Influence studies of Nano Materials and its Technology for Efficient Designing of Fuel Cell – A Review

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Abstract - *Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering. The contributions of nanotechnology to the production of efficient fuel cells are discussed in this article. The focus is primarily on improvements in reliability, the viability of Proton Exchange Membrane (PEM) fuel cells, and comparative analysis of the performance of fuel cells with nanotechnology are given special attention. Climate change, exacerbated by greenhouse gas pollution, has resulted in increased interest in alternative energy sources, as have shifted in public sentiment and pressure. In this review article how nanomaterials such as carbon nanomaterial and platinum-based nanomaterials are used to increase the efficiency of fuel cells and reducing the cost of fuel cells. This study paper reflects on the work of researchers who have used nanotechnology to fabricate gasoline cells, Direct methanol fuel cells (DMFC), and microbial fuel cells (MFC). Microbial fuel cell (MFC) is a type of bio electrochemical fuel cell system that generates electric current by diverting electrons produced from the microbial oxidation of reduced compounds (also known as fuel or electron donor) on the anode to oxidized compounds (also known as an oxidizing agent or electron acceptor) on the cathode through an external electrical circuit. In addition how nanomaterials such as nitrogen-doped carbon nanotubes, platinum based nanomaterial and other metal based nanomaterials can be also implemented in other types of fuel cells such as solid oxide fuel cell, Nafion powered fuel cell is reviewed in this article*

Keywords: Nanotechnology, carbon nanotubes, Microbial fuel cell (MFC), Fuel Cells, Proton Exchange Membrane (PEM)

1.INTRODUCTION

One of the most serious issues these days is the fuel crisis. The fossil fuel is the most used source of energy in automobiles and other internal combustion engines. So the fuel cell can solve this crisis ,but fuel cells have many problems. This issue is addressed by incorporating nanotechnology into the manufacture of fuel cells. A fuel cell is a system that transforms chemical energy into electrical energy by using hydrogen or hydrocarbons and oxygen as input fuels and producing electricity and water as output fuels. Microbial fuel cell (MFC) is a bioreactor that converts energy contained in organic compound chemical bonds into electrical energy. In fuel cell technology hydrogen plays important role, the hydrogen used in the fuel cell actually transforms hydrogen's chemical energy into water, electricity, and heat. Represented as $H2 + 1/2\ O2 \longrightarrow H2O$ + Electricity + Heat, so storing of hydrogen is also important, Hydrogen storage affects both hydrogen demand and hydrogen uses, and hence plays an important part in launching a hydrogen economy. For storing hydrogen there need to achieve many criteria based on properties of hydrogen, The critical properties of hydrogen storage materials to be tested for automotive applications are (1) light weight, (ii) cost and availability, (iii) high volumetric and gravimetric density of hydrogen, (iv) rapid kinetics, (v) ease of activation, (vi) low temperature of dissociation or decomposition, (vii) sufficient thermodynamic properties, (viii) long-term cycling stability, and (ix) high temperature of dissociation or decomposition .various hydrogen storage system is explored for onboard hydrogen storing but none of these materials qualifies and fulfill all hydrogen storage criteria. Because of their peculiar properties such as surface adsorption, inter- and intragrain borders, and bulk absorption, nanostructured materials hold great promise in hydrogen storage. Nanotechnology also plays vital role in increasing efficiency of the fuel cell, the material used as a catalyst is the most significant element affecting fuel cell efficiency. Catalysts accelerate reactions at both the anode and cathode. There are many varieties of fuel cells. They are classified based on the composition of the electrolyte. For various uses, each type of fuel cell necessitates the use of special materials and fuels. Here in this paper we discuss particular electrolyte called proton exchange membrane fuel cells (PEMFCs). Platinum (Pt) and its alloys with other metals sputtered on the surface of industrial carbon are the most commonly used catalysts for electrochemical oxidation of hydrogen in PEFCs. Pt nanoclusters and hyperfine layers on PEFC electrodes are used to reduce the volume of platinum while increasing its catalyst activity. In contrast, the use of different nanostructures as a support for finely scattered Pl particles, such as carbon nanotubes (CNTs) and graphene membranes, results in higher electrochemical reaction efficiency and fuel cell efficacy as compared to a catalyst sputtered on industrial hydrogen. In this paper we also discuss about Titanium nitride nanoparticles based electrocatalysts for proton exchange membrane fuel cells. The current paper provides an in-depth examination of various uses of nanomaterials in the technology of manufacturing fuel cells for motor vehicles. Because of the relatively large number of publications on this topic, the current analysis only refers to the more common works on each of the above-mentioned fields of application of the materials.

2. What is a fuel cell?

Pandiyan , G.K et al (2020) studied about fuel cell as shown in fig 1 and the problems in the conventional fuel cell and they studied how the implementation of nanotechnology in fuel cell technology will get rid of all the problems faced by conventional fuel cell. The fuel cell is an electro chemical system that generate electricity by converting chemical energy into electrical energy. Storage of hydrogen faces many problems which cannot be solved by ordinary method, so they implemented nanotechnology in hydrogen storage to solve this problem, they found that carbon nano tubes can be used to store the required amount of hydrogen needed

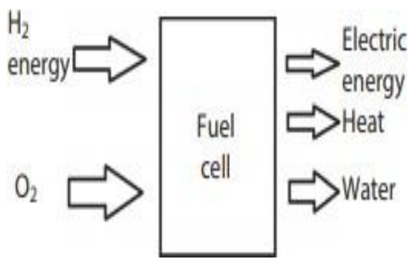

Figure 1. Fuel cell inputs and outputs

Gondal .I.A et al (2018) reported how the nanotechnology is used to increase the efficiency of the fuel cell. they examined how to improve the hydrogen technology, they gave special emphasis on photo-electrochemical technology and hydrogen storage techniques. They also talked about Solar cells-the photo-electrochemical effect and fuel cell economy

D. S. Mainardi et al (2006) explains that fuel cells have been known for a long time and still developments in areas such as electro catalyst, developments in cathodes and anodes, developments in PEMS and catalytic supports etc. recent advances in the application of nanostructured carbon-based materials have opened up a path to use carbon nanotubes as novel electro catalyst supports. Studies has shown that Pt nanoparticles supported on carbon nanotubes display remarkably higher electro catalytic activity toward the reduction of oxygen than Pt nanoparticles supported on carbon black, which would contribute to substantial cost reduction in PEM fuel cells which influences the thermodynamics and kinetics of oxygen reduction due to their length scale and specific properties further research to improve these nanotubes provide a new platform for the design of more selective and impurity-tolerant catalysts for the fuel cell.

