cell Bus Program and Europe‗s Fuel Cell and Hydrogen Joint Technology Initiative. Stockholm runs the Mercedes-Benz Citaro fuel cell buses, which consist of two fuel cell stacks with a total power of 250 kW and 40 kg hydrogen stored at 350 bar that provides fuel for about 200 km operation.

In addition to transports, fuel cells can be used to portable devices, such as laptops, power toys, robot toys, boats and emergency lights. Fuel cells are also used in military applications, such as for powering portable electrical devices like radios. Currently, fuel cell systems are used for stationary applications, such as heat-power cogeneration for household/residential use and uninterruptable power supply (UPS). They also find applications as back-up power supply devices in banks, hospitals, and telecom companies for maintaining their business operations during unexpected power breakdowns.

References

Aravindan, V., J. Gnanaraj *(2014) Insertion-type electrodes for nonaqueous Li-ion capacitors, Chem. Rev.,* ***114****.*

Biswal M., A. Banerjee, M. Deo *and* ***S. Ogale*** *(2013) From dead leaves to high energy density supercapacitors, Energy Environ. Sci.,* ***6****.*

Das, D., S. Santra *and* ***K. K. Nanda*** *(2018) In situ fabrication of a nickel/molybdenum carbide-anchored N-doped graphene/CNT hybrid: An efficient (Pre) catalyst for OER and HER, ACS Appl. Mater. Interfaces,* ***10***

Dutta, S., A. Bhaumik *and* ***K. C. -W. Wu*** *(2014) Hierarchically porous carbon derived from polymers and biomass: effect of interconnected pores on energy applications, Energy Environ. Sci.,* ***7****.*

A. K. Ganguli *(2014) Nickel cobaltite nanostructures with enhanced supercapacitance activity. J. Physical Chemistry C,* ***118****,*

C. D. Lokhande *(2013) Performance evaluation of symmetric supercapacitor based on cobalt hydroxide [Co(OH)2] thin film electrodes, Electrochim. Acta,* ***98****, 32– 38.*

M. Sathish *(2016) Aloe vera derived activated high-surface-area carbon for flexible and high-energy supercapacitors, ACS Appl. Mater. Interfaces,* ***8****, 35191−35202.*

Kulkarni, P., S. K. Nataraj, R. G. Balakrishna, *(2017) Nanostructured binary and ternary metal sulfides: synthesis methods and their application in energy conversion and storage devices, J. Mater. Chem. A,* ***5****.*

Kumar, K. S. *and* ***J. Thomas*** *(2019) Two-dimensional Mn3O4 nanowalls grown on carbon fibers as electrodes for flexible supercapacitors, ACS Omega,* ***4****.*

Maheswari, N. *and* ***G. Muralidharan*** *(2017) Controlled synthesis of nanostructured molybdenum oxide electrodes for high performance supercapacitor devices, Appl. Surf. Sci.,* ***416****.*

Mathur A., S. B. Dutta, D. Pal, J. Singhal, A. Singh *and* ***S. Chattopadhyay*** *(2016) High efficiency epitaxial-graphene/silicon-carbide photocatalyst with tunable photocatalytic activity and bandgap narrowing, Adv. Mater. Interfaces (1–8).*

Ojha, K., B. Kumar *and* ***A. K. Ganguli*** *(2017) Biomass derived graphene-like activated and non-activated porous carbon for advanced supercapacitors, J. Chem. Sci. 397–404.*