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Performance and Load Analysis of Lithium Ion Battery for Electric Vehicle Using Thermal Modeling in Ansys

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***Abstract:** The paper here studies about the behavior of Li-Ion Battery cell or battery pack under various fluctuating and combined loads. The thermal model of a unit cell is designed and they are assembled to form a battery pack. The software tool Ansys 13.0 is used for analysis. The study is done on a single cell and various thermal properties are calculated under the simulated environment. Now the entities like heat generation and dissipation is found out for a cell. The cells are aligned in an orderly manner and the result obtained from individual cell can be used to find out the cumulative battery pack heat generation as a multiple of electrode location and the rate of duration. The rate of charge flow and voltage characteristics are depicted in the IV curve and various important parameters are calculated. The Sporadic dispersal of heat generation during charge and discharge was studied in a systematic way and robust battery pack design is suggested in the paper which can be used in the electric vehicle as well as hybrid electric vehicles.*
***Keywords:** Electric vehicles, Lithium Ion Battery, Thermal management, Design of battery, Ansys*

I. INTRODUCTION

The importance of renewable energies and electric energy has been increasing on a rapid rate considering the decline of fossil fuel resources and increase in global warming causing erratic behavior of nature and climate. Lithium ion battery is considered as one of the best source of power to run automotives with electrical energy, a cleaner and safe energy. The Li-Ion batteries have prolonged life, low rate of discharge, and other various performance characteristics. A lot of research has been done on the behavior of Li-Ion Battery analytically and experimentally. The significance of this analysis is that when there is an intermittent distribution of heat in the system and it affects the electrical stability and causes under performance. So it is evident from above that a robust thermal management is necessary to take the performance to optimality. In this work, a 3D thermal model is made with battery pack containing eight unit cells and thorough analysis is made with accurate mesh generation using Ansys software.

II. LITHIUM ION POWER PACK WORKING

The lithium-ion battery is the power source for modern electric Vehicles these days everyone's heard of lithium-ion batteries but what makes them so special first to follow each battery is made up of many smaller batteries called cells old let's take a closer look at want to see how it works the electrical current reaches the cells by a conductive surfaces in this case aluminum on one side and copper on the other then just as in every other battery there's a positive and negative electrode called the cathode and the anode the cathode or positive electrode is made it a very pure lithium metal oxide the more uniform its chemical composition the better the performance and the longer the battery life is as you'd expect the an old or negative electrode is located on the other side it's made of graphite a form of carbon with the layered structured . The battery is filled with the transport medium the electrolyte so that the lithium ions carrying the battery's charge can flow freely, this electrolyte must be extremely pure and is free of water as possible in order to ensure efficient charging and discharging for to prevent a short circuit there's a layer placed between the two electrodes the separator to the tiny lithium ions and the separators are actually permeable. When a battery is charged the positively charged lithium ions pass from the cathode through the separator into the layered graphite structure of the anode where they're stored. Now the battery is charged. when the battery discharges that is when energy is removed from the cell the lithium ions travel by the electrolyte from the anode through the separator back to the cathode , then the motor converts the electrical energy into mechanical energy making the cargo the amount of energy available and how long the batteries last is closely related to the quality of the materials used them to sum it all up higher quality pure materials along with customized formulations lead to longer battery life and better battery performance.

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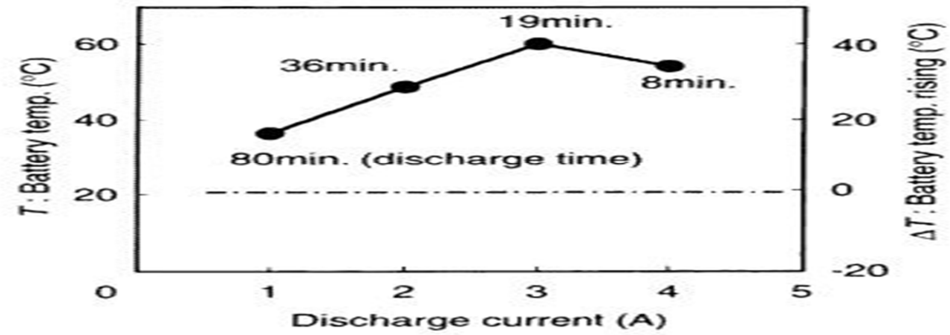
Figure 1. Discharge current vs. Battery temperature