3. Proton Exchange Membrane (PEM) fuel cells

Najjar, Y.S et al (2016) by knowing the importance of Proton Exchange Membrane (PEM) fuel cells investigated Role of Nanotechnology in Improving the Performance of PEM Fuel Cell in Future Automotive Applications. they also talked about Gas Diffusion Layer (GDL). they conducted experiment on PEM fuel cell with their own made catalyst, Membrane Electrode Assembly (MEA) and other measuring meters like voltmeters as a result they plotted the polarization curve and they found that the performance of the cell relatively decreased using silver Nano-particles

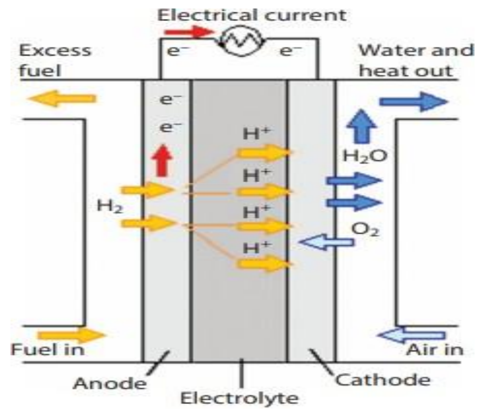

Figure 2. Typical PEM cell

Yu-Huei Su et al (2007) by knowing Improvements in properties of the polymer electrolyte membranes have been strongly related to the developments of high-performance proton exchange membranes (PEM) as shown in fig 2 for direct methanol fuel cells (DMFC) analyzed Proton exchange membranes modified with sulfonated silica nanoparticles for direct methanol fuel cells They measured proton conductivity of the nanocomposite membranes at different temperatures. As a result, they found that the strong –SO3H/–SO3H interaction between sPPEK chains andsilica-SO3Hparticles leads to ionic cross-linking in the membrane structure, which increases both the thermal stability and methanol resistance of the membranes

Saeed Moghaddam et al (2010) studied that PEM has been used as a potential for applications in energy conversion and energy storage but it has a impeded problem with its membrane electrode assembly ,to rectify the issue a silicon based inorganic-organic membrane is introduced .The silicon PEM is prepared with pores with diameters of ~5–7 nm, adding a self-assembled molecular mono layer on the pore surface ,and then capping the pores with a layer of porous silica.

Tripathi, B. P., & Shahi, V. K. - (2011), organic–inorganic nanocomposite polymer electrolyte membrane (PEM) carries nano sized inorganic constructing blocks in natural polymer through molecular degree of hybridization. The latest of polymer electrolyte membrane gas cell technology is based totally on perfluoro sulfonic acid membranes, which have some key issues and shortcomings which includes: water control, CO poisoning, hydrogen reformate and gasoline crossover. natural–inorganic nanocomposite PEM display awesome capacity for solving these problems and have attracted a lot of interest over the last ten years The motive right here is to summarize the modern day within the improvement of natural–inorganic nanocomposite PEMs for gas cellular program

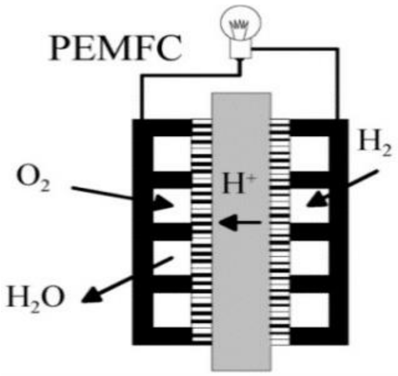

Figure3.A Typical PEMFC consumes reactant and generates a current

K.S. Dhathathreyan et al(2017) the use of nanotechnology in Proton-exchange membrane fuel cells (PEMFC) as shown in fig 3 and A *solid oxide fuel cell* (or SOFC) to increase the performance, covering all the areas related to synthesis of nanomaterials, their use as different components in fuel cells, electro catalytic medium ,electrochemical activity in a fuel cell environment, alkaline/acidic medium, various fuels etc. In the case of SOFC, the use of nanomaterials has helped bringing down the temperature of SOFC as well Sulphur tolerance at the anode and reduced coke formation, The long-term stability of the materials used in the nanotech and retention of the high conductivity need to be studied for further improvement of fuel cells.

G. Ya. Gerasimov (2015) studied nanomaterials in proton exchange fuel cells (PEFC), The central component of the PEFC system is the proton-exchange membrane. He a so studied on catalyst based on nano materials, Electrochemical reduction of Pt nanoparticles on a porous and highly formed surface of a carbon support (carbon black, CNTs) is an alternative approach for making electrodes for PEFCs that allows metal particles to be localized in specific areas of the electrode surface while reducing the thickness of the catalytic layer. Special consideration was given to the cathode catalyst, since the oxygen reducing reaction is most likely responsible for the voltage drop in the fuel cell. Carbon nanotubes have a large specific c area, a high corrosion resistance, a good electronic conductivity, and a high stability. Catalysts are precipitated on the surface of CNTs by various methods of reducing salts of Pt (II), including microemulsion, Chemical vapor deposition (**CVD**), and electrochemical methods. he also studied membrane based on nano materials and found that Nanostructured materials are also used in developing less expensive and effective membranes for fuel cells.

Brian P. Setzler et al (2016) studied Introduction of fuel cell in the automotive industry especially in automobiles by replacing the major powertrain components ,through the application of PEMFCs which has shown a higher power density, recently Hydroxide exchange membrane fuel cells (HEMFC) has gained a major traction due to its possibility of its long term advantages due to its long term cost advantages because of its possibility to use platinum group metal free catalyst, in order to achieve this in HEMFCs nanostructures are carefully optimized to pack higher surface areas into small volumes, while maintaining high area-specific activity and favorable pore-transport properties.

Shao, Y., Sui, J., et al - (2008), The studies and development of catalysts with excessive activity and excessive durability is a good-sized issue for proton alternate membrane fuel cellular (PEMFC). The nitrogen doping techniques of carbon nanostructures and the electrocatalytic factors of nitrogen-containing carbon with and without catalytic metals on it are reviewed. Pt-based catalysts with nitrogen-doped carbon as assist exhibit more suitable catalytic activity and durability. For most of the non-Pt steel catalysts (Fe, Co, and many others.) currently investigated for capability utility in PEMFC, nitrogen is the critical detail. However, the catalytic interest is still low and the steadiness problem is any other difficult trouble for non-Pt metallic catalysts. Nitrogen-doped carbon, without catalytic metals on it, additionally suggests stronger catalytic pastime.

