CHEMICAL AND PHYSICAL CHANGES THROUGHOUT THE LIFE OF A BATTERY SEPARATOR

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UHMWPE GEL PROCESSING

UHMWPE 
(-CH₂-CH₂-)ₓ

Silica

Oil

Twin Screw Extrusion
UHMWPE + OIL + SHEAR $\rightarrow$ CHAIN DISENTANGLEMENT
SILICA AGGREGATES DISPERSED THROUGHOUT THE POLYMER MATRIX
OIL EXTRACTION + SOLVENT DRYING → POROUS SEPARATOR
DEGRADATION MECHANISM - SHEAR

UHMWPE chains are susceptible to chain scission during twin-screw extrusion.

Reactive end groups
- Hydrogen abstraction
- Oxidation
- Crosslinking

\[ R\cdot + O_2 \rightarrow ROO\cdot \]
Evidence of Shear Degradation

- Soxhlet extraction
  - Para-xylene
  - 138°C
CHAIN SCISSION VS. CROSSLINKING IN BATTERY ENVIRONMENT

More crosslinking $\rightarrow$ less extractables
PROCESS OILS ARE COMPLEX CHEMICAL MIXTURES

C-13 NMR Analysis provides a chemical fingerprint for process oils
C-13 NMR ANALYSIS (ALIPHATICS)

Mineral Oil

Naphthenic Oil #1

Naphthenic Oil #2

Naphthenic Oil #3

Pulse Sequence: z2p1

60 50 40 30 20 ppm
C-13 NMR ANALYSIS (AROMATICS)
Virgin Naphthenic Oil
Area = 67 units

Naphthenic Oil extracted after battery failure
Area = 21 units
SEPARATOR OXIDATION RESISTANCE

Test methods
- Perox 80
- Potassium dichromate
- Oxidation induction time
- Electrochemical oxidation test
- High temperature battery life test

Material considerations
- Polymer matrix
- Residual oil
- Oil / PE ratio
CHEMICAL RESISTANCE VS. OXIDATION RESISTANCE

After 20 hrs in H₂SO₄ at 80 °C

After 20 hrs in H₂SO₄/H₂O₂ at 80 °C
PEROX 80 --- % XMD ELONGATION VS EXPOSURE TIME

Polymer content: XLR > LR > STD
PEROX 80 --- PUNCTURE STRENGTH VS EXPOSURE TIME

0.15 mm backweb

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PEROX 80 --- PUNCTURE STRENGTH VS EXPOSURE TIME

0.25 mm backweb

Polymer content: XLR > LR > STD
CAN A 0.15 BW SEPARATOR BE DESIGNED TO HAVE AS GOOD OF OXIDATION RESISTANCE AS 0.25 BW?

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SURFACE SEM --- BEFORE AND AFTER PEROX 80 TEST

STD Separator

BEFORE

AFTER
SURFACE SEM ---- BEFORE AND AFTER PEROX 80 TEST

XLR Separator

BEFORE

AFTER
5cm x 5cm specimens were overcharged with 200mA/cm² current between 2 pure lead plates at 75°C:

- Three specimens per separator type
- Samples “fail” when \( \Delta V/\Delta t \geq 0.2 \) V/min

The polymer matrix within the separator is oxidized, allowing PbSO₄ to eventually grow to the positive plate, resulting in short-circuit.
ELECTROCHEMICAL OXIDATION RESISTANCE

Polymer content: XLR > LR > STD

AGM Failure ~ 35 hrs
ELECTROCHEMICAL OXIDATION RESISTANCE (CONT’D)

Even after aggressive oxidation test, 0.15 XLR has comparable puncture strength to pristine 0.25 STD

Polymer content: XLR > LR > STD
SUMMARY

Ɇ PE/SiO₂ separators are susceptible to many chemical and physical changes both during their manufacture and within a Pb-acid battery environment.

Ɇ The *polymer content* and *oil/PE ratio* are two critical parameters in the design and engineering of battery separators.

Ɇ ENTEK has introduced a series of LR and XLR separators that have low electrical resistance, good mechanical properties, and excellent oxidation resistance.

Ɇ Although some OEMs are reluctant to use thinner backweb separators in their battery designs, 0.15 XLR outperforms many 0.25 STD separators.