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# The effect of Carbon Aerogel on improving the expander and NAM performance of lead-acid batteries

A. Alagheband
SARV SANAT TOOS (SST Co.)
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## -SST Co. Introduction and work experience :

SST Co. was established in 2002 as a technical and trading company in the battery industry.

We supply raw materials, components, battery manufacturing equipment, and technical consultancy for the biggest and most well-known battery manufacturers.
SST Co.'s policy is to supply the best quality products and services. More than 23 years of experience in the battery industry has made us a professional partner of battery manufacturers.
The scope of the company activities is defined in 4 main fields:

**1-1 Trading Field:**

For more than 22 years, we have been pleased to supply battery components and battery manufacturing machinery for all applications of lead-acid battery manufacturers.

**1-2-Production Field:**

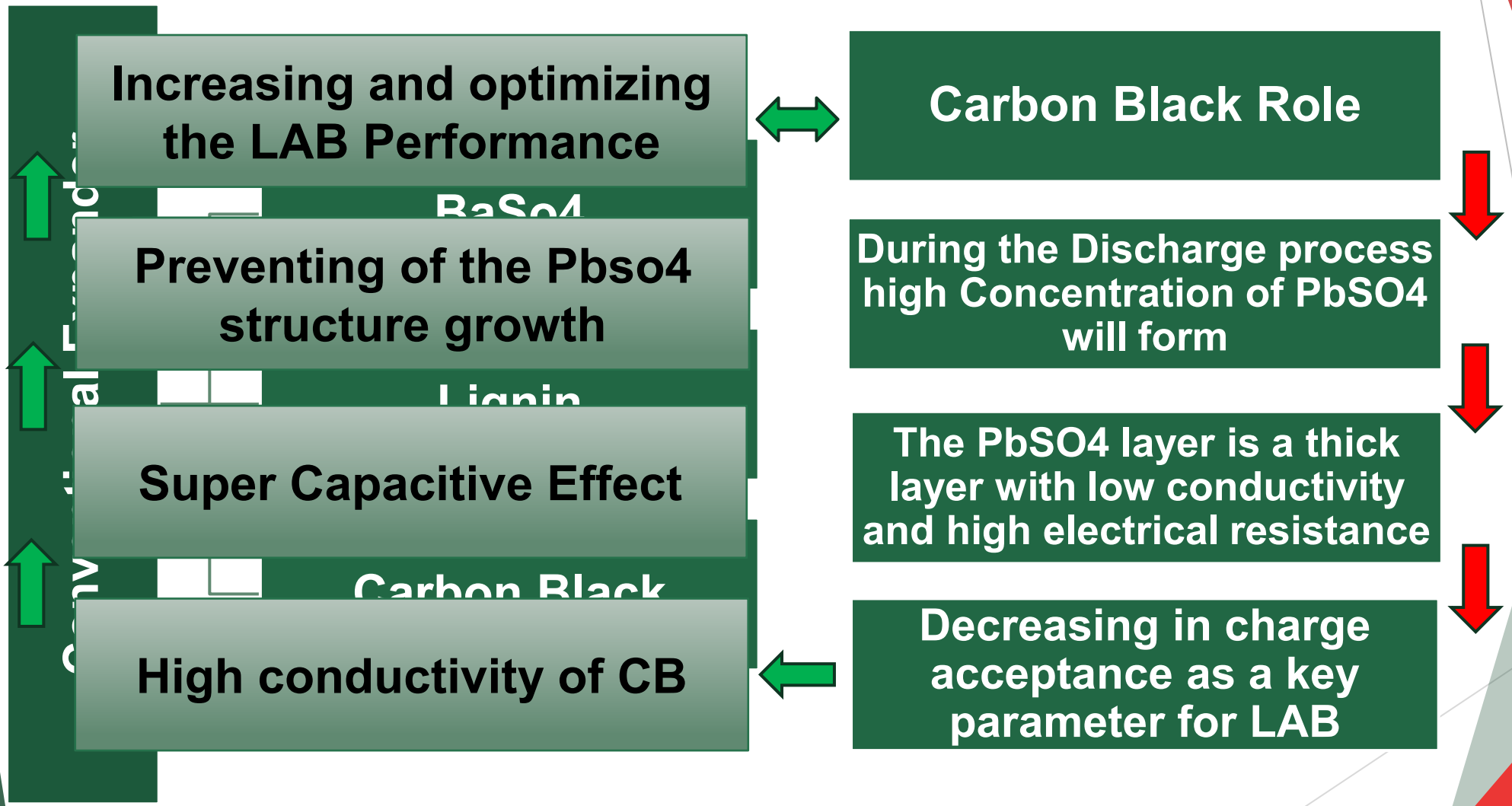
In 2017, thanks to the experience and ceaseless efforts of SST Co.'s expert staff, SST Co. started producing some of the battery production components, raw materials, and manufacturing machinery.
Some of our products are:

B-1- Unique, pioneer, and high-performance battery terminals.
B-2- BCI Type terminals.
B-3- Fully Automatic cold forge terminal-making Production line.
B-4- NAM expander.
B-5- Red Lead and 4BS (near future).