4. Performance of fuel cell with nanotechnology:

Avasarala, B et al (2008) presented work showing that TiN nanoparticles can be used as a catalyst support material for noble metals such as Pt in PEMFCs, outperforming the traditional Pt/C electrocatalyst in terms of catalytic operation. Nanostructured TiN has proven to be a promising material for super capacitors and its application as an electrode material has also been reported. Datta and Kumta also discovered that Pt 50 percent Ru/TiN as an anode catalyst help in direct methanol fuel cells had higher catalytic activity. However, no literature explaining the use of TiN nanoparticles as a catalyst support for Pt in hydrogen-based PEMFCs has been found to our knowledge

Chen et al(2006) organized Nafion/TiO2 composites with mesoporous TiO2. The composite made with TiO2 with the pleasant surface vicinity showed the largest strength density and the first-class cell ordinary overall performance. A try has additionally been made to include a layer of TiO2 as a spacer among Nafion and the Pt catalyst. The presence of a TiO2 layer as thick as 18 nm did now not seem to have an effect on the cellular ordinary performance. It was, therefore, counseled that it is able to be feasible to update Nafion in PEMFC with TiO2. better water absorption and retention competencies of membranes at a temperature [90-degree Celsius] are of particular hobby within the higher temperature operation of gas cells. it's been said that the addition of nanoparticles of oxides including ZrO2, TiO2, and SiO2 results inside the development of water retention residences of Nafion at 90 c

Wu.J et al and T. Matsumoto et al prepared the graph fig 4 and fig 5 showing comparison on fuel cell performance using nanotechnology .they did experiment with various materials with different composites in the catalysts and electrodes and they plotted the result into graph

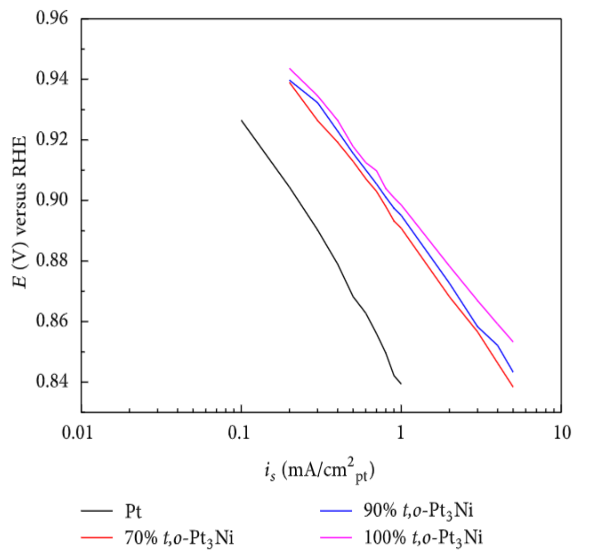

Figure 4: The performance of catalysts

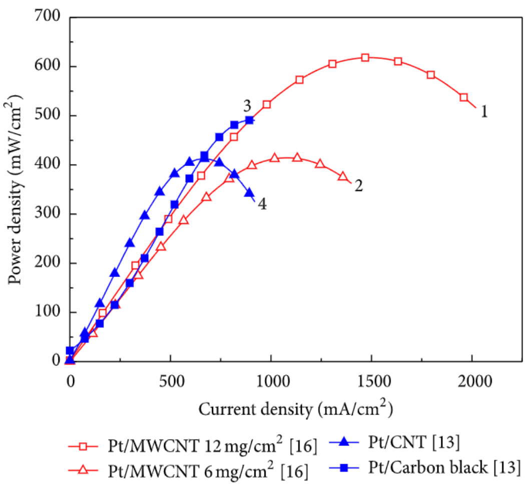

Figure 5: Current density based fuel cell performance curves

4.1 Increasing efficiency and cost reduction of fuel cells

Song, Z et al(2016) found that the problems faced by the fuel cells when using Nobel metal catalyst's are the catalyst's poor durability and higher cost, this affects the fuel cells potential in consumer marketplace ,studies are done to address this problem one of the recent progress in that field is using MOF-derived Nano catalyst which has good oxygen reduction reaction (**ORR**) activity and durability with sufficient stability ,e.g.) Zn-based metal-organic framework (MOFs) as precursor and template can be used to fabricate heteroatom-doped Nano carbon catalysts, demonstrate excellent ORR activity and long-term durability in alkaline media.

Kingshuk Dutta (2020) explains to eliminate the various bi factors which hinders performance in the FC's and provide cost effective solutions polymeric nanoparticles has been used in the catalyst system to improve the thermal and electrical conductivity, by providing a higher surface, uniform dispersion of metal catalyst, better interaction with the deposited particles, and by generating more electrons with better interfacial properties

Mei Zhang et al (2012) studied the using of carbon nanomaterials as a metal free catalyst in fuel instead of platinum. they are convinced that carbon heteroatom doping is beneficial. We are convinced that carbon heteroatom doping is successful. Nanomaterials are a kind of material that is made up (e.g., nanotube, graphene, mesoporous carbon). It has been shown to cause intramolecular charge transfer.to be a viable strategy for the production of metal-free, catalysts dependent on carbon

4.1.1 influence of CNT (carbon nanotubes) in producing cost effective fuel cell:

Garlyyev ,Kratzl et al (2019) by knowing the high cost of the electrocatalysts utilized in the oxygen reduction reaction (ORR) at the cathode of fuel cell. More specifically, only Pt-based electrocatalysts have shown sufficient activity and stability which is very costly, they synthesized platinum nanoparticles in optimum size for Enhanced Mass Activity in the Electrochemical Oxygen Reduction Reaction. Accord ing to a Sabatier study of the adsorption energies of rival intermediate species *OH and *OOH, sites with 7.5 GCN,8.3 have higher behaviors than sites with Pt. Small differences in size will significantly rearrange the surfaces of nanoparticles, as seen in Figure 6. On the optimal 2.87 nm nanoparticle, active sites form at step bottoms < beside small facets, which are stacked on top of underlying surfaces by computational analysis they found that a small increase from the optimal 2.87 nm nanoparticle up to 3 nm results in an approximately 60% lower mass activity. They showed metal–organic frameworks (MOF)-templated Pt nanoparticles with a diameter of 1.1 nm, which was estimated to be the best size in our computational screening. They highest activity reported among pure Pt-based electrocatalysts for the ORR, of similar sizes.