III. MATHEMATICAL MODEL AND THERMAL MODELLING

The battery pack is a pouch-type Lithium unit cells used as a model in the present analysis. The Lithium unit cell Contains Li, Mn, Co, Ni as anodes and graphite as cathode electrodes. There is a porous membrane type separator which is a plasticized polymer electrolyte. . There are many types of connections for a battery pack and one among such is two unit cells are aligned in parallel. This forms a unit big length. Then the four fragments are arranged in parallel).

Figure 2 $: Q = aJ\left[Vo - Vcell - T\frac{dVo}{dT}\right] + Aa\left[\left[\frac{\nabla Va^2}{ra}\right]\right] + Ac\left[\left[\frac{\nabla Vc\text{^}2}{rc}\right]\right]$

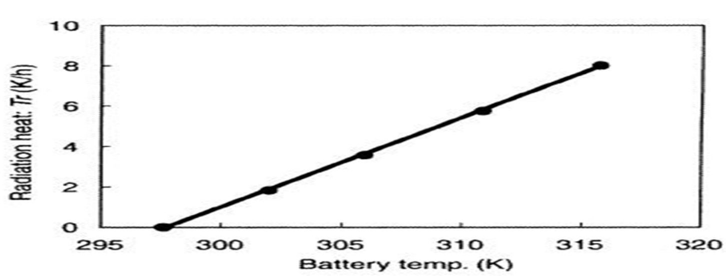
Q=heat generation J= current density Vo=open circuit voltage Vcell= Voltage of unit cell ra=resistance of anode rc= resistance of cathode Va= voltage of anode Vc= Voltage of cathode

Figure 3.Properties of materials used for various departments in the Lithium Ion Cell

Thermal Property (unit)	Battery	Aluminum	Air	Plastic
ρ (kg·m^{-3})	2765	2705	1.225	1360
C_p (J·kg^{-1}·°C^{-1})	1394	900	1006	1500
k_x (W·m^{-1}·°C^{-1})	25.7	231	0.0242	0.35
k_y (W·m^{-1}·°C^{-1})	25.7	231	0.0242	0.35
k_z (W·m^{-1}·°C^{-1})	0.794	231	0.0242	0.35

A Mathematical equation is deduced in terms of rate of charge flow and the voltage parameters and using this heat distribution rate is found out as function of location of the electrode and this information is fed as input for making a thermal model. The various parameters like velocity, pressure, temperature are found out at various operational loads. For CFD Analysis turbulence model was used. The boundary analysis conditions at the entrance for the fluid flow analysis are set to 0.006589, 0.01235, 0.01985, and 0.03514 kg/s for the different volume rates of 15, 26, 35, and 45 ft3/min.

Figure 4. Battery temperature and the corresponding radiation heat.



The boundary conditions at the exit for the fluidic flow field are to be fixed at an appropriate pressure and this is set to be 1.2 atm. So the pressure parameter is decided for the analysis but the entrance and exit temperatures are maintained at ambient temperature i.e. 25 degree centigrade. For thermal analysis we know that the heat transfer coefficient is necessary and we

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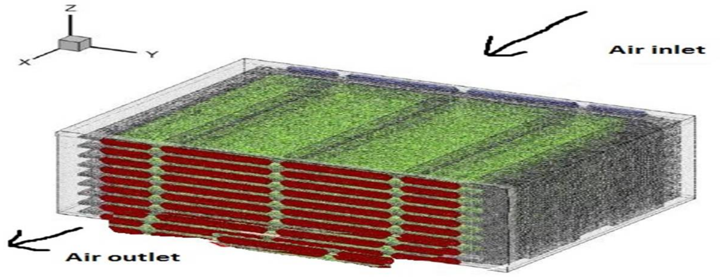
assume that the surface exposed to the atmosphere has an h= 7 W/m2·°C1. The meshing should be thorough and improper meshing leads to absurd results completely deviate from the real analysis and the analysis has been started with 2,929,250 cells.