**1-3-Research and development.**

**1-4-Technical and Consulting Service.**

# Introduction of the conventional Expander and CB role

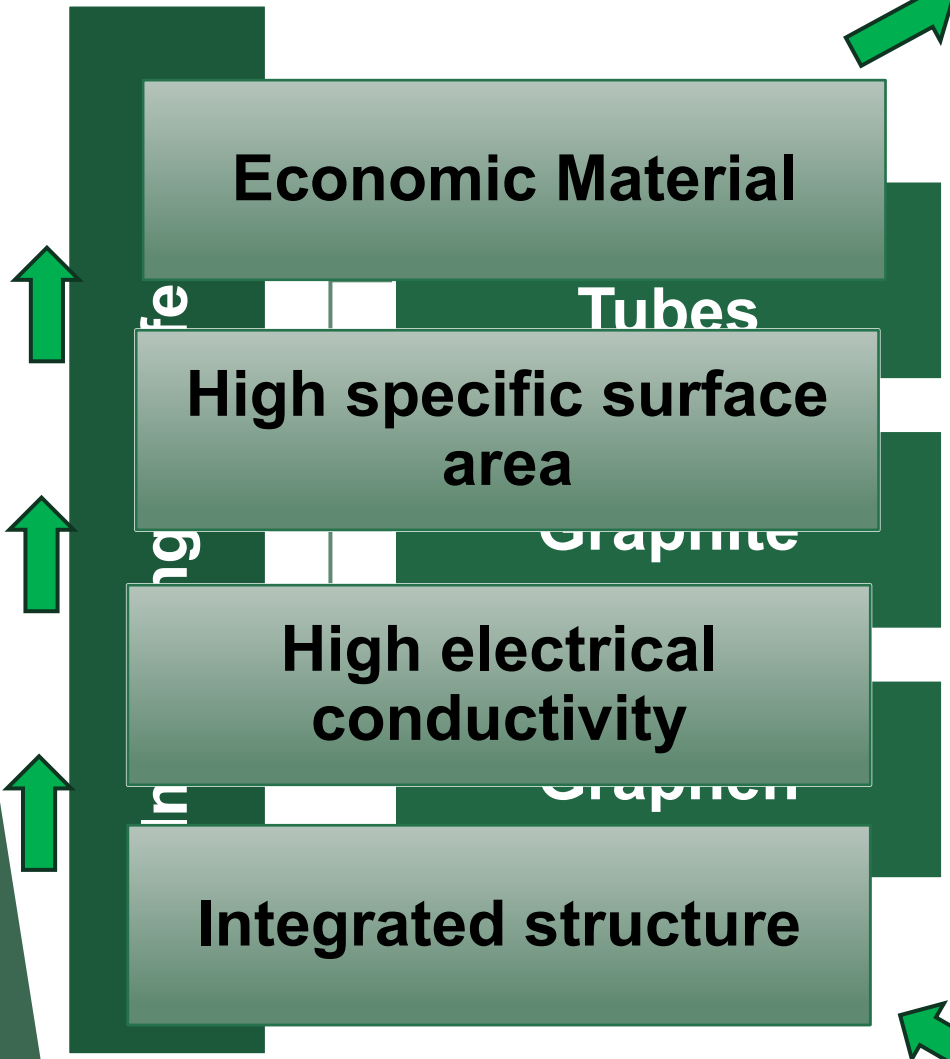



Carbon Black Role

During the Discharge process high Concentration of PbSO4 will form

The PbSO4 layer is a thick layer with low conductivity and high electrical resistance

Decreasing in charge acceptance as a key parameter for LAB




Increases battery life, Charge acceptance, storage capacity and...

Carbon nanotubes and graphene compounds are expensive compounds

Finding carbon materials with favorable performance characteristics and lower cost will significantly contribute to the commercial development of improved batteries.

Carbon Aerogel

# Sol-Gel method as Carbon Aerogel Synthesis Method

Resorcinol and Formaldehyde were dissolved in distilled water in specific proportions to make a Gel, while HTAB was used as a catalyst to accelerate the polymerization process with a stirring process to homogenize the solution.

Aging process at 80 ℃ for 5 days, and then remove the volatile compounds and drying process to obtain a dry Gel

Thermolysis and carbonize the obtained aerogel in an electric tubular furnace at high temperature with a nitrogen flow during this process

The grinding and dispersing process to obtain fine and uniform Carbon Aerogel with 100-1100 m2/g specific surface area, regarding the synthesis process parameters, which is a highly porous structure

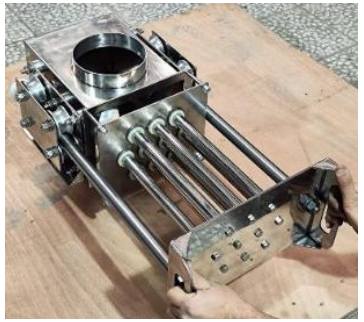
# Samples Preparation

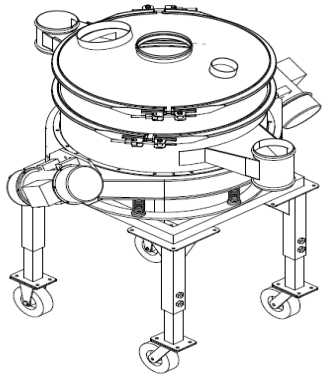
**To make sure about the best performance of the Carbon Aerogel, we used it as a fourth element in the expander material in SST Co.'s Negative Expander production line, which is producing pre-blended negative expander with the optimized homogenous uniform particle size, which consists of three main stations**

## 1-Grinding Station.

## 2-Mixing Station

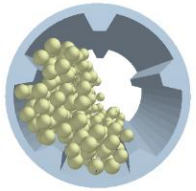
## 3-Vibrating Sieve and Magnet Unit Station