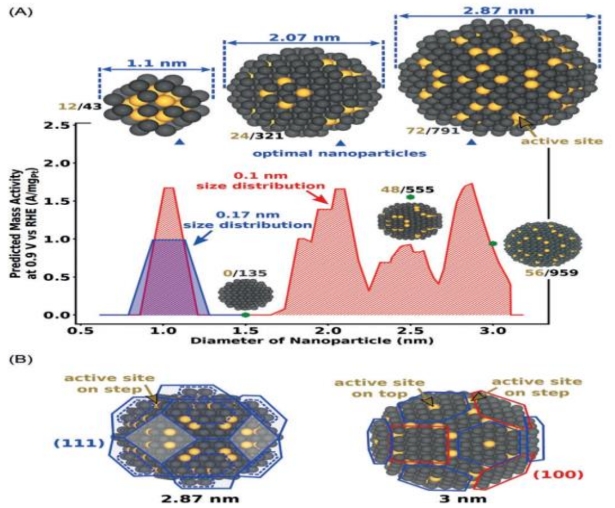

Figure 6:A) Predicted mass activities plotted versus nanoparticle diameters. Optimal nanoparticles (blue triangles) are identified at diameters of 1.1 nm, 2.07 nm, and 2.87 nm. Three less active nanoparticles (green hexagons) are exemplified at 1.5 nm, 2.5 nm, and 3 nm. The red and blue curves show predicted mass activities for nanoparticles with 0.1 nm and 0.17 nm size distribution, respectively. The ratio between active sites with 7.5, GCN,8.3 (highlighted in yellow) and the total number of sites is given for all illustrated nanoparticles. B) Low-index surfaces (111) (blue) and (100) (red) depicted on the 2.87 and 3 nm nanoparticle. On the 2.87 nm, dashed enclosed (111) surfaces are stacked on top of solid enclosed (111) surfaces.

Saha et al (2008) devised a new method for producing uniformly spaced high loading Pt nanoparticles on carbon nanotubes grown directly on carbon paper. The procedure involved treating CNTs with glacial acetic acid, which reduced the amount of Pt ion on the surface of the CNTs. Fig. 7(a-c) shows typical TEM images of CNTs/carbon paper after deposition of Pt nanoparticles synthesized by using different concentrations of Pt precursor and chemical reduction with glacial acetic acid. The monodispersed Pt particles on the CNT surface ranged in size from 2–4 nm, depending on the Pt precursor concentration. According to X-ray photoelectron spectroscopy review, the reducing agent glacial acetic acid was capable of producing high density, oxygen-containing functional groups on the surface of CNTs, resulting in high density and monodispersed Pt nanoparticles It is well established that acid treatment of CNT surfaces can significantly reduce the mechanical and electronic efficiency of nanotubes due to the introduction of a large number of defects. Nitrogen-doped carbon nanotubes (N-CNTs) have recently been stated to have improved Pt nanoparticle dispersion and have been used as support materials for fuel cell catalysts.

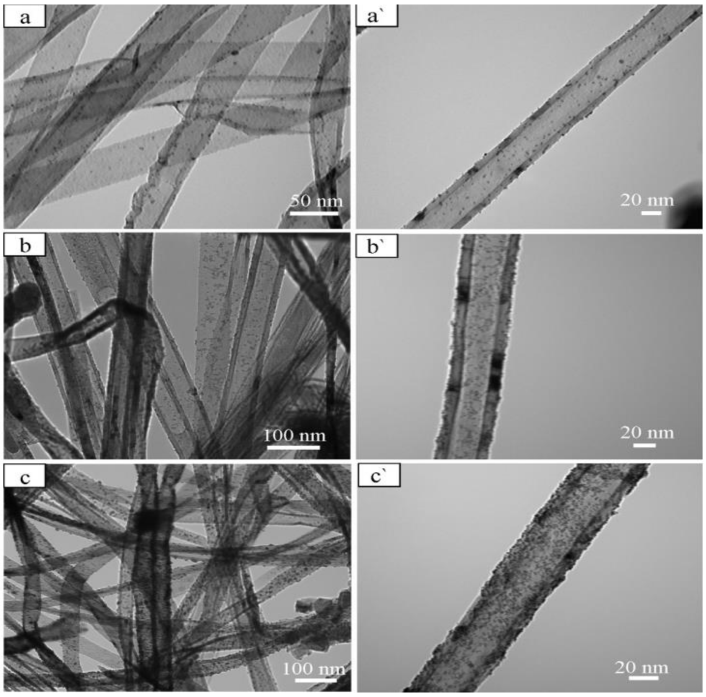

Figure 7: TEM images of Pt nanoparticles deposited on the CNTs/carbon paper from different concentrations of Pt precursor (a) 1 mM, (b) 2 mM and (c) 4 mM in glacial acetic acid. Right panel: Pt nanoparticles deposited on single CNT. The corresponding Pt loadings on the CNTs are 0.11, 0.24 and 0.42 mg Pt cm−2.

Mahesh M Wajeet al (2005) studied that CNT play a major role in leading the nanoscale investigation due to its unique structure dependent electronic and mechanical property, in this study CNTs is used as catalyst supports for Pt in a PEMFC,The deposition of small Pt nanoparticles 2–2.5nm in size has been achieved on organically functionalized carbon nanotubes deposited in situ on carbon paper , which act as molecular sites for the Pt ion adsorption and also avoid nonuniform Pt deposition on the surfaces of CNT Fig 8 shows the TEM image of Pt deposited on CNTs functionalized with the diazonium salt. , The MEA with Pt/CNT as cathode and a conventional ETEK electrode as anode was prepared, which showed a better performance than a conventional E-TEK based MEA.

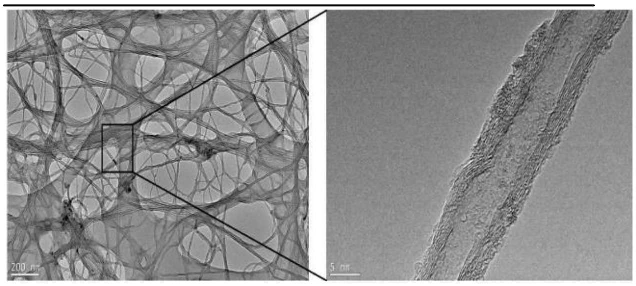

Figure 8: TEM morphology of carbon nanotubes (CNT)

According to Zeis et al (2007),Pt-plated nano porous gold leaf (Pt-NPGL) was created by means of coating a conformal, atomically skinny pores and skin of Pt over the excessive surface location pores of a skinny membrane of nano porous gold. since the Pt loading in Pt-NPGL may be regulated all the way down to 10 LG/cm2, the cloth turned into indicated to have potential as a low Pt loading, carbon-free electrocatalyst. A substance like this may be used as both an electrode and a catalyst. This method might also save you particle aggregation and consequently result in excessive dispersion and smaller nanoparticles

5. Direct methanol fuel cells (DMFC) and nanotechnology:

Ryan S Hsu et al (2010) studied that a direct ethanol fuel cell (DEFC) is a promising technology for power supply for transportation and portable electronic device applications. Ethanol has a distinct advantage over methanol and hydrogen as it is non-toxic .and is in the liquid state at room temperatures, but DFC can't be commercialized because slow reaction kinetics at the anode, (ii) low catalyst tolerance to reaction intermediates and, poor performance due to unfavorable end-product selectivity. To overcome this issues Pt/SnO_2–SWNT electro catalysts they are optimized by varying the SnO_2 loadings.