Figure 5. Thermal model of Lithium ion battery



The following reactions lead to discharge due to complex interaction of multiple reactions.

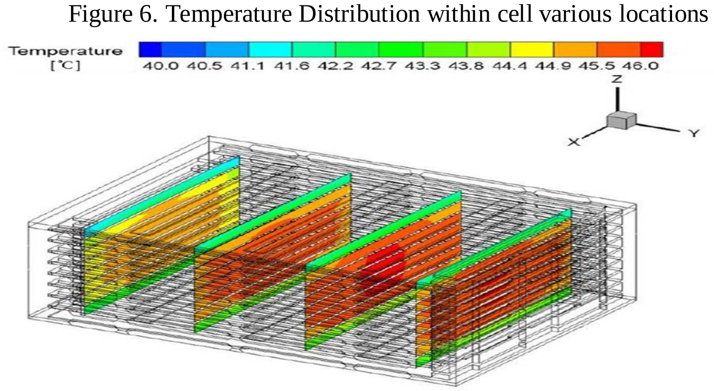
$$HCOOCH_3 \rightarrow HCOOLi + alkanes$$
$$HCOOCH_3 \rightarrow CH_3COLi + CO_2 + H_2$$
$$EC \rightarrow (CH_2OCO_2Li)_2 + CH_2{=}CH_2$$
$$ROCO_2Li + H_2O \rightarrow ROH + CO_2 + Li_2CO_3$$
$$H_2O \rightarrow LiOH + H_2 \rightarrow Li_2O + H_2$$
$$HCOOCH_3 + LiOH \rightarrow HCOOLi + CH_3OH$$
$$CH_3OH \rightarrow CH_3OLi + H_2$$
$$LiPF_6 \rightarrow 3LiF + PF_3$$
$$PF_3 \rightarrow Li_xPF_y + LiF$$

But the discharge is not completely attributed to these reactions only.

IV. RESULTS

We initially obtain the voltage and rate of charge flow values and using this the temperature distribution is found using the mathematical equation mentioned above Figure 2 . Initially the temperature dissemination in the modelling at discharge rate durations of 450 followed by 1800 is studied. All the temperature variations are at 3C rate. Following this same temperature variation is studied for discharge rate time of 300,600,1200seconds with 2C rate is studied. From the temperature dispersion in software it is clearly evident that the temperature value close to the charge accumulation point of the anode is greater than the temperature at the cathode .The significant reason for this situation is that the thermal conductivity value of the active anode is greater than that of the cathode. As a result it can be seen that though the same amount of charge flows near both the electrodes the temperature varies a bit.

Figure 6. Temperature Distribution within cell various locations



A. Discharge Rate Representation

Charge and Discharge rate are expressed in terms of C –rate. 1C means 1Ah capacity battery can deliver 1amp of current for 1hr when it is 100% charged. 1C is here the rated capacity of a battery. If the same capacity battery discussed above has 2C discharge rate, it means that it can output 2amp of current for 30 minutes and if it is 3C discharge rate 3amp of current for 20 minutes, 0.5C means it can give 0.5A for 120 minutes or 2 hrs.

