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Enhancing Charge Acceptance of Lead Acid Battery Using Graphene-Infused Grid

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KEYWORDS

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ABSTRACT

This paper presents a solution to improve the charge acceptance rate, enhancing life cycle and improving efficiency of lead acid battery by making lead Graphene composite for positive grid. This study introduced varying amounts of Graphene by powder metallurgy techniques into lead using powder metallurgy techniques, with lead serving as the as the grid material. An allotropic form of carbon, Graphene possesses superconductive qualities and primarily prevents corrosion and lowers the resistance between sulphuric acid and spongy lead. It does not take part in the process. This study follows an experimental approach to achieve the aim of improvement in the lead acid battery. A series of composites specimens were fabricated in different composition. A series of tests performed, include Energy Dispersive X-ray Spectrometer (EDS), Scanning Electron Microscopy (SEM), Microstructure, Electrical Resistivity, Electrical Conductivity, Charge Potential, Impedance Spectroscopy, Corrosion, Cyclic Voltammetry (CV) and X-ray Diffraction (XRD). Results revealed that the sample with 1.5% graphene exhibited optimal performance. Compared to pure lead grids, electrical conductivity improved by 13.3%, and electrical resistance decreased significantly. Corrosion analysis showed a notable reduction in corrosion rate, particularly in the 1.5% graphene sample, due to uniform granular bonding observed in SEM images. CV curves of this sample also demonstrated enhanced redox behaviour and current density, indicating better charge retention. This study analyses the results and compares those results with the spongy lead results which are being used in normal lead acid batteries as positive grid. In this study, it is noted that notable improvements in the lead acid battery were achieved by using the lead Graphene composite.

1. INTRODUCTION

Currently, the whole world is looking for sustainable development in the energy sector so that it can improve the green environment. Renewable energy resources exist over wide geographical areas, as compare to other energy sources. Renewable energy is derived from natural processes that are replenished constantly. In its various forms, most renewable energy comes either indirectly or directly from the sun. For increasing the efficiency of renewable energy sources, there is great need of energy storage devices. Energy storage devices are especially helpful when utilizing intermittent energy sources and are necessary to fully utilize renewable energy. The primary needs for modern batteries are weight reduction, long lifespan, high specific power and high specific energy. These days, replacing heavy-weight lead grids with lighter ones is linked to the majority of efforts to enhance lead-acid batteries. Batteries plays an important role in industry and electric vehicles etc..Thus the battery needs to be secure from damage. As rechargeable batteries have net zero emission, they are also environment friendly. As rechargeable batteries have several failures due to uneven condition so these batteries also require some advancement to improve their performance and other parameters. Electrolyte sulfation, electrolyte stratification, electrode corrosion, and non-cohesion of active mass are the primary issues with rechargeable batteries. These

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malfunctions cause the lead acid battery's life cycle, efficiency, charge acceptance rate, and other factors to decline.

Previous studies have shown that lead film anodes placed on a metal substrate, such as copper, aluminum, titanium, or treated steel, can support a lead-acid battery's positive plate [1,2]. Because they can be utilized for lead compound frameworks to decrease the weight of lead acid batteries and hence increase their specific energy [6], materials such as graphite [5] and carbon [3,4] have been proposed. In Ref. [7], lead and lead dioxide were electrodeposited onto carbon cathodes that are inactive in sulfuric acid configurations. Based on its effectiveness as lead acid battery terminals, carbon was an acceptable choice for lead acid battery negative current collectors.

2. LITERATURE REVIEW

Carbon additives added to negative plates under HRPSOC serve the following main purposes, according to P.T. Moseley [8,9]: (i) increasing the final electrical conductivity of NAM; (ii) preventing the development of lead sulfate crystals; (iii) maintaining abundant charge flow as a capacitor; and (iv) lowering the hydrogen over-potential and thus promoting hydrogen emanation. Since it was shown in [5] that graphite foams not able to be used as positive current collectors for lead acid batteries, while non-graphitized ones could, the feasibility of using lead-graphite terminals as positive current collectors is still up for debate. Graphite foams were also unable to be used as positive collector currents due to oxygen evolution [7].