Eiichi Sakaue et al (2005) Approaches are made to resize the DMFCs into compact and simple to use for commercial approaches and to do that nanotechnology and MEMS play a Important role in this approach. The carious strategic approach to downsize of DMFCs are as following increasing the efficiency ,increasing the catalysts activity ,reduction in methanol crossover ,reduction in ohmic loss Decreasing the size of the fuel tank without the decrease in the energy density downsize of auxiliary devices .and regular improvements in PEM and MEA layer reduces the diameter of the pores and ensures their hydration and the proton conductivity 2 to 3times of higher magnitude than that of Nafion at low humidity thus the application of nanotechnology improves the conductivity of the Fuel cell.

Zhongwei Chen et al (2006) reported that Direct-methanol *fuel cells* DMFCs had an issue of poor methanol oxidation at the cathode and the methanol crossover transfer from the anode to cathode remains the main problem faced by the DMFCs these problems are addressed By combining conductive polymer and metal nanoparticles, new electrocatalysts, with higher surface areas and enhanced methanol oxidation activity, can be generated these electro catalyst are used to solve the issues in the DMFCs. the catalyst used in this study is Pt/PaniNFs. It shows higher electrocatalytic activity and catalyst tolerance for the methanol oxidation reaction

Basri, S., Kamarudin, S. K., et al - (2010), Nanotechnology has recently been carried out to direct methanol fuel cells (DMFC), one of the most suitable and promising alternatives for transportable gadgets. With characteristics along with low operating temperature, excessive strength-conversion performance and occasional emission of pollutants, DMFCs may also assist clear up the destiny energy crisis. Catalysts composed of small, metal debris, which include platinum and ruthenium, supported on nanocarbons or metal oxides are widely utilized in DMFC. Thus, this paper gives a top-level view of the improvement of nano catalysts for DMFC. Mainly, this overview focuses on nano catalyst shape, catalyst guide, and challenges inside the synthesis of nano catalyst. This paper also tells about computational methods for theoretical modeling of nanomaterials consisting of carbon nanotubes (CNT) through molecular dynamic techniques.

Du, H et al (2018) studied the implementation of Carbon Nanomaterials in Direct Liquid Fuel Cells, they started with MWCNT-supported Pt-Pd bimetallic nanoparticles. X-ray diffraction, scanning electron microscopy, and transmission electron microscopy were used to classify the catalysts, which revealed an average particle size of 4.0 nm scattered uniformly on the Multi-walled carbon nanotubes (MWCNT) surface. Pd has recently been discovered to have higher catalytic activity than Pt in the ethanol oxidation reaction in alkaline media, leading to the invention of Pd or Pd based alloy or composite nano catalysts. Direct formic acid fuel cells, unlike direct methanol/ethanol fuel cells, can run in acidic solutions. The electrodes, electrolytes, and working conditions all play a role in the formic acid oxidation reaction. They used Pd-coated MWCNTs to investigate the effects of different operating conditions on the reaction, including formic acid and sulfuric acid concentrations, as well as temperature. They produced some TEM images of PdO/MWCNT, PdO/graphene, and PdO/graphite.

6. Microbial gas cells (MFCs) and nanotechnology:

Rojas, J. P., & Hussain, M. M. (2015) - Innovative solutions are paramount to the identification and improvement of alternative energy assets. Microbial gas cells (MFCs) are a trending rising generation that guarantees green strength production while simultaneously treating wastewater. At present, numerous studies efforts are operating towards which bacteria, fuels, and materials are surest for growing the greenest MFCs; micro sized MFCs have a key role in this intention. The current microfabrication techniques for building micro sized cells and problematic on their advantages and the demanding situations that need to be overcome. The focus on the integration of nanomaterials into MFCs and finish with the demanding situations to scale up MFCs and capacity makes use of for those miniature cells.

Morozan, A., Stamatin, L., et al - (2007) - Carbon nanotubes have been organized and their biocompatibility with specific species of carbon nanotubes (CNTs) evaluated in phrases of their incorporation right into a microbial fuel cell (MFC) anodic design. Multi wall carbon nanotubes (MWNTs) with various morphologies and systems, as received, and synthesized via the pyrolysis of novolac with ferrocene addition had been used. MWNTs had been characterized by TEM and toes-IR spectroscopy. Designed Bio nanocomposites (BNCs) are excellent subculture cells media and the electrodes primarily based on synthesized CNTs may be used with properly outcomes in MFCs, from the point of view of bacteria biocompatibility the performance of catalysts

Ghasemi M., Daud W. R. W., et al - (2013), The microbial fuel mobile (MFC) is a totally promising technology for producing electric power from anaerobic fermentation of organic and inorganic. The overall low overall performance of the MFC compared to other extra established gas mobile technology and the excessive cost of its additives in comparison to the low fee of the wastewater it dealt with, are the two main obstacles to commercialization. In latest years, MFC's performance has been advanced through using amongst other things, inexpensive nano-composite materials including nano-established carbon within the electrodes which are more conductive and mechanically stabile with large surface region and better electrochemical catalytic interest in comparison to the conventional Pt on carbon

e Quynh Hoa et al (2017) studied Carbon-Based Nanomaterials in Biomass-Based Fuel-Fed Fuel Cells, he proposed starch-based fuel cell, It is much simpler to process than cellulose because it is easier to degrade, thus requires relatively less energy to process. Spets et al. proposed a direct fuel cell operating with Pt–Pd as an anodic catalyst and the cathode electrode contained a catalyst loading of 3.15 mg cm^{-2} of Cobalt-meso-tetraphenylporphyrine (CoTPP) in concentration of 18% on carbon and of 17.5 mg cm^{-2} of $MnCo_2O_4$. This direct fuel cell, operating with 10 g L^{-1} of starch in 2 M KOH, although utilized noble metal as catalyst, could not gain more than 1 mA cm^{-2} at 51 ∘ C

5. Other influence of nanotechnology in fuel cell:

Lee, J. W., & Kjeang, E. - (2013), Gasoline cells are gaining momentum as a essential aspect within the renewable strength mix for desk bound, transportation, and transportable electricity packages. In the present article, a nanofluidic fuel cell that makes use of fluid glide through nano porous media is conceptualized and verified for the primary time. This transformative idea captures the advantages of recently developed membrane less and catalyst-unfastened gasoline mobile architectures. While compared to formerly pronounced microfluidic gasoline cells, the prototype nanofluidic gasoline cellular demonstrates improved surface place, reduced activation overpotential, in the excessive cellular voltage regime with up to fourteen% higher power density. however, the expected mass delivery benefits within the high cutting-edge density regime have been confined with the aid of excessive ohmic cell resistance.