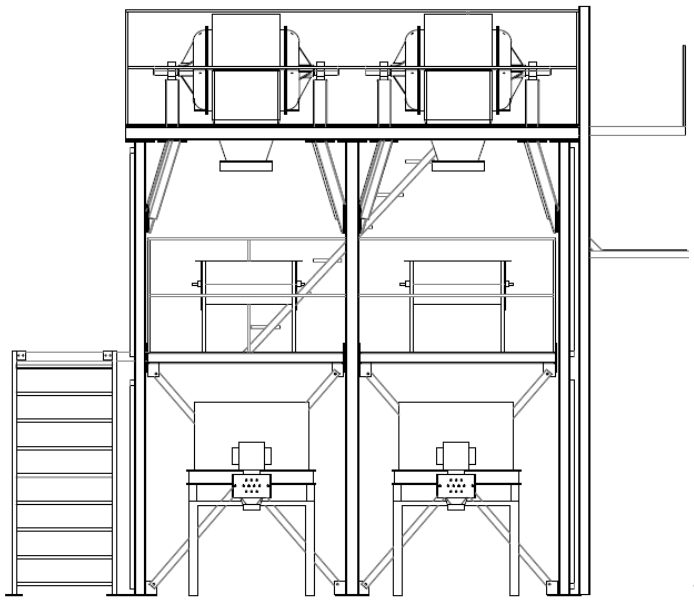


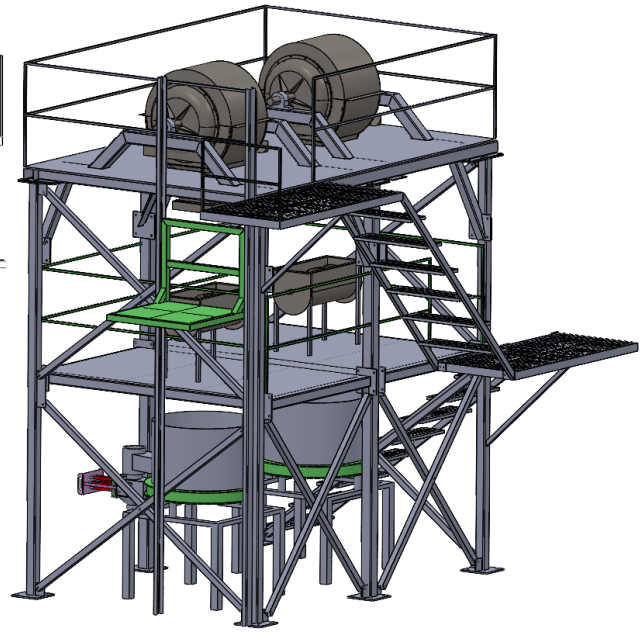


# SST Co. Pre-Blended Expander production line schematic

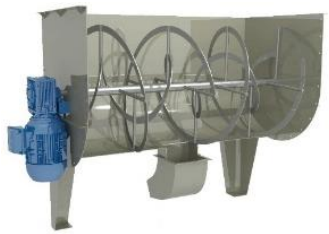
## 1-Grinding Station



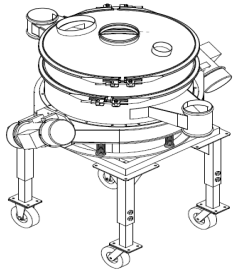




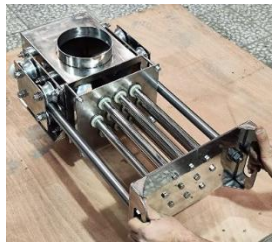
## 2-Mixing Station



## 3-Vibrating Sieve and Magnet Unit Station



1-High-performance Vibrating Sieve equipped with a dispersing Mesh and an auto mesh cleaning system.



2-The Magnet unit includes several magnets with an easy cleaning system for the Separation of iron impurities.

# SSTEX Pre-Blended Expander

**The SSTEX Expander for automotive applications and Stationary Lead-Acid Batteries is now produced in various types, as outlined in the tables below. However, the composition and component types can be customized according to the customer's needs.**

| | Property | SLI-A | SLI-B | SLI-C | SLI-D | SLI-E | SLI-F | SLI-G | Remark |
|---|---|---|---|---|---|---|---|---|---|
| SLI Application | Advantage | Conventional with better charge acceptance | Conventional | Conventional with better Cold Cranking | Longer Cycle life | Longer Cycle life | 50%DOD | Conventional | ... |
| | Compatible with Climate weather conditions | Normal Climate zones | | | | Hot climate zones | Hot climate zones | Cold Climate zones | |

| | Property | SLA-A | SLA-B | SLA-C | SLA-D | SLA-E | Remark |
|---|---|---|---|---|---|---|---|
| Stationary Application | Application | Telecommunication | UPS | EB | AGM Motorcycle | High Rate Telecommunication | ... |

| Property | Specification |
|---|---|
| Mn | Max 5 ppm |
| Fe | Max 100 ppm |
| Ni | Max 10 ppm |
| Cu | Max 50 ppm |
| Technology | Pre blended |
| Packing | Regarding to customers' needs |


# Samples Preparation

**Three expander samples with 0,5 and 10% of Carbon Aerogel content in their composition as a fourth element in the expander and with the constant amount for CB+CA were made, with the same Baso4 and Lignin content.**

| Sample | Baso4 Content | Lignin content | CB N-550 | Carbon Aerogel |
|---|---|---|---|---|
| Reference Expander | 47 | 33 | 20 | … |
| Sample (1) 5% CA | 47 | 33 | 15 | 5 |
| Sample (2) 10% CA | 47 | 33 | 10 | 10 |

To investigate the electrochemical behavior and the Carbon Aerogel effect in the expander and NAM performance of lead-acid batteries, the following tests were considered :

1- The electrochemical test

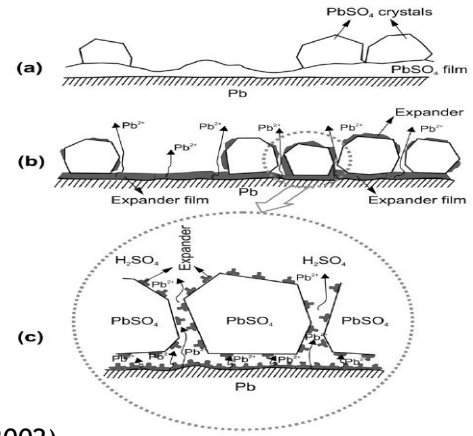
2- Single cell test

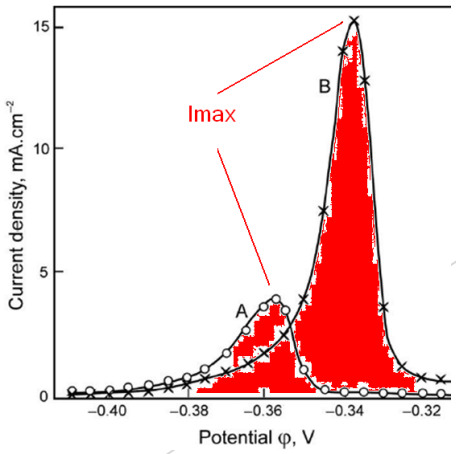
# The electrochemical test Theory

**During the discharge process**

**In the Pb | PbSO4 electrode, when a maximum current value Imax is reached passivation of the electrode starts due to the formation of a PbSO4 layer. While using an expander, the passivation of the surface is prevented by its organic part, which leads to an increase in the current passed through the negative plate during the discharge process. Thus, the discharge process occurs more effectively when a good expander is used resulting in an increased area under the i-t curve and the shifted passivation potential at Imax to more positive values.**

**Increase the discharge rate by increasing the discharge current and consequently increase the capacity.**

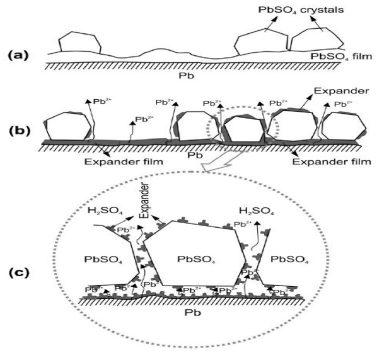


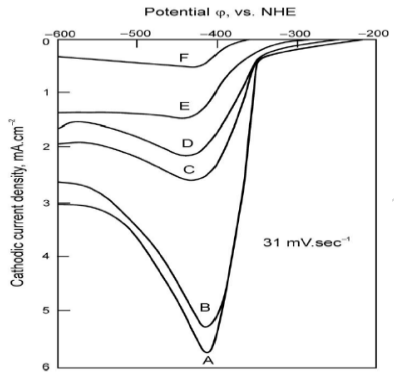



# The electrochemical test Theory

During the **Charge process**

Due to the adsorption of expander onto the metallic surface and decreasing the surface area, an organic expander impedes the process of PbSO4 reduction to Pb, leading to decreasing in charge acceptance ability. In this way, various commercial expanders reveal different performance that they normally decrease the cathodic Imax when compared to the no-expander condition; Carbon additives play a key role in increasing the Pbso4 layer conductivity and porosity and effectively increase the passed current during the charge process. On the other hand, the adsorption of expander onto the metallic surface retards the hydrogen evolution process, which is a useful event.