The impact of carbon on the electrochemical characteristics of the negative terminal [10,11] is now being examined in a number of articles, despite the fact that the function of carbon in better the performance of the lead battery is not well understood. Some people believe that adding carbon to a lead-acid battery increases its capacity [12]. Additionally, carbon can act as a stage, block the development of lead sulfate crystallites [13] and preventing the lumping of lead sulfate crystals into larger objects. Carbon materials used as additives to the cathode and anode slurry of lead-acid batteries in the form of carbon nanotubes or nanopowder [4].

Lead-graphite and lead-graphene metallic alloys have superior corrosion and electrochemical resistance, and they can be employed as positive grids in lead acid batteries [14].In the accessible writing of lead-graphene, a valid solution to usher in a latest era of lead-acid batteries is obtained in a fundamentally novel way. As anticipated, the use of lead-graphene metal terminals would significantly better the discharge of lead batteries by lower the weight of the battery cathodes, increasing their conductivity, and enhancing their electro-chemical movement. This is in addition to the previously mentioned benefits of carbon anodes in lead batteries.The typical in-wrinkle in the consumption opposition of the anode materials is another factor that makes the use of lead-graphene metal cathodes interesting. This is because the graphene of the composite isn't broken up in the weaker sulfuric acid electrolyte. We anticipate that utilizing lead-graphene metal material will prevent the current leads from being decimated by intergranular consumption; in other words, the combination used today, Pb-Sb, Pb-Sn and Pb-Ca will increase the lead acid battery's lifespan

3. EXPERIMENTAL METHOD

The relation between powders of lead and graphene is achieved by powder metallurgy technique. Powders of lead and graphene is blended manually and poured in a die. Sintering of powders is performed by hydraulic press using pressure of 5 tons. Compaction is done in an electrical furnace by setting up the temperature of 80% of lead. The main experiment performed at temperature of 229 °C. The time for compaction varied from 1 to 1.5 h. following high temperature exposure the composite of lead and graphene is cooled by natural air for 1h.

In terms of the LAB's positive electrode, lead-graphene metallic composites with different graphene percentages ranging from 0.5 to 2% is examined. Figure 1 illustrates the enhanced conductivity of the lead-graphene composite as compared to lead. The anisotropy of characteristics that characterizes typical composite materials is absent from lead graphene composites.

The lead-graphene composites, performed number of tests to investigated their behavior. Electrical resistivity and conductivity determined by means of multimeter, Micro-structure tests is conducted by addition of 2% etchant of nital at surface of composite by means of metallurgical microscope, charge potential tests performed by means of DC power supply SPS-1820. The voltage varies between 0.7 V and 2.2 V.

Energy dispersive x-ray spectrometer and Scanning electron microscopy is analyzed by “JEOL JSM-6490 LV” and X-ray diffraction performed by means of unit device. Corrosion electrochemical behavior and impedance spectra of lead-graphene investigated in 26% dilute H2SO4. Cyclic Voltammetry curves measured using a three-electrode system, with an Ag/AgCl electrode as the reference electrode. The scans performed at a speed of 0.1 V/s over a potential range of 0.7 V to 2.2 V for 10 cycles. The primary objective of this paper is to develop a lead-graphene composite with varying graphene percentages and analyze its different parameters for use as a positive grid in lead-acid batteries.

Fig. 1. Lead-graphene composite

4. RESULTS AND DISCUSSION

4.1. Synthesis and Characterization of Lead- Graphene Metal Composite

*The greatest impediment to the production of lead-*graphene composite by regular metallurgy strategy is amazingly low dissolvability of graphene ahead of the lead. Another reason which makes making of lead-graphene composite greatly troublesome is the way that non-transition metals as lead, artificially inactive regarding graphene, framed on surface of graphene. A novel lead-graphene material with a low graphene content has been investigated as a potential material for the positive grid of lead-acid batteries.

New technique for synthesis metallic lead-graphene composite material is based on powder metallurgy technique in which powders of lead and graphene are mixed at the temperature of 229 °C. As a result, lead-graphene powders mixed and formed the composite. The content, size, and type of graphene particles in lead powder can vary depending on the concentration, temperature, and interaction time during composite formation. As evident from the XRD analysis of the lead-graphene composite shown in Figure 2, graphene forms a distinct phase within the lead.