Tsuchiya, M., Lai, B.-K., et al - (2011), Using oxide gasoline cells and different strong-kingdom ionic devices in strength packages is constrained via their requirement for expanded working temperatures, generally above 800 °C. skinny-movie membranes allow low-temperature operation with the aid of lowering the ohmic resistance of the electrolytes. The nanoscale yttria-stabilized zirconia membranes with lateral dimensions on the scale of millimeters or centimeters may be made thermomechanical strong through depositing metallic grids on them to function as mechanical supports. Our massive-place membranes can also be applicable to electrochemical electricity applications inclusive of gasoline separation, hydrogen production and permeation membranes.

Chen, Z., Higgins, D., et al - (2009), one of the main challenges inside the commercialization of low temperature gasoline cells is the sluggish oxygen reduction reaction kinetics and the excessive value and scarcity of platinum (Pt)-based totally catalysts. As a end result, alternative non-noble electrocatalysts to Pt substances for ORR is wanted to recognize the sensible software of gasoline cells. On this examine, nitrogen-doped carbon nanotubes (NCNTs) have been synthesized as a non-noble electrocatalyst for the ORR the usage of ethylenediamine (EDA-NCNT) and pyridine (Py-NCNT) as one of a kind nitrogen precursor by using a single-step chemical vapor deposition (CVD) process. by using combining the results of ORR pastime and fabric characterization, it is concluded that higher nitrogen content and greater defects of NCNT lead to excessive ORR overall performance.

Krishnakumar, M., & Ramaprabhu, S. - (2007), Palladium nano catalysts supported on surface-oxidized multiwalled carbon nanotubes had been prepared by the aqueous answer discount of $PdCl_2$. MWNT had been synthesized by catalytic chemical vapor deposition (CCVD) approach. Pyrolysis of acetylene using a set-mattress catalytic reactor over uncommon earth (RE) primarily based AB_2 alloy hydride catalyst, obtained thru hydrogen decrepitation approach, has been achieved to synthesize MWNT. Investigations of hydrogen sensing properties of Pd–MWNT ensembles have been achieved. the steadiness of Pd–MWNT skinny films after several cycles of adsorption and desorption changed into studied. The alternate in electrical resistance because of hydrogen adsorption is reversible, with growth to saturation on exposure to hydrogen fuel. The effects display that chemically treated MWNT functionalized with nanostructured Pd display correct H_2 sensing response at room temperature.

Luo, C., Xie, H., et al - (2015), Fuel cells constitute an appealing generation for day after today's energy vector due to the fact hydrogen is an green gas and environmentally easy, but one of the crucial challenges for fuel cell commercialization is the preparation of energetic, strong and occasional-price catalysts. The synthesis and processing of molecularly-capped multimetallic nanoparticles, as described in this report, serves as an exciting manner to deal with this project. This newsletter discusses current findings of our investigations of the synthesis and processing of nanostructured catalysts with managed length, composition, and floor residences with the aid of highlighting a few examples of bimetallic/trimetallic nanoparticles and supported catalysts for electrocatalytic oxygen reduction.

Tang, J., Liu, J., et al - (2014), The ideal catalyst support closer to improvement of excessive-overall performance electrodes for gas cells must possess effective structural and chemical functions concerning accessibility to framework surfaces and electrochemical stability of conducting frameworks. In this evaluation, the recent developments of nano porous carbon materials synthesis are summarized with advent in their potentials in gasoline cells. The focuses are placed on precise controls of porosity, crystallinity, and morphology, blended with the designs of floor shape, framework composition, and encapsulation of metallic and metallic oxide nanoparticles. subsequently, a few perspectives are supplied for future tendencies and guidelines of the synthesis and functionalization of nano porous carbon substances for fuel cellular design.

Thiam, H. S., Daud, W. R. W., et al - (2011), Fuel cells are predicted to soon become a source of low- to zero-emission electricity generation for programs in portable technology and electric powered motors. Nanostructures were recognized as essential elements to improve the overall performance of fuel cellular membranes. They offer a top-level view of research and development of nano based membranes for distinctive gas mobile packages and focuses on improvement of gas cellular membranes by means of these nanostructures. Theoretical studies the use of molecular-scale modeling and simulation of fuel cell membranes have also been covered in this review. other troubles regarding the era limitations, research demanding situations and future traits are also reviewed.

CONCLUSIONS

One of the major issues that we are now dealing with is air quality. The exhaust smoke from factories and cars is the primary source of air emissions. Air emissions can be reduced to a significant extent if fuel cells are used as a power source in vehicles and factories.so we bring fuel cell technology to the lime light. Fuel cells used today are enormous in scale and cannot be used as internal combustion engines (IC engines), which are used for automobiles. Nanostructures and nanoscale processes tend to be suitable for improving the efficiency of catalysts in fuel cell and electrodes, hydrogen storage products, and fuel cell membrane electrode assemblies. Physisorption, a non-dissociative mechanism, is used to store hydrogen in mofs and carbon nanostructures. Nanotechnology is playing an increasingly important role in improving process performance. PEMFCS have the ability to be used as a transportation power source. The reduction of cost by reducing Pt loading in the electrode and improving the membrane's conductivity and water retention properties are the two most pressing problems in the commercialization of fuel cells. The total cost can be reduced by reducing the size of Pt nanoparticles by novel synthesis methods and the discovery of alternate catalysts. Sulfonated silica nanoparticles incorporated into sulfonated polymers to form nanocomposite membranes increase thermal stability while lowering methanol crossover. We studied how nanotechnology can also be implemented in microbial fuel cell, The Naval Research Laboratory of the United States developed nano porous membrane microbial fuel cells that produce passive diffusion inside the cell using a non-PEM. We also found that Nano particles as catalysts are characterized by large surface area and a high degree of dispersion of metal constituents on the surface of the support. Still many of this research is in laboratory level when it applies to the real life it can be the game changer of this century