# The electrochemical test Theory

**To measure the effect of the expander on the formation of the lead sulfate layer, lead electrode was polarized in 100 cc of 5M H2SO4 solution with and without the addition of 3 gr of the different organic expanders at a scanning rate of 2 mV/s and from -0.325 mV/SCE to -0.725 mV/SCE at 25C, which is close to the equilibrium potential of Pb | PbSO4 for 15 cycles.**

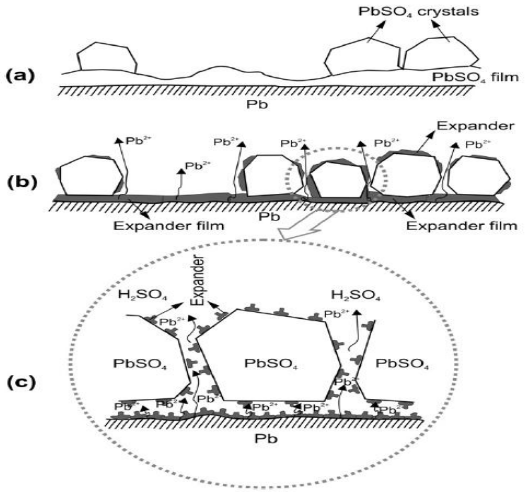
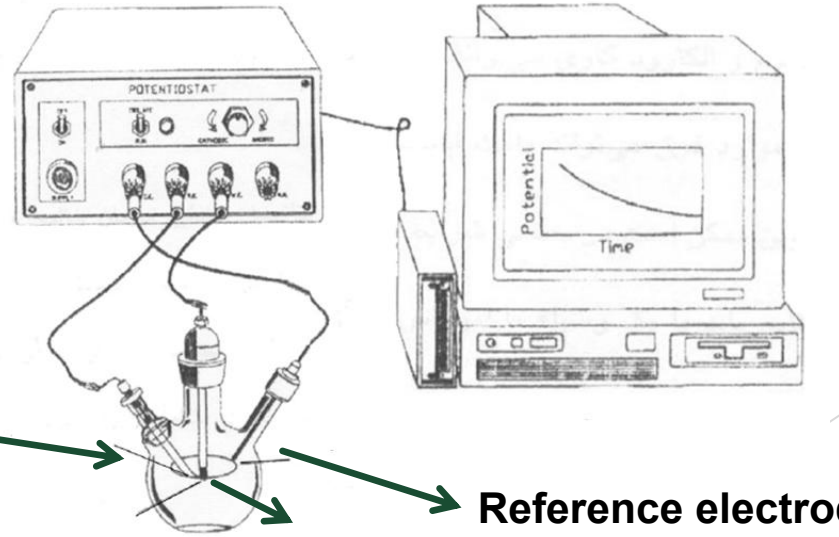