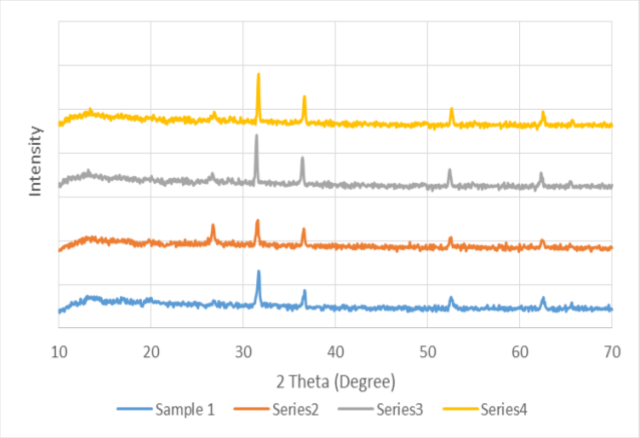
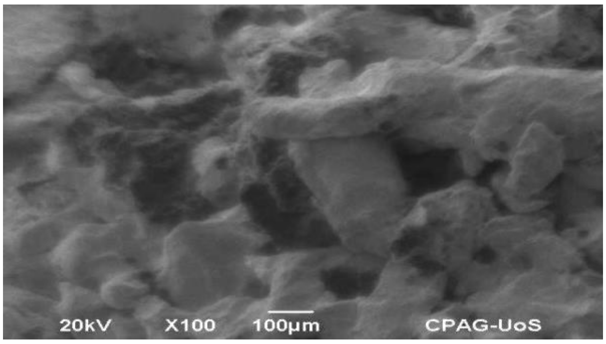
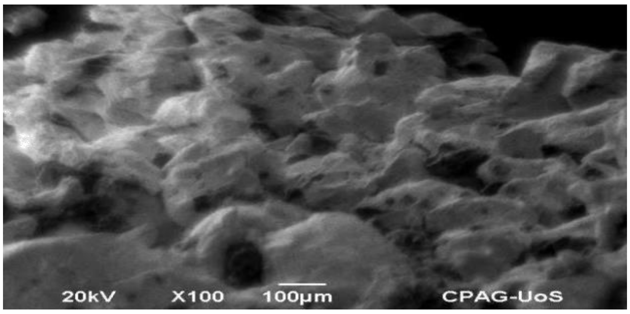


Fig. 2. XRD of 4 samples of lead-graphene composite



Sample (a)



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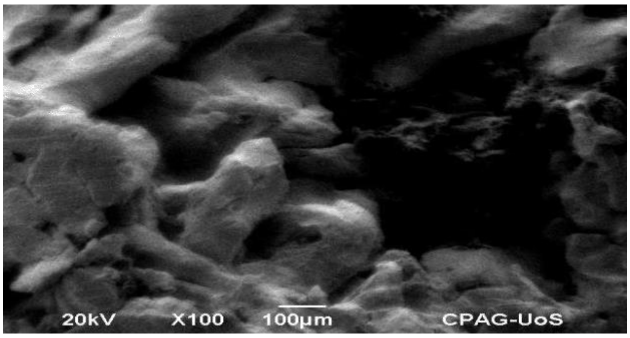
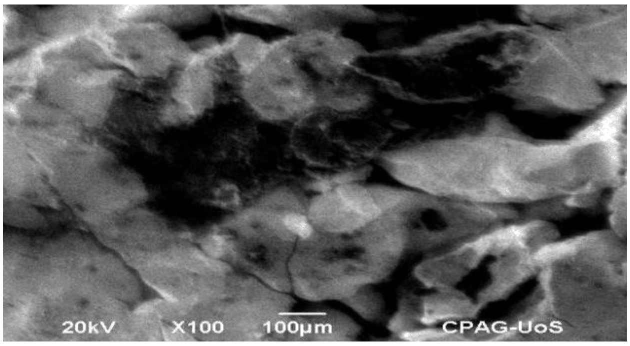
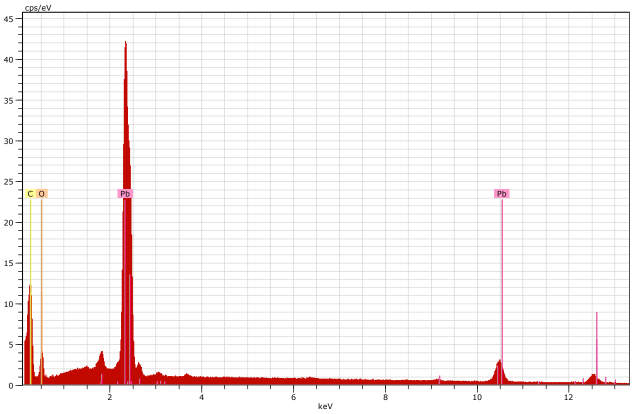