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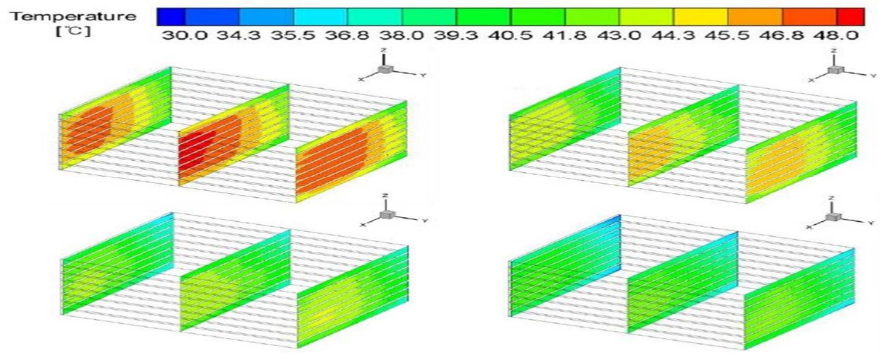
Figure 7. Temperature distribution of unit cells within the module with various volume flow rates of air

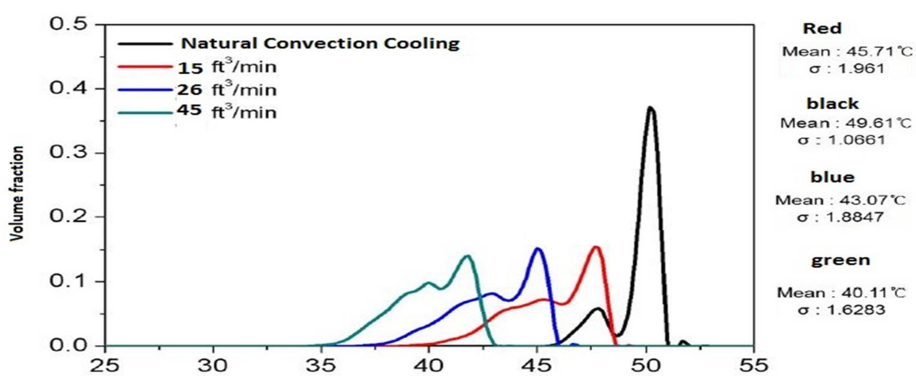


The unit cell temperature distributions are calculated from thermal modeling in Figure 5.The results are calculated for discharge rate of 2C and 3C. We choose here the process of natural convective cooling first and then we go to forced convection. So initially for the case of natural cooling, the unit cells present at the lower and upper portion of the battery pack has very less temperature and the other unit cells have very high temperatures. These values are collected from the analysis and these almost match the real time data too. Initially from the Figure 1 we said that the temperature values goes on increasing with the discharge increase and here with our thermal modelling too we see that the behavior is same and is shown in figure 6. But the unit cells at the lower part behave abnormally due to the factor that the thermal environment created by setting up the terminal conditions does not match with the real time conditions. The surface exposed to atmosphere is the convective layer and the transfer of heat achieved with the given conditions for thermal analysis did not create an equivalent of actual ambient layer. Also the temperatures behave intermittently at the corners of the cell. The surface of the left corner is cooler than the right surface corner due to the fact that the ambient air has to travel less distance to come in contact with the surface layer at left than the right. More the air is contact, more heat transfer take place according to heat convection law.

$$q = hA(Ts - Ta)$$

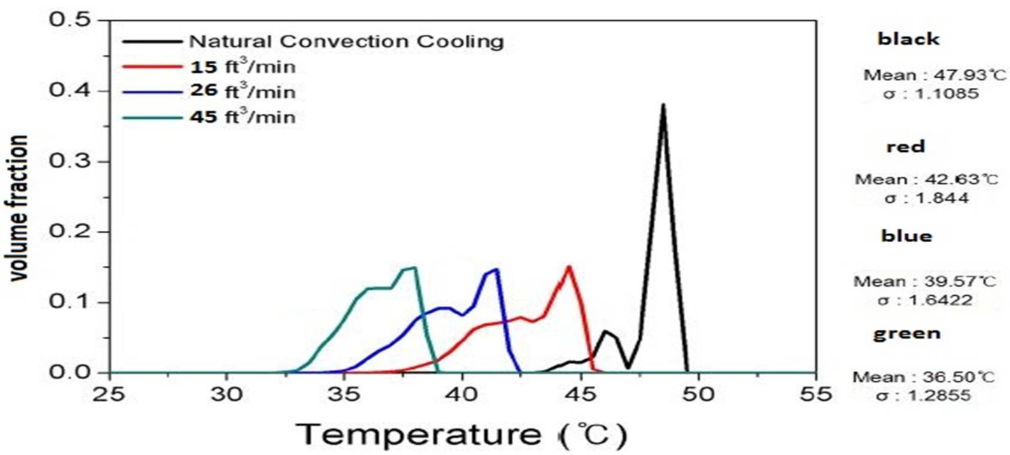
Now we are done with the natural convection. We now study the behavior of unit cells with high volume flow rate of air in to the battery pack. This is what we say as forced convection, i.e. we allow more amount of air to flow into the system and allows for cooling. When this happens we noticed that there is a significant drop in the average temperatures across the battery module where a temperature difference of up to 10 degree is observed. From the above data in case of natural convection where there is very less flow of air through the system we observed that the temperature values of the first and last cell is relatively high but here the values are normal and close to the real time behavior. This is due to the fact that there is high gradient of air flowing into the module and the convective boundary layer conditions don’t play a significant role in the case of forced convection.