**Figure 7.4:**
Schematic of the structure of the $PbSO_4$ layer: (a) with no expander; (b,c) with expander [14].

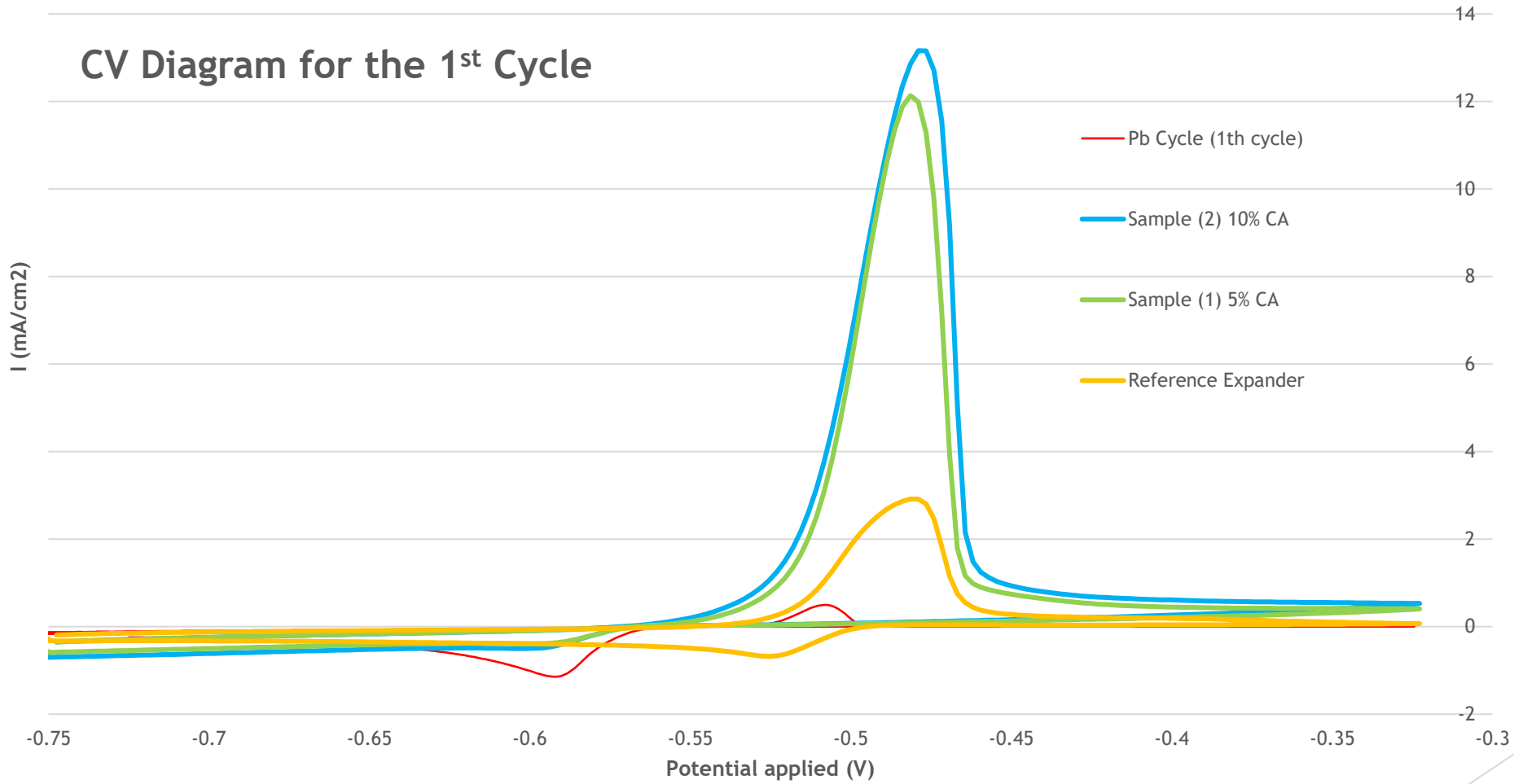



**Working electrode**

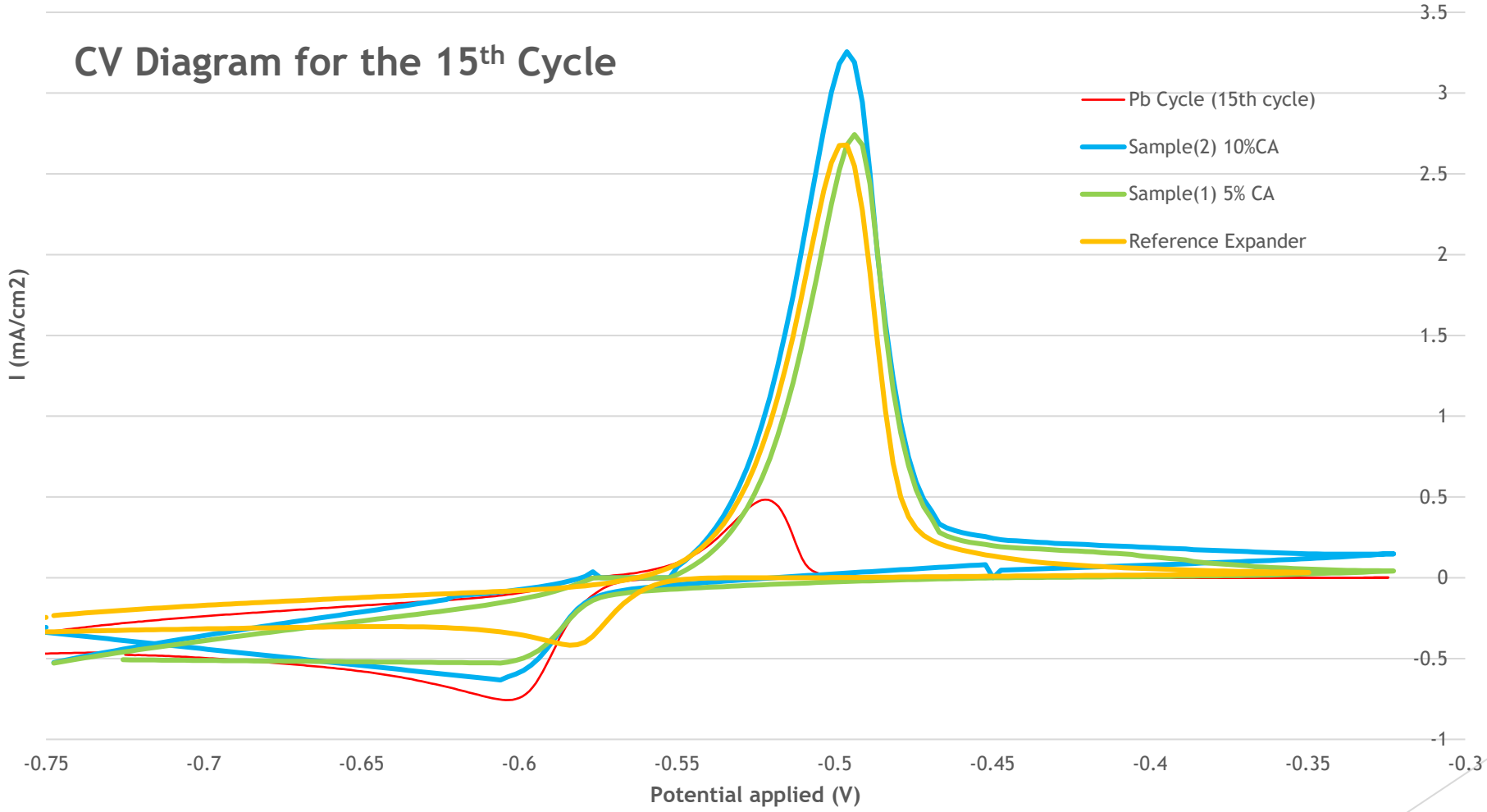
**Reference electrode**

**Inert electrode**

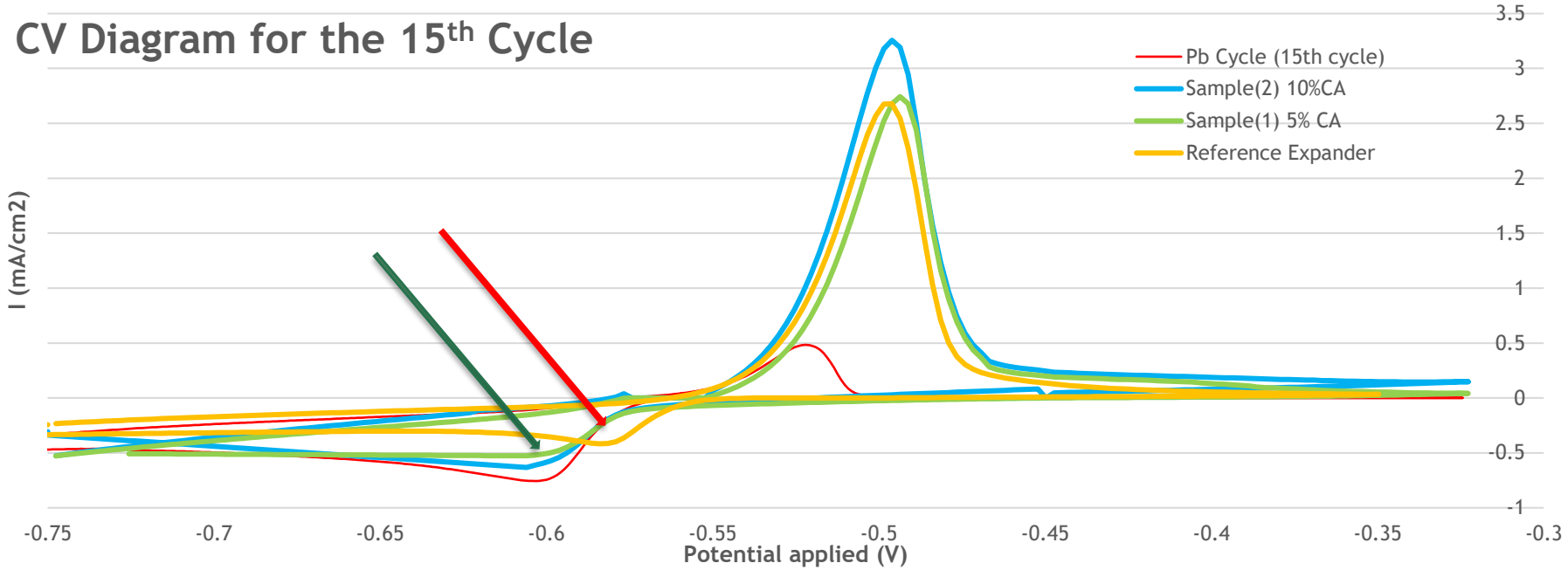
# The electrochemical test Results



# The electrochemical test Results



# The electrochemical test Results




| 15th Cycle | I max anodic (mA/cm2 ) | | I max cathodic (mA/cm2 ) | |
|---|---|---|---|---|
| Pb | 0.484 | % Improvement | -0.757 | % Improvement |
| Reference Expander | 2.679 | … | -0.417 | … |
| Sample (1) 5% CA | 2.744 | 2% | -0.530 | 27% |
| Sample (2) 10% CA | 3.256 | 22% | -0.633 | 52% |

# The electrochemical test Conclusion

**2- Electrochemical study of expanders shows that Sample(2) Expander containing 10% Carbon Aerogel has the best performance in Cathodic 15th cycle with 52% improvement in Cathodic maximum