Sample (c)

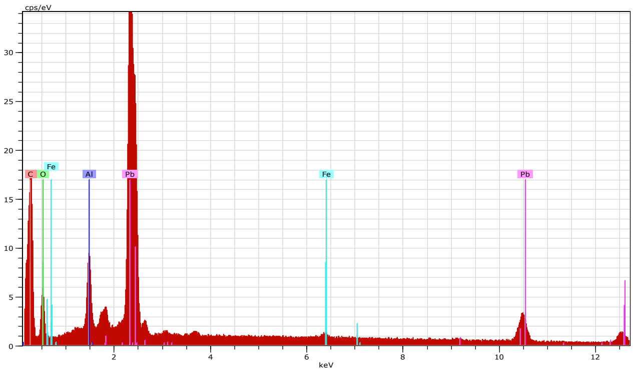


Sample (d)

Fig. 3. Material Mixing of lead graphene composite



Sample (a)



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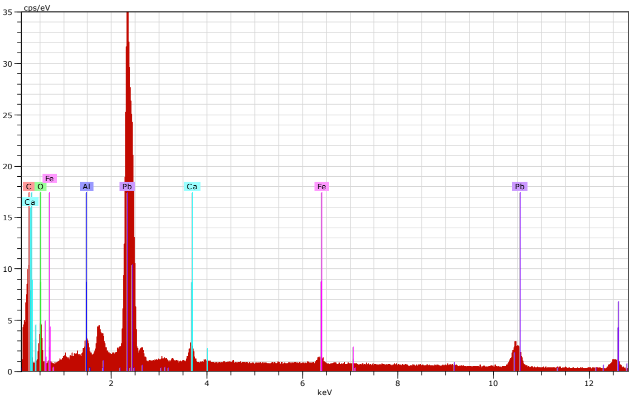

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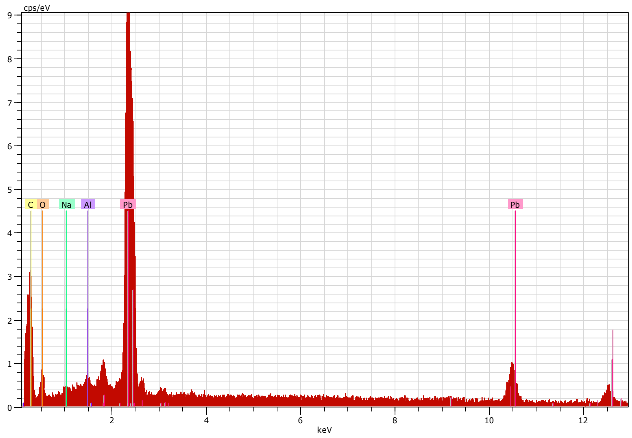
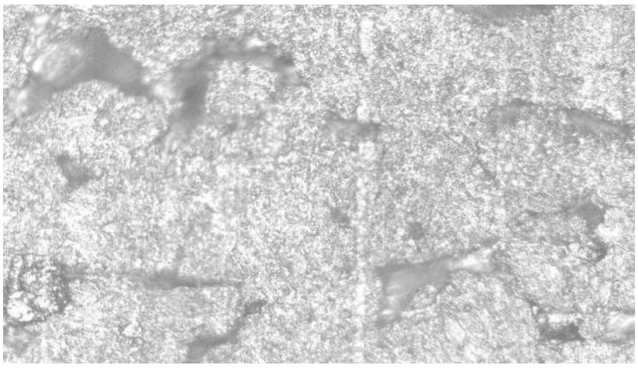


Sample (d)

