



New understanding of novel components in advanced lead batteries

Lead-Carbon Cloth Composite: Serving a Dual Purpose in a Lead-Acid Battery (LAB)

National Formosa University, Taiwan Department of Materials Science and Engineering Associate Prof. Shu-Huei Hsieh

Sep 16-19, 2024

Introduction of Nano Materials Lab Department of Materials Science & Engineering

- Synthesis of nanoparticles, nanorods, nanowires, GO by wet chemical method(electro-electroless plating, sol-gel, hydro-thermal method etc.)
- Modification of Carbon Materials
- Lead Carbon Fiber Composite (LCF)



SEM image of Pb/graphene

Outline

- 1. Why Use CF cloth applied in Lead-Acid Batteries?
- 2. Application of Pb-CF Cloth composite applied in Lead-Acid batteries
- 3. Why does inserting LCF enhance the performance of Lead Acid batteries
- 4. Conclusion

Lead – Carbon: Low Interaction Energy

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Table 1. Surface tensions of various liquids and their wetting ability of nanotubes

Element/ compound	Surface tension (mN/m)	Wetting	Reference
HNO ₃	43	Yes	[15]
S	61	Yes	[7]
Cs	67	Yes	[7]
Rb	77	Yes	[7]
V_2O_5	80	Yes	[14]
Se	97	Yes	[7]
Pb oxides	(PbO ~132)	Yes	[11]
Bi oxides	$(Bi_2O_3 \sim 200)$	Yes	[12]
Te	190	No	[7]
РЬ	470	No	[7]
Hg	490	No	[7]
Ga	710	No	[7]

Ebbesen, J. Phys. Chem. Solids, 57, 951, 1996



Mechanism of PbSO₄ accumulation

Ref: Pavlov and Nikolov, "Lead-Carbon Electrode with Inhibitor of Sulfation for Lead-Acid Batteries Operating in the HRPSoC Duty", 159(8) JES 2012



Adding EAC_Highly catalytic effect on the charge reaction



Ref: D. Pavlov etc. "Mechanism of action of electrochemically active carbons on the processes that take place at the negative plates of lead-acid batteries" • 191 JPS 2009.

Lead Carbon Cloth Composite

To Be

A continuous carbon material 100% coverage of Pb on C



Monolithic and flexible Carbon Cloth





Carbon Fiber/Cloth SEM Morphology







As is NLA w/C and 3D Pore Structure (100% DoD)



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Lead Carbon Fiber Cloth Composite (LCF)



CF Electrode

Cross section SEM Morphology of CF electrode

Low Temperature HOT Press Yes! $600^{\circ}C \rightarrow 400^{\circ}C \rightarrow < 200^{\circ}C$

✓ A continuous carbon material
 ✓ 100% coverage of Pb on C



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Cyclic Voltammetry of Pb vs. LCF



Electrochemical Impedance Spectroscopy of Pb vs. LCF



Battery assembly

Battery Consultant: Mr. Hank Wu

LCF electrodes act as electrodes to assemble a cell.



CF electrodes/plates



Tools / Battery parts



Plate Group



2V Battery

LCF 2V Battery_+/- 6.6*3.9 cm

High-rate cycling test with 4C charge/10C discharge

A Pb/CF cloth/Pb composite as a highly efficient lead-carbon electrode exhibits notable charge acceptance and long cycle life for lead-acid batteries (LAB) during HRPSoC cycling



+ 2/- 3 LCF composed 2 V battery C10=0.3Ah

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High-rate cycling test with 1C charge/3C discharge, then IEC61427



High-rate cycling test with 1C charge/3C discharge, then IEC61427



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After Charge/Discharge cycling Porous Nano_Pb Structure



Summary of Findings

- > A Pb/CF cloth/Pb composite can be fabricated using a low-temperature process.
- A Pb/CF cloth/Pb composite as a highly efficient lead-carbon electrode exhibits notable charge acceptance and long cycle life for lead-acid batteries (LAB) during HRPSoC cycling.
- According to the IEC 61427 standard, the Pure LCF Battery has currently achieved 10 years.

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Impact of insert Lead-Carbon Fiber (LCF)Plate on LA Battery

Battery Capacity during 1C Charge/Discharge Cycling



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Lab Battery(12V6AH) vs Commercial Battery (12V7AH)

500W Cycling Performance Comparison

Lab:240 cycles consistent discharge time & remaining capacity 100% Com:80 cycles decay discharge time & remaining capacity 41%



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Water loss after constant 500W Discharge for 1st 60 cycles



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Lab Battery(12V6AH) vs Commercial Battery (12V7.5AH)



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Lab Battery(12V6AH) Idle Stop-Start Test

The life cycle of Labs:220000 cycles VS Top Brand:80000~100000 cycles Test method: Honda ISS for 90 cc Motorcycles



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LCF Battery Light Up Longyan Station

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NFU NanoMaterials Lab

Lab Battery(12V50AH) vs Commercial Battery (12V50AH)

 LCF Battery(on work): 20231124 to Now over 9 Months
 Commercial Battery (failed):2023/06/09-2023/11/24
 <6 Months

PV Charge to 28.8V /Discharge from 18:00~00:00
 No power_No sunshine due to rainy days or leaf shielding



LCF Battery Light Up Longyan Station

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Lab Battery System vs Commercial Battery System





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Battery inserted LCF (12V6AH) vs Battery without inserting LCF (12V7AH)

High Rate 119 A discharge 15sec Battery inserted LCF 19.83C vs Battery without inserting LCF



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Battery inserted LCF (12V6AH) vs Battery without inserting LCF (12V7AH)

The charge voltage shows a pulse voltage in a battery-inserted LCF, which is used as a capacitor to enhance charge acceptance.



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Positive Paste electrode of Failed Batteries after CP cycling



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Negative Paste electrode of Failed Batteries after CP cycling



Battery inserted LCF



Battery without inserting LCF











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Inhibit Bulging Side

Battery inserted LCF













Battery without inserting LCF





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Conclusion

- A Pb/CF cloth/Pb composite as a highly efficient lead-carbon electrode exhibits notable charge acceptance and long cycle life for lead-acid batteries (LAB) during HRPSoC cycling.
- Lead-Acid Battery Inserted LCF:
 - ✓ Tripled High-rate Cycle life with Consistent Discharge Time
 - ✓ High charge acceptance
 - ✓ Effect of pulse charge
 - ✓ Inhibit Sulfation
 - \checkmark Inhibit Bulging Side

Further study is in progress.

- Develop a low-temperature continuous process to fabricate the Pb/CF cloth/Pb composites.
- Using recycled CF to replace activated CF in Pb/CF cloth/Pb composites.

Thank you for your Attention