current (mA/cm2 ), which will cause better performance in battery charge process (Charge acceptance) and Sample(1) Expander containing 5% Carbon Aerogel found 27% improvement in compare with the reference expander in 15th cycle cathodic maximum current.**

| 15th Cycle | I max anodic (mA/cm2 ) | | I max cathodic (mA/cm2 ) | |
|---|---|---|---|---|
| Pb | 0.484 | % Improvement | -0.757 | % Improvement |
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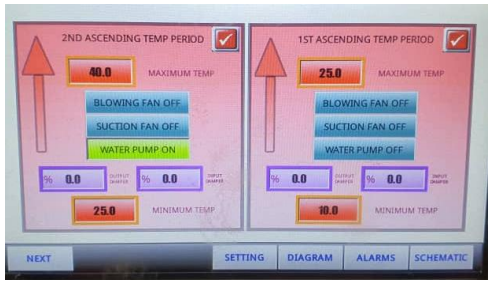
# 2- Single cell test

## Plate making at SST Co. Prototyping laboratory


### Paste making



| Parameter | Battery Sample (1) | Battery Sample (2) | Battery Sample (3) | Unit |
|---|---|---|---|---|
| Lead oxide | 3 | | | Kg |
| Reference Expander | 30 | 0 | 0 | gr |
| Sample(1) Expander with 5% CA | 0 | 30 | 0 | gr |
| Sample(2) Expander with 5%10% CA | 0 | 0 | 30 | gr |
| F/F | 3 | | | gr |
| H2O | | | | |
| H2SO4 (1.400 gr/cm3) | | | | |