Fig. 5. SEM images of lead graphene composite

The composition of lead-graphene metallic composites was determined through both chemical analysis and EDS technique. It is important to note that the graphene content measured by EDS may be overestimated due to the inherent characteristics of the method. Lead-graphene powders properly mixed in 3rd sample as shown in Figure 3(c) of SEM test. Proper mixing results in good conductivity and less formation of lead sulphate crystals during reduction. Total graphene % vary from sample 1 to sample 4 i.e. 0.5% to 2%. At each % of graphene, composite of lead-graphene shows different results under the investigation of different tests. Microstructure test of given composites performed, given data used to decide whether the auxiliary parameters are inside sure determinations. The investigation results are utilized as a foundation for acknowledgment or dismissal. These examinations are frequently utilized in failure investigation to help recognize the sort of material being referred to and decide whether the material got the proper processing treatments. Figure 5. shows the microstructure test results of all sample composites



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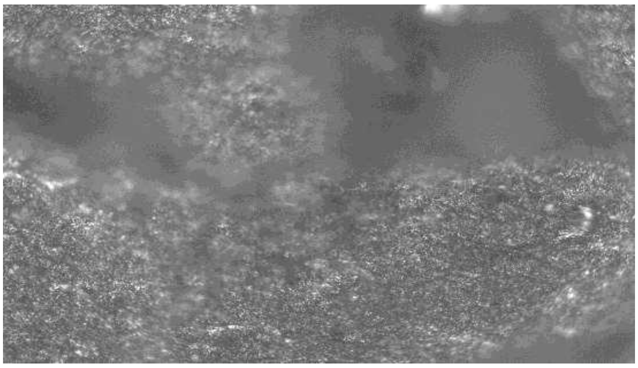

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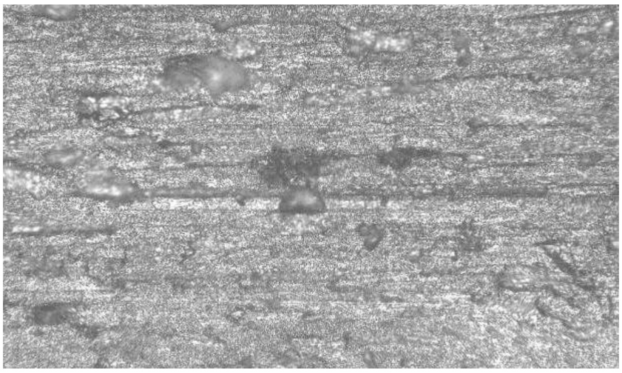

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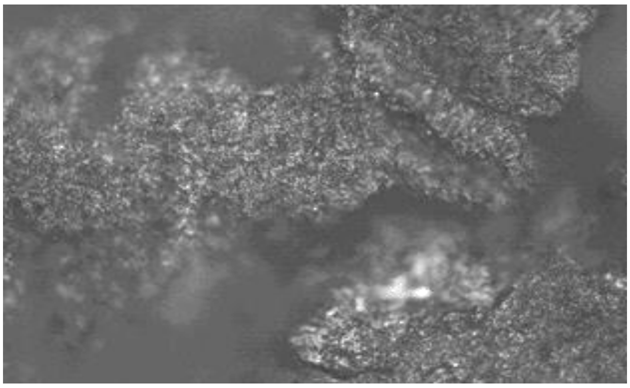
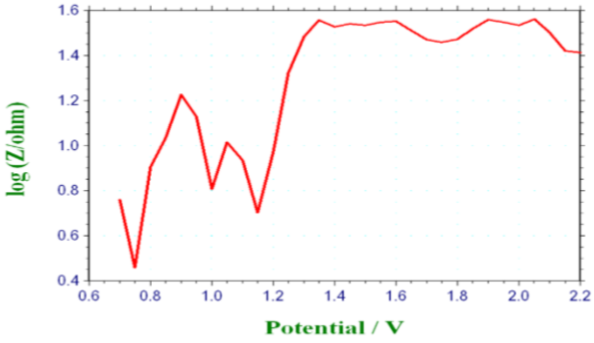


Sample (d)