REFERENCES:

[1] Avasarala, B., Murray, T., Li, W. and Haldar, P., 2009. Titanium nitride nanoparticles based electrocatalysts for proton exchange membrane fuel cells. Journal of materials Chemistry, 19(13), pp.1803-1805.https://doi.org/10.1039/B819006B

[2] Basri, S., Kamarudin, S. K., Daud, W. R. W., &Yaakub, Z. (2010). Nanocatalyst for direct methanol fuel cell (DMFC). International Journal of Hydrogen Energy, 35(15), 7957–7970. doi:10.1016/j.ijhydene.2010.05.111

[3] Chen, Z., Higgins, D., Tao, H., Hsu, R. S., & Chen, Z. (2009). Highly Active Nitrogen-Doped Carbon Nanotubes for Oxygen Reduction Reaction in Fuel Cell Applications. The Journal of Physical Chemistry C, 113(49), 21008–21013. doi:10.1021/jp908067v

[4] Chen, Z., Xu, L., Li, W., Waje, M. and Yan, Y., 2006. Polyaniline nanofibre supported platinum nanoelectrocatalysts for direct methanol fuel cells. Nanotechnology, 17(20),p.5254.

[5] Dhathathreyan, K.S., Rajalakshmi, N. and Balaji, R., 2017. Nanomaterials for fuel cell technology. Nanotechnology for Energy Sustainability, pp.569-596.

[6] Du, H., Zhao, C.X., Lin, J., Guo, J., Wang, B., Hu, Z., Shao, Q., Pan, D., Wujcik, E.K. and Guo, Z., 2018. Carbon nanomaterials in direct liquid fuel cells. The Chemical Record, 18(9), pp.1365-1372.https://doi.org/10.1002/tcr.201800008

[7] Dutta, K., 2020. Polymeric nanomaterials in fuel cell applications. In Nanostructured, Functional, and Flexible Materials for Energy Conversion and Storage Systems (pp. 105-129). Elsevier.

[8] Fan, L., Wang, C., Chen, M. and Zhu, B., 2013. Recent development of ceria-based (nano)composite materials for low temperature ceramic fuel cells and electrolyte-free fuel cells. Journal of Power Sources, 234,pp.154-174.

[9] Fan, L., Zhu, B., Su, P.C. and He, C., 2018. Nanomaterials and technologies for low temperature solid oxide fuel cells: recent advances, challenges and opportunities. Nano Energy, 45,pp.148-176.

[10] Garlyyev, B., Kratzl, K., Rück, M., Michalička, J., Fichtner, J., Macak, J.M., Kratky, T., Günther, S., Cokoja, M., Bandarenka, A.S. and Gagliardi, A., 2019. Optimizing the size of platinum nanoparticles for enhanced mass activity in the electrochemical oxygen reduction reaction. AngewandteChemie International Edition, 58(28), pp.9596-9600.DOI: 10.1002/anie.201904492

[11] Gerasimov, G.Y., 2015. Nanomaterials in proton exchange fuel cells. Journal of Engineering Physics and Thermophysics, 88(6), pp.1554-1568.

[12] Ghasemi, M., Daud, W.R.W., Hassan, S.H., Oh, S.E., Ismail, M., Rahimnejad, M. and Jahim, J.M., 2013. Nano-structured carbon as electrode material in microbial fuel cells: a comprehensive review. Journal of Alloys and Compounds, 580, pp.245-255.

[13] Guo, S. and Wang, E., 2011. Noble metal nanomaterials: controllable synthesis and application in fuel cells and analytical sensors. Nano Today, 6(3), pp.240-264

[14] Hoa, L.Q., Vestergaard, M.D.C. and Tamiya, E., 2017. Carbon-based nanomaterials in biomass-based fuel-fed fuel cells. Sensors, 17(11), p.2587

[15] Hsu, R.S., Higgins, D. and Chen, Z., 2010. Tin-oxide-coated single-walled carbon nanotube bundles supporting platinum electrocatalysts for direct ethanol fuel cells. Nanotechnology, 21(16),p.165705.https://doi.org/10.1002/ente.201500126

[16] J. Wu, J. Zhang, Z. Peng, S. Yang, F. T. Wagner, and H. Yang, “Truncated octahedral Pt3Ni oxygen reduction reaction electrocatalysts,” Journal of the American Chemical Society, vol. 132, no. 14, pp. 4984–4985, 2010.

[17] KRISHNAKUMAR, M., & RAMAPRABHU, S. (2007). Palladium dispersed multiwalled carbon nanotube based hydrogen sensor for fuel cell applications. International Journal of Hydrogen Energy, 32(13), 2518–2526. doi:10.1016/j.ijhydene.2006.11.015

[18] Lee, J.W. and Kjeang, E., 2013. Nanofluidic fuel cell. Journal of power sources, 242, pp.472-477.

[19] Luo, C., Xie, H., Wang, Q., Luo, G., & Liu, C. (2015). A Review of the Application and Performance of Carbon Nanotubes in Fuel Cells. Journal of Nanomaterials, 2015, 1–10. doi:10.1155/2015/560392

[20] Mainardi, D.S. and Mahalik, N.P., 2006. Nanotechnology for fuel cell applications. In Micromanufacturing and Nanotechnology (pp. 425-440). Springer, Berlin,Heidelberg.

[21] Mao, S.S., Shen, S. and Guo, L., 2012. Nanomaterials for renewable hydrogen production, storage and utilization. Progress in Natural Science: Materials International, 22(6), pp.522-534.

[22] Moghaddam, S., Pengwang, E., Jiang, Y.B., Garcia, A.R., Burnett, D.J., Brinker, C.J., Masel, R.I. and Shannon, M.A., 2010. An inorganic–organic proton exchange membrane for fuel cells with a controlled nanoscale pore structure. Nature Nanotechnology, 5(3), pp.230-236..

[23] Morozan, A., Stamatin, L., Nastase, F., Dumitru, A., Vulpe, S., Nastase, C., … Scott, K. (2007). The biocompatibility microorganisms-carbon nanostructures for applications in microbial fuel cells. Physica Status Solidi (a), 204(6), 1797–1803. doi:10.1002/pssa.200675344

[24] Najjar, Y.S. and Safadi, M., 2016. The Role of Nanotechnology in Improving the Performance of PEM Fuel Cell in Future Automotive Applications. Journal of Sustainable Energy Engineering, 4(1), pp.59-79.