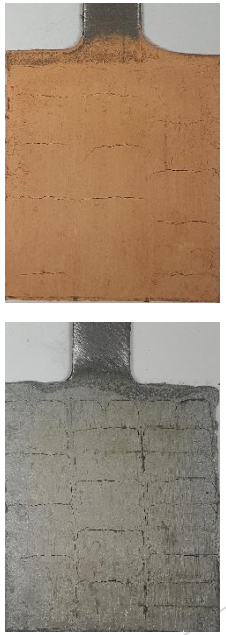
# 2- Single cell test

## Plate making at SST Co. Prototyping laboratory

### CURING

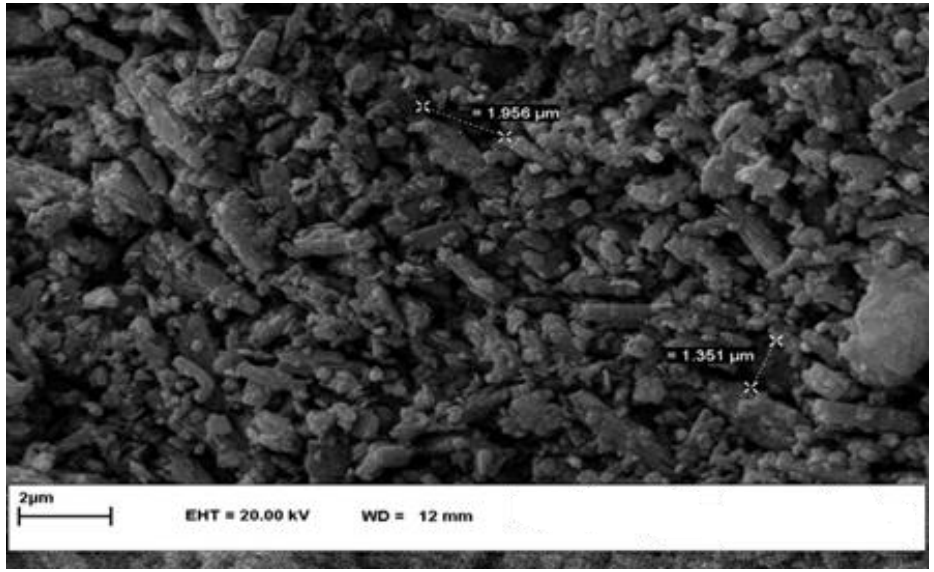

### Pasting

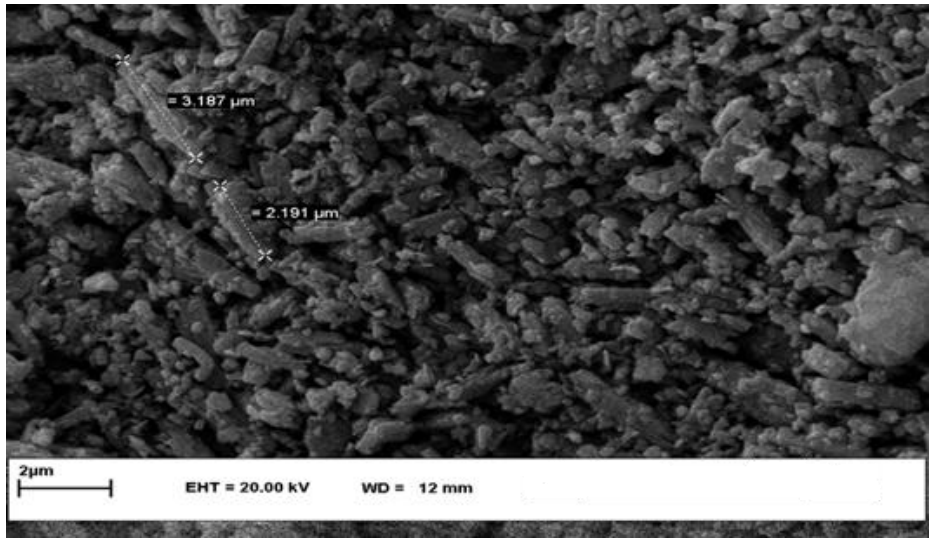
| Polarity | Grid weight (gr) | Pasting weight (gr) | Cured plate weight (gr) |
|---|---|---|---|
| Positive plate | 19 | 30 | 28 |
| Negative plate | 19 | 25 | 23 |

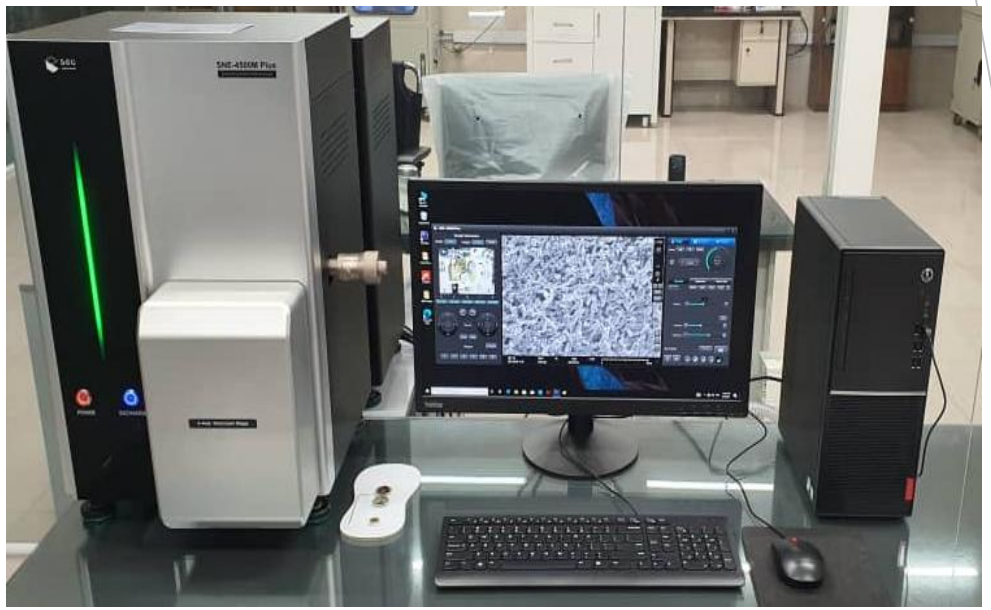


# 2- Single cell test

## Plate making at SST Co. Prototyping laboratory



Ion Sputter Coater

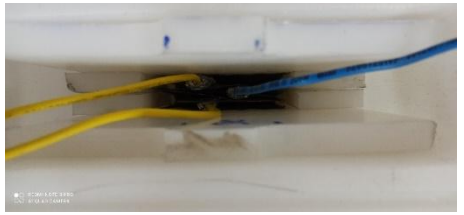
# 2- Single cell test

## Plate making at SST Co. Prototyping laboratory

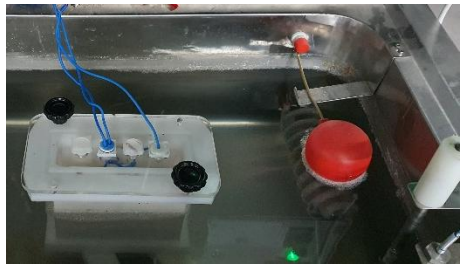
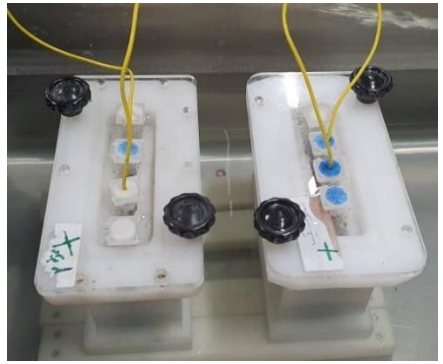
### Assembly of Sample 1-3 single cells with 2P1N as 2AH Single Cell







### 10AH Single cell Formation

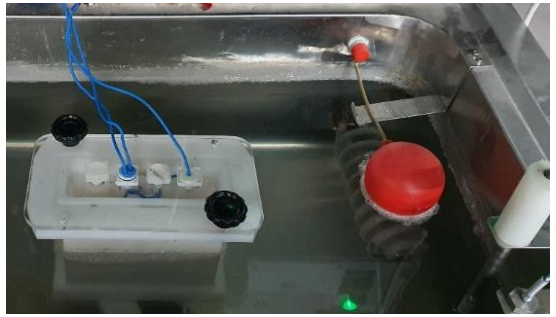




### Formed Plates

# 2- Single cell test

## SST Co. Testing laboratory

- 2-1- C20 Test
- 2-2- CCA Test
- 2-3- CA Test
- 2-4- Water Consumption



# 2- Single cell test

## SST Co. Testing laboratory

## 2-1- C20 Test

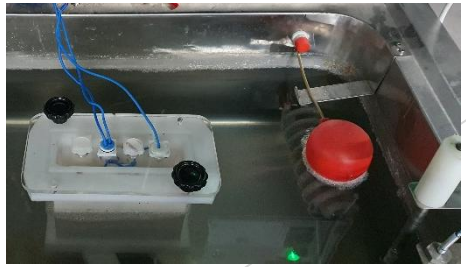
### According to IEC 60095-1 2018 Standard

| Sample | C20(1) | C20(2) | C20(3) | AVE | Improve |
|---|---|---|---|---|---|
| Reference Single Cell with Reference Expander | 2.17 | 2.13 | 2.15 | 2.15 | |
| Sample (1) Single Cell with Expander containing 5% CA | 2.24 | 2.22 | 2.22 | 2.23 | 3.5 |
| Sample (2) Single Cell with Expander containing 10% CA | 2.36 | 2.47 | 2.32 | 2.38 | 10.8 |