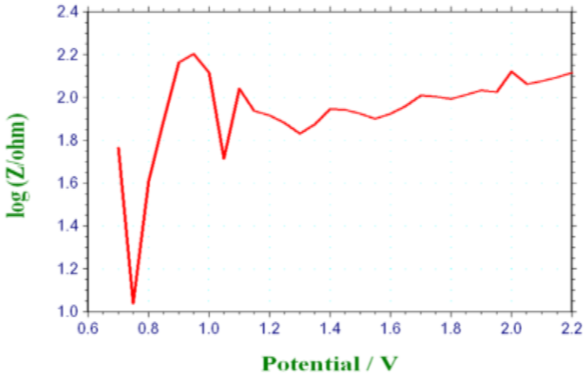
Fig. 5. Sample-(d)Microstructure images of lead graphene composite

4.2 Electrochemical Characterization of lead-graphene composite

With the end goal to comprehend the electrochemical properties of lead-graphene composite, impedance spectra and cyclic voltammetry were performed at a sweep rate of 0.1 V/s at room temperature in dilute sulfuric acid solution. Impedance spectra presented in Figure 6 (a,b,c,d). Cyclic voltammograms presented in Figure 7 (a,b,c,d). In this studied potential range from 0.7V to 2.2V (vs Ag/AgCl reference electrode), possibly some redox reaction occurs. In impedance spectra Figure 6(c), peak amount of current conducted between 0.8V to 2.2V, results in less internal resistance.



Sample (a)



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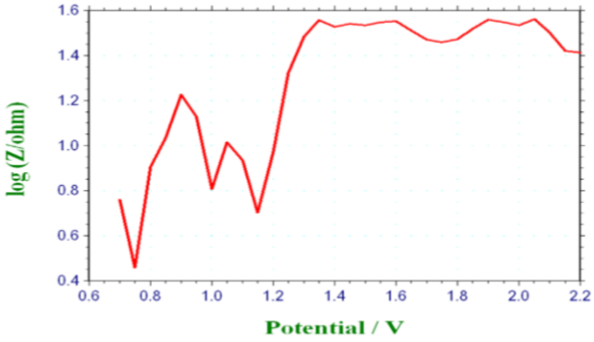

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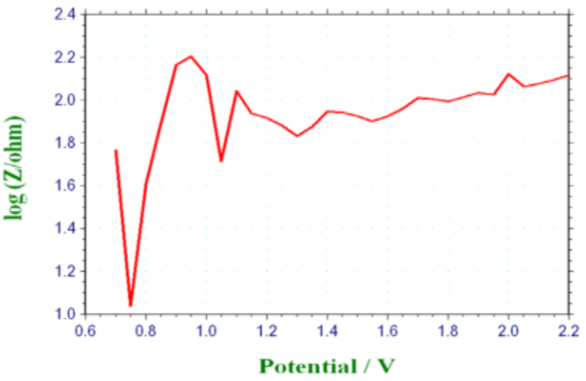
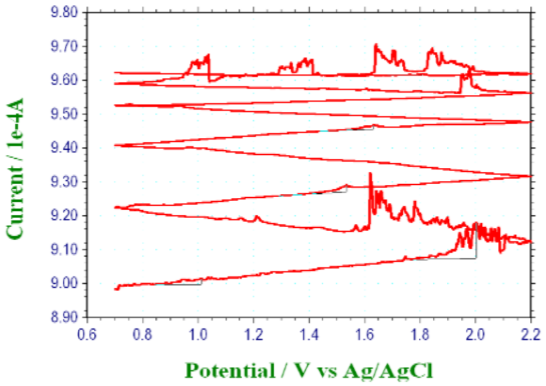
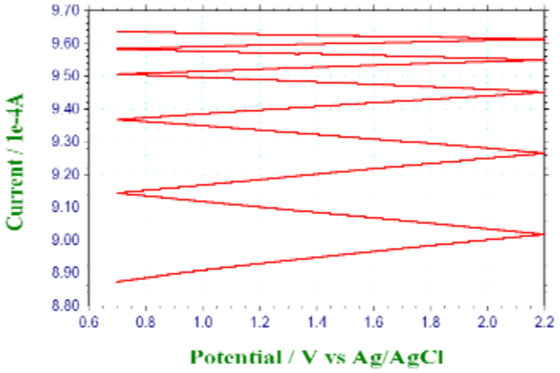


Sample (d)