Figure 8. Volume fraction distribution vs temperature of cells (discharge rate -3C and discharge duration-600s) different volumetric flow of air



To show it in form of graph two figures 9 and 8 the volume fraction of unit cells in the battery pack is given in terms of temperature dependent with discharge rate of 2C and 3C for 1200s and 600s. From the graphs we can see that the mean temperatures of the unit cells comparatively decreases in case of forced convection and distribution of cell temperatures also attains uniformity in case of high volumetric flow of coolant air. The present analysis focused on optimal design of battery module for effective thermal management system which can be used in electric vehicles as the performance, life Cycle of the battery depends on various loads that act on the cells and how effectively these loads are distributed to maintain less and uniform temperatures across the battery pack.

Figure 9. . Volume fraction distribution vs. temperature of cells (discharge rate -2C and discharge duration-1200s) different volumetric flow of air



V. CONCLUSION

An analytical approach was supported with model designed in Ansys. First the voltage and charge carrier capacity dispersion are studied as a dependent of discharge rate. Erratic Heat dispersion rate is observed. This heat generation rate is given as dependent on location of the electrode and a mathematical model is derived. Using this mathematical model velocity, pressure and temperature distributions as function of discharge rate duration are studied. Thermal modeling is done and using this we came to know that the forced convection and the case where there is high volume rate of cooling air i.e. forced convection, there is uniform temperature distribution and also the mean temperatures of the unit cell is comparatively less when compared to the case where there is less volume rate of coolant air i.e. natural convection. This analysis is very significant because the life cycle and performance, safety of the battery pack is dependent on how effectively the temperature is distributed in the unit cells and battery pack.

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REFERENCES

[1] Berger C, Song Z, Li X, Wu X, Brown N, Naud C, Mayou D, Li T, Hass J, Marchenkov AN, Conrad EH: Science. 2006, 312: 1191-1196. 10.1126/science.1125925
[2] Kim, U.S.; Shin, C.B.; Kim, C.S. Effect of electrode configuration on the thermal behavior of a lithium-polymer battery. J. Power Sources 2008, 180, 909–916
[3] Kwon, K.H.; Shin, C.B.; Kang, T.H.; Kim, C.S. A Two-dimensional modeling of a lithium-polymer battery. J. Power Sources 2006, 163, 151–157
[4] Doyle, M.; Fuentes, Y. Computer simulations of a lithium-ionp battery and implications for higher capacity next-generation battery designs. J. Electrochem. Soc. 2003, 150, A706–A713.
[5] Doyle, M.; Fuller, T.F.; Newman, J. Modeling of galvanostatic charge and discharge of the lithium/polymer/insertion cell. J. Electrochem. Soc. 1993, 140, 1526–1533.
[6] Kim, U.S.; Shin, C.B.; Kim, C.S. Modeling for the scale-up of a lithium-ion polymer battery. J. Power Sources 2009, 189, 841–846.
[7] Kim, U.S.; Yi, J.; Shin, C.B.; Han, T.; Park, S. Modeling for the thermal behavior of a lithium-ion battery during charge. J. Power Sources 2011, 196, 5115–5121.