### The electrochemical test Conclusion

| 15th Cycle | I max anodic (mA/cm2 ) | |
|---|---|---|
| Pb | 0.516 | % Improvement |
| Reference Expander | 2.679 | ... |
| Sample (1) 5% CA | 2.744 | 2% |
| Sample (2) 10% CA | 3.256 | 22% |

**2V single-cell battery test results show 3.5-10.8% improvement in C20 Test**



# 2- Single cell test

## SST Co. Testing laboratory

## 2-2- CCA(-18C) Test With 20A Discharge current

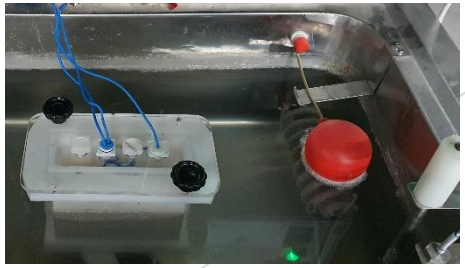
### According to IEC 60095-1 2018 Standard

| Sample | CCA(1) | CCA(2) | CCA(3) | AVE | Improve |
|---|---|---|---|---|---|
| | V(10S) | | | | |
| Reference Single Cell with Reference Expander | 1.345 | 1.488 | 1.377 | 1.403 | |
| Sample (1) Single Cell with Expander containing 5% CA | 1.493 | 1.584 | 1.577 | 1.551 | 10.5 |
| Sample (2) Single Cell with Expander containing 10% CA | 1.526 | 1.655 | 1.695 | 1.625 | 15.8 |

### The electrochemical test Conclusion

| 15th Cycle | I max anodic (mA/cm2 ) | |
|---|---|---|
| Pb | 0.516 | % Improvement |
| Reference Expander | 2.679 | ... |
| Sample (1) 5% CA | 2.744 | 2% |
| Sample (2) 10% CA | 3.256 | 22% |

**2V single-cell battery test results show 10.5-15.8% improvement in CCA Test**



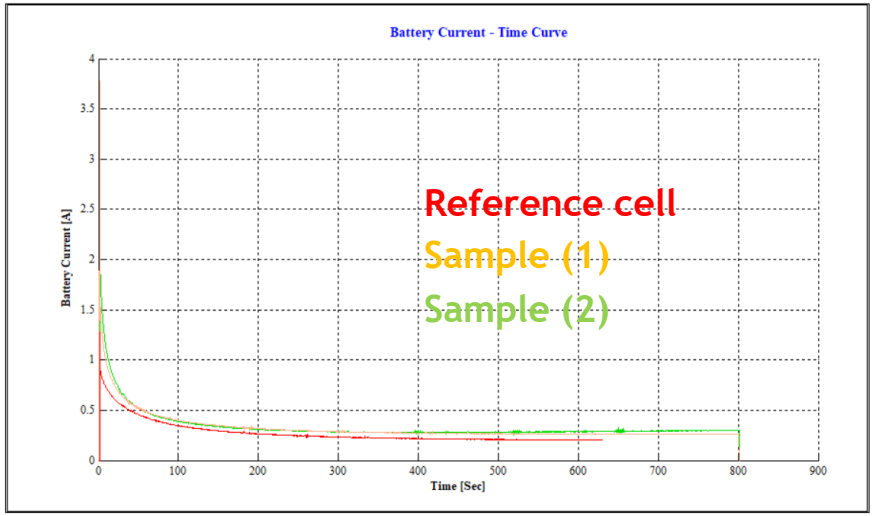
# 2- Single cell test

## SST Co. Testing laboratory

## 2-3- CA Test

### According to IEC 60095-1 2018 Standard

| Sample | CA | Improve |
|---|---|---|
| Reference Single Cell with Reference Expander | 0.207 | |
| Sample (1) Single Cell with Expander containing 5% CA | 0.266 | 28.5 |
| Sample (2) Single Cell with Expander containing 10% CA | 0.298 | 44 |




**2V single-cell battery test results show 28.5-44% improvement in CA Test**

### The electrochemical test Conclusion

| 15th Cycle | I max cathodic (mA/cm2 ) | |
|---|---|---|
| Pb | -1.017 | % Improvement |
| Reference Expander | -0.417 | ... |
| Sample (1) 5% CA | -0.530 | 27% |
| Sample (2) 10% CA | -0.633 | 52% |

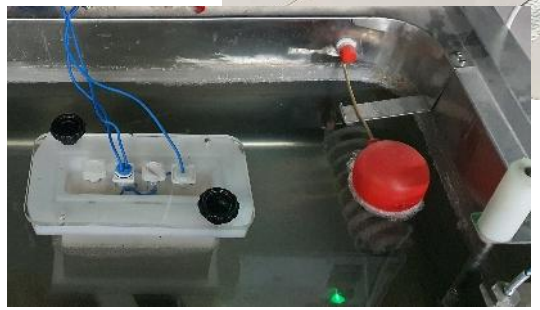
# 2- Single cell test

## SST Co. Testing laboratory

## 2-4- Water Consumption Test
## 21 days charging with 2.4v at 40c

**According to IEC 60095-1 2018 Standard**

| Sample | WC (gr/Ah) |
|---|---|
| Reference Single Cell with Reference Expander | 0.76 |
| Sample (1) Single Cell with Expander containing 5% CA | 0.72 |
| Sample (2) Single Cell with Expander containing 10% CA | 0.79 |



**2V single-cell battery test results show that the water consumption of the batteries remains almost constant by using CA in Expander.**

# Electrochemical and Single cell test Conclusion

**By using 5&10% CA in Expander composition**

**2V single-cell batteries test results according to IEC60095-1-2018**

**Electrochemical study of expanders**

**3.5&10.8% improvement in C20 test**

**2&22% improvement in Cathodic maximum current (mA/cm2 ) at the 15th cycle of the CV test**

**10.5&15.8% improvement in CCA test**

**28.5%&44% Improvement in charge acceptance test**

**27&52% improvement in Anodic maximum current (mA/cm2 ) at the 15th cycle of the CV test**

**The water consumption of the batteries remains almost constant**

# Further investigations

- Optimum Percentage of use for different applications
- Developing the different expander types containing CA for different applications
- Cycle life test at high temperature for tropical climate
- Electrochemical test at higher temperatures
- Electrochemical test for more cycles

SST Co

SARV SANAT TOOS (SST Co.)


**9th Baharestan St.- North khayyam Blvd.- Mashhad-IRAN**

**Tel : +98 51 37 57 17 10-12**

**Fax : +98 51 37 57 17 14**

**Website : WWW.SSTCO.BIZ**

For more information please contact: **Tech@sstco.biz**