Fig. 6. Sample-(d) Impedance Spectra graphs of lead-graphene electrode in H2SO4



Sample (a)



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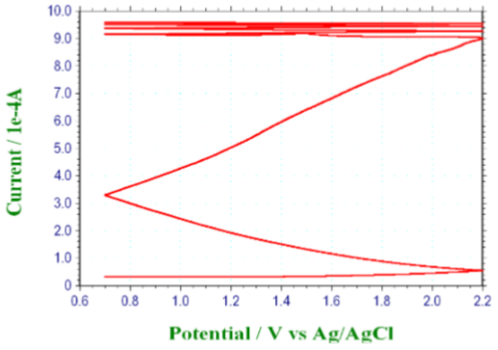

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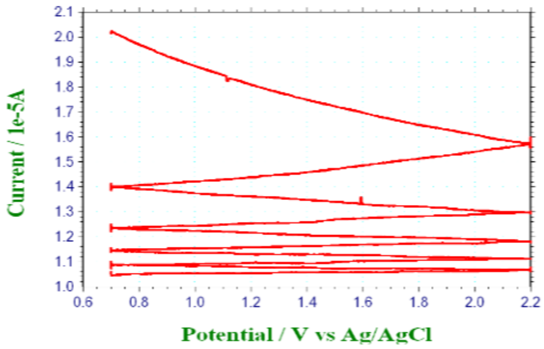
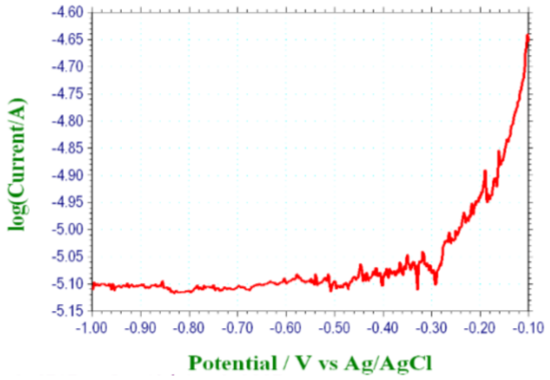
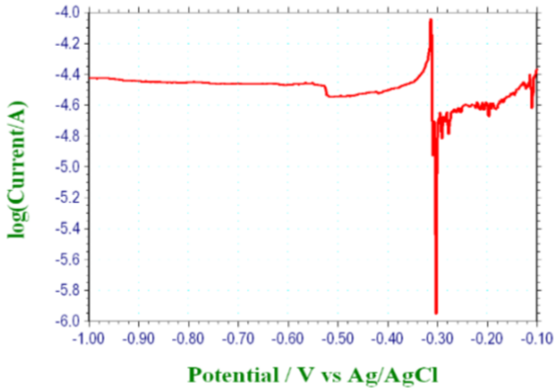


Sample (d)

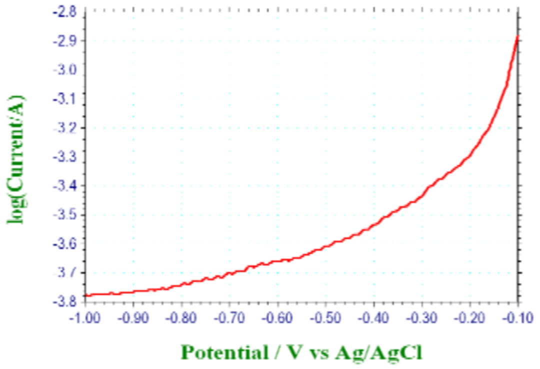
Fig.7. Sample-(d).Cyclic voltammograms graphs of lead-graphene electrode at in H2SO4**.**



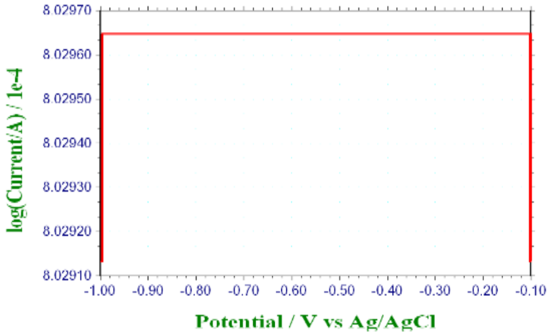
Sample (a)



Sample (a)



Sample (c)



Sample (d)

Fig. 8. Corrosion/Tafel Plot of lead-graphene composite in H2SO4

Cyclic voltammograms results 3rd & 4th sample as shown in Figure 7(c, d) by comparing with lead grid, is showed consistent reduction peaks [15].