[25] Niemann, M.U., Srinivasan, S.S., Phani, A.R., Kumar, A., Goswami, D.Y. and Stefanakos, E.K., 2008. Nanomaterials for hydrogen storage applications: a review. Journal of Nanomaterials, 2008.

[26] Pandiyan, G.K. and Prabaharan, T., 2020. Implementation of nanotechnology in fuel cells. Materials Today:Proceedings.

[27] Qiao, Y. and Li, C.M., 2011. Nanostructured catalysts in fuel cells. Journal of Materials Chemistry, 21(12), pp.4027-4036.https://doi.org/10.1039/C0JM02871A

[28] Rojas, J. P., & Hussain, M. M. (2015). The Role of Microfabrication and Nanotechnology in the Development of Microbial Fuel Cells. Energy Technology, 3(10), 996–1006. doi:10.1002/ente.201500126

[29] Saha, M.S., Li, R. and Sun, X., 2008. High loading and monodispersed Pt nanoparticles on multiwalled carbon nanotubes for high performance proton exchange membrane fuel cells. Journal of Power Sources, 177(2), pp.314-322.

[30] Sakaue,E., 2005, January. Micromachining/nanotechnology in direct

methanol fuel cell. In 18th IEEE International Conference on Micro Electro Mechanical Systems, 2005. MEMS 2005. (pp. 600-605). IEEE.

[31] Salar-García, M.J. and Ortiz-Martínez, V.M., 2019. Nanotechnology for wastewater treatment and bioenergy generation in microbial fuel cells. In Advanced Research in Nanosciencesfor Water Technology (pp. 341-362). Springer,Cham.

[32] Setzler, B.P., Zhuang, Z., Wittkopf, J.A. and Yan, Y., 2016. Activity targets for nanostructured platinum-group-metal-free catalysts in hydroxide exchange membrane fuel cells. Nature nanotechnology, 11(12),pp.1020-1025.

[33]Shao, Y., Sui, J., Yin, G., & Gao, Y. (2008). Nitrogen-doped carbon nanostructures and their composites as catalytic materials for proton exchange membrane fuel cell. Applied Catalysis B: Environmental, 79(1), 89–99.

[34]doi:10.1016/j.apcatb.2007.09.047

[35] Song, Z., Cheng, N., Lushington, A. and Sun, X., 2016. Recent progress on MOF-derived nanomaterials as advanced electrocatalysts in fuel cells. Catalysts, 6(8), p.116.

[36] Su, Y.H., Liu, Y.L., Sun, Y.M., Lai, J.Y., Wang, D.M., Gao, Y., Liu, B. and Guiver, M.D., 2007. Proton exchange membranes modified with sulfonated silica nanoparticles for direct methanol fuel cells. Journal of Membrane Science, 296(1-2), pp.21-28.https://doi.org/10.1016/j.memsci.2007.03.007

[37] Sun, F., Qin, L.L., Zhou, J., Wang, Y.K., Rong, J.Q., Chen, Y.J., Ayaz, S., Hai-Yin, Y.U. and Liu, L., 2020. Friedel-Crafts self-crosslinking of sulfonated poly (etheretherketone) composite proton exchange membrane doped with phosphotungstic acid and carbon-based nanomaterials for fuel cell applications. Journal of Membrane Science, 611,p.118381.

[38]T. Matsumoto, T. Komatsu, K. Arai et al., "Reduction of Pt usage in fuel cell electrocatalysts with carbon nanotube electrodes," Chemical Communications, vol. 10, no. 7, pp. 840–841, 2004.

[39]Tang, J., Liu, J., Torad, N. L., Kimura, T., & Yamauchi, Y. (2014). Tailored design of functional nanoporous carbon materials toward fuel cell applications. Nano Today, 9(3), 305–323. doi:10.1016/j.nantod.2014.05.003

[40] Thiam, H.S., Daud, W.R.W., Kamarudin, S.K., Mohammad, A.B., Kadhum, A.A.H., Loh, K.S. and Majlan, E.H., 2011.Overviewonnanostructuredmembraneinfuelcell applications. International journal of hydrogen energy, 36(4),pp.3187-3205.

[41]Tripathi, B. P., & Shahi, V. K. (2011). Organic–inorganic nanocomposite polymer electrolyte membranes for fuel cell applications. Progress in Polymer Science, 36(7), 945–979. doi:10.1016/j.progpolymsci.2010.12.005

[42]Tsuchiya, M., Lai, B.-K., & Ramanathan, S. (2011). Scalable nanostructured membranes for solid-oxide fuel cells. Nature Nanotechnology, 6(5), 282–286. doi:10.1038/nnano.2011.43

[43]Waje, M.M., Wang, X., Li, W. and Yan, Y., 2005. Deposition of platinum nanoparticles on organic functionalized carbon nanotubes grown in situ on carbon paper for fuel cells. Nanotechnology, 16(7), p.S395

[44]Zeis R, Mathur A, Fritz G, Lee J, Erlebacher J (2007) J Power Sources 165:65. doi:10.1016/j.jpowsour.2006.12.007

[45]Zhang, M. and Dai, L., 2012. Carbon nanomaterials as metal-free catalysts in next generation fuel cells. Nano Energy, 1(4), pp.514-517.

[46]Zhang, W., &Pintauro, P. N. (2011). High-Performance Nanofiber Fuel Cell Electrodes. ChemSusChem, 4(12), 1753–1757. doi:10.1002/cssc.201100245

[47]Zhao, H., Li, L., Yang, J., & Zhang, Y. (2008). Nanostructured polypyrrole/carbon composite as Pt catalyst support for fuel cell applications. Journal of Power Sources, 184(2), 375–380. doi:10.1016/j.jpowsour.2008.03.024

[48]Zhong, C.-J., Luo, J., Fang, B., Wanjala, B. N., Njoki, P. N., Loukrakpam, R., & Yin, J. (2010). Nanostructured catalysts in fuel cells. Nanotechnology, 21(6), 062001. doi:10.1088/0957-4484/21/6/062001

[49]Zhong, C.-J., Luo, J., Njoki, P. N., Mott, D., Wanjala, B., Loukrakpam, R., … Xu, Z. (2008). Fuel cell technology: nano-engineered multimetallic catalysts. Energy & Environmental Science, 1(4), 454. doi:10.1039/b810734n

[50]Zhu, B. (2009). Solid oxide fuel cell (SOFC) technical challenges and solutions from nano-aspects. International Journal of Energy Research, 33(13), 1126–1137. doi:10.1002/er.1600