[8] Kim, U.S.; Yi, J.; Shin, C.B.; Han, T.; Park, S. Modeling the dependence of the discharge behavior of a lithium-ion battery on the environmental temperature. J. Electrochem. Soc. 2011, 158, A611–A618

[9] Yi, J.; Koo, B.; Shin, C.B. Three-Dimensional Modeling of the Thermal Behavior of a Lithium-Ion Battery Module for Hybrid Electric Vehicle Applications. Energies 2014, 7, 7586-7601

[10] http://www.thefreelibrary.com/United+States+%3A+US+Dow+lithiumion+battery+jv+to+limit+oil+dependence.-a0229686849

[11] Onda K, Ohshima T, Nakayama M, Fukuda K and Araki T 2006 Thermal behavior of small lithium-ion battery during rapid charge and discharge cycles J. Power Sources 158 535-542

[12] Pesaran A A 2001 Advanced Automotive Battery Conference Las Vegas,Nevada

[13] Benger R, Wenzl H, Beck H, Jiang M, Ohms D and Schaedlich G 2009 Electrochemical thermal modeling of lithium-ion cells for use in HEV or EV application World Electric Vehicle Journal 3 Stavenger, Norway

[14] Jeon D H and Baek S M 2011 Thermal modeling of cylindrical lithium ion battery during discharge cycle Energy Conversion and Management 52 2973-81

[15] Wang F and Li M 2010 Thermal performance analysis of the Lithium-ion Batteries International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT) (Wuhan, 8-11 Dec. 2010) 483-486

[16] Bernadi D, Powlikowski E and Newman J 1985 A general energy balance for battery systems J. Electrochem. Soc. 132 5-12

[17] Zhu X, Zhu Y, Murali S, Stoller MD, Ruoff RS: J Power Sources. 2011, 196: 6473-6477. 10.1016/j.jpowsour.2011.04.015

[18] Khateeb S A, Amiruddin S, Farid M, Selman J R and Al-Hallaj S 2005 Thermal management of Li-ion battery with phase change material for electric scooters: experimental validation J. Power Sources 142 345-353

[19] Villano P, Carewska M and Passerini S 2003 Specific heat capacity of lithium polymer battery components Thermochemica Acta 402 219-224

[20] Pan AD, Choi D, Zhang JG, Liang JS, Cao G, Nie Z, Arey BW, Liu J: J Power Sources. 2011, 196: 3646-3649. 10.1016/j.jpowsour.2010.12.067

[21] Tao L, Zai J, Wang K, Zhang H, Xu M, Shen J, Su Y, Qian X: J Power Sources. 2012, 202: 230-235.

[22] Lian P-C, Zhu X-F, Liang S-Z, Li Z, Yang W-S, Wang H-H: Electrochim Acta. 2010, 55: 3909-3912. 10.1016/j.electacta.2010.02.025