4.3 Corrosion investigation of lead-graphene metallic composite

The corrosion resistance of the positive current collector plays a crucial role in ensuring the long lifespan of lead-acid batteries. The corrosion behavior of lead-graphene was investigated in a sulfuric acid solution. Cross section of samples was studied during corrosion test at a scan rate of 0.01 V/s (vs Ag/AgCl reference electrode). The generated Tafel plots of corrosion of given samples as shown in Figure 8 (a, b, c, d).

It is clear from *Figure 8(c),* corrosion rate of 3rd sample is in range with less corrosion as SEM test both lead and graphene form uniform granular structure. So, it is concluded that from corrosion test the lead-graphene composite corrosion rate is less as compare to commercially use lead grid [16].

4.4 Electrical Characterizations of lead-graphene metallic composite

Electrical resistivity, conductivity and charge potential rate also plays an important role to charge acceptance rate of lead acid battery. For charge potential test, voltage ranges from 0.7V to 2.2V. Following table (1) shows electrical resistivity and conductivity while table (2) shows charge potential rate of lead-graphene composite.

From Table 1, sample B and sample C withstands high conduction and less resistance while from Table 2, sample 3 shows good current density as compared to other samples. So, it is concluded that sample C is favorable due to the high charge density, which enhances electrostatic interactions and improves reactivity and has also less resistance

5. CONCLUSION

Lead-graphene metallic composite with shifting % of graphene from 0.5% to 2% were examined in 25% sulfuric acid solution. Lead-graphene metallic composites have a liquefying temperature of the softening purpose of lead. The composite indicates enhanced electrical conductivity as compared with starting lead. Cyclic voltammetry results of lead-graphene metallic composite with 1.5% shows significant improvement in oxidant current. The lead-graphene metallic

Table 1. Sample characteristics of lead-graphene composites

Sample	Composition % Lead (Pb) Graphene (G)	Length (m)	Width (m)	Area (m2)	Electrical resistance (Ω)	Electrical resistivity (Ω*m)	Electrical Conductivity (s/m)
A	Pb=99.5 G=0.5	0.054	0.054	0.002916	1.7	0.0918	10.8932
B	Pb=99 G=1	0.054	0.054	0.002916	1.5	0.081	12.346
C	Pb=98.5 G=1.5	0.054	0.054	0.002916	1.5	0.081	12.346
D	Pb=98 G=2	0.054	0.054	0.002916	1.7	0.0918	10.8932

Table 2. Charge Potential of lead-graphene composites

Sample A		Sample B		Sample C		Sample D	
Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)
0.82	7.0	0.7	4.2	0.73	10.0	0.82	4.9
1.0	9.0	0.96	6.0	0.82	12.9	1.0	6.2
1.23	12.0	1.0	6.0	1.05	16.0	1.25	12.6
1.41	15.0	1.2	8.0	1.20	17.7	1.47	17.0
1.60	15.7	1.46	10.0	1.42	17.8	1.63	17.2
1.80	18.0	1.66	11.8	1.62	18.1	1.82	17.7
2.0	19.0	1.82	16.0	1.84	18.3	2.05	20.0

composite with 1.5% graphene exhibited improved conductivity and corrosion resistance, making it a promising candidate for use as a positive grid material in next-generation lead-acid batteries.

6. FUTURE SCOPE

The lead-graphene composite shows potential as a positive grid material in lead-acid batteries. However, an increase in charge acceptance rate can result in elevated electric field intensity, generating excessive heat that may degrade the structural integrity of the grid mesh. This issue can be mitigated by increasing the grid thickness. Additionally, under high-temperature conditions, the presence of oxygen and carbon in the graphene additive may react with sulfuric acid, potentially producing unwanted gaseous by-products that negatively affect battery performance. To address this, the replacement of sulfuric acid with an alternative electrolyte should be explored. Based on experimental trends, a graphene concentration between 1.5% and 2.0% is recommended for cyclic applications.

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