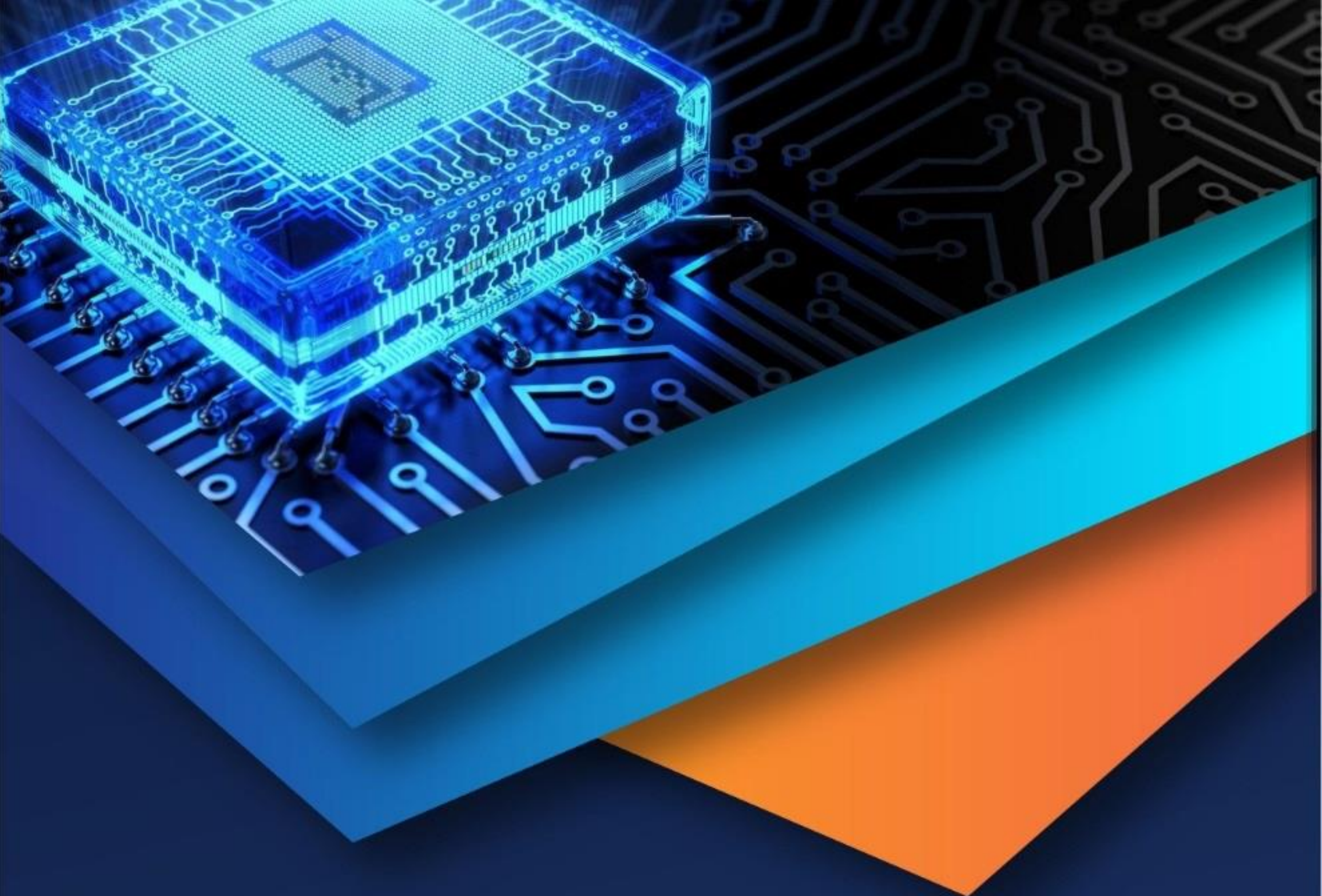
[23] Dokko K, Mohamedi M, Fujita Y, Itoh T, Nishizawa M, Umeda M, Uchida I: Electrochem Soc. 2001, 148: A422-A426. 10.1149/1.1359197

[24] Fernandez-Merino MJ, Guardia L, Paredes JI, Villar-Rodil S, Fernandez PS: Phys Chem C. 2010, 114: 6426-6432. 10.1021/jp100603h

[25] R. Anderson. "Requirements for Improved Battery Design and Performance," SAE Transactions, September 6, 1990, Volume 99, pp. 1190-1197.

[26] P. Nelson, V. Battaglia, and G. Henriksen. “Thermal Control of Electric Vehicle Batteries,” Proceedings of the 30th Intersociety Energy Conversion Engineering Conference, July 30-August 4, 1995, Volume 3, pp. 267-273.

[27] F. Wicks and E. Doane. "Temperature Dependent Performance of a Lead Acid Electric Vehicle Battery," Proceedings of the 28th Intersociety Energy Conversion Engineering Conference, 1993



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