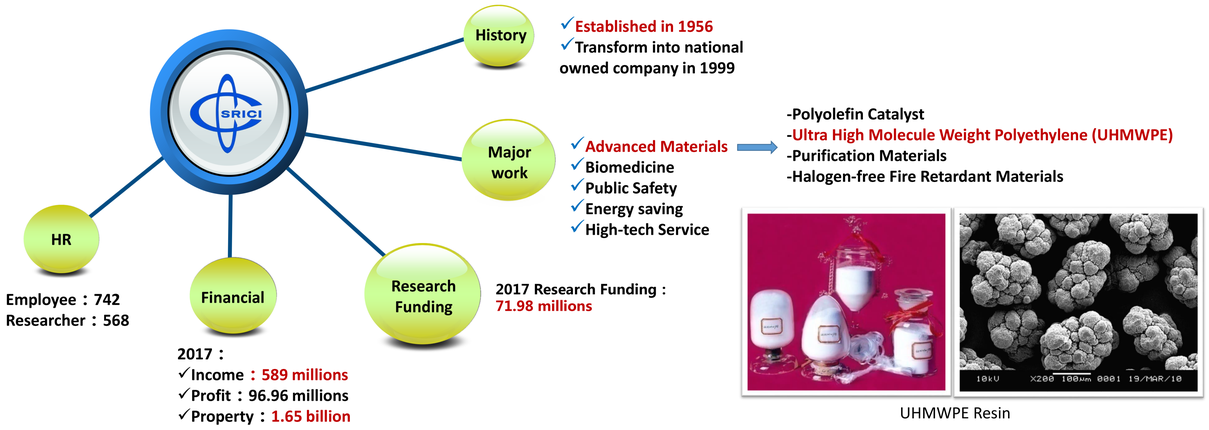
SHANGHAI RESEARCH INSTITUE OF CHEMICAL INDUSTRY CO. LTD.



UHMWPE Resin

Ultra-high molecular weight polyethylene (**UHMWPE**), is polyethylene with molecular weight larger than 1 million.
Structure: $(-CH_2-CH_2-)_n$
Appearance： Milky powder

UHMWPE Lithium Ion Battery Separators

- **Chemical, impact, abrasion resistance**
- **Better mechanical properties and heat resistance than traditional PE/PP separators. Protection from lithium dendrites impale.**
- **Maintain gel structure at high temperature and can prevent shortcut.**

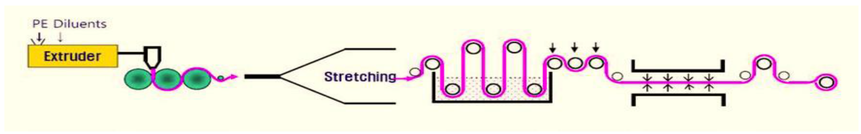


UHMWPE Separator Fabrication Equipment

Properties of Separator Specialized UHMWPE Resin

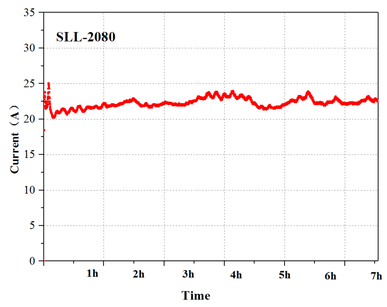
Characteristics	SLL-UHMWPE Resin	Test Method
Mw (10^4 g/mol)	Range from 70-150	ISO 1628
Particle Diameter D50 (μm)	170	ISO 13320
Melting Temp (oC)	137.16	ISO 3146
Crystalinity (%)	56.6	ISO 3146
Chlorinity (ppm)	1.42	ICP
Ashes (ppm)	77.7	GB1635-1979

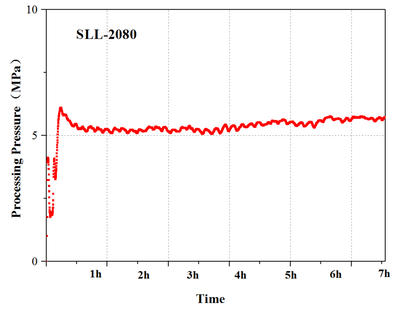
Separator Fabrication:



Mixing → Extrusion → Cooling → Extraction → Drying → Stretching → Setting

Fabrication Control





UHMWPE MATERIAL FOR LITHIUM ION BATTERY SEPARATORS

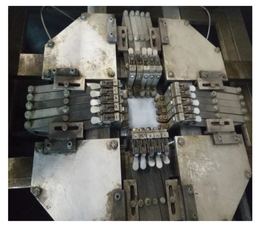
DPS Experiment Design:

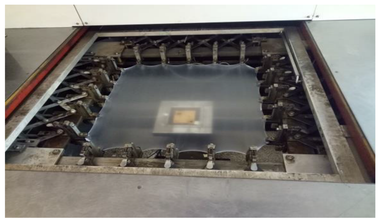
UHMWPE separators were prepared by thermally induced phase separation (TIPS), using liquid paraffin (LP) as diluent. Specified UHMWPE resin for LiB separators with 1.2 million viscosity molecular weight in average was produced by Shanghai Research Institute of Chemical Industry and used as raw material. The UHMWPE resin was dissolved by LP under heat and shear of a twin-screw extruder, then processed to be film. Raw films were cooled through a series of casting rolls and followed with solid-liquid phase separation, where paraffin was extracted from the film by dichloromethane. The film was then drawn to ideal thickness and tested.

The preparation process was optimized by Uniform Design, where permeability, tensile strength, puncture intensity and heat shrinkage was considered as key characteristic for the separators.

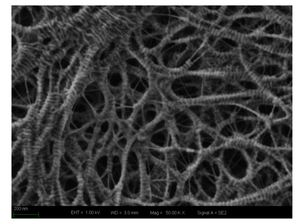


As-produced UHMWPE Films





Bi-axial Stretching



SEM Figure of UHMWPE Separator

Table 1. Uniform Design Experiment

试验号	X_1 Extruding Temp ℃	X_2 Extruding Speed rpm	X_3 UHMWPE Concentration %	X_4 Cooling Temp ℃	Y_1 Permeability s/100ml	Y_2 Tensile Strength MPa	Y_3 Puncture Strength N/μm	Y_4 Heat Shrinkage %
1	185	24	22	60	405	106	0.151	5.6
2	190	30	19	55	436	125	0.173	5.1
3	195	36	16	50	418	137	0.186	5.2
4	200	22	23	45	453	143	0.215	4.6
5	205	28	20	40	464	151	0.228	5.8
6	210	34	17	35	450	136	0.221	4.8
7	215	20	24	30	442	109	0.197	5.3
8	220	26	21	25	416	124	0.192	6.2
9	225	32	18	20	402	116	0.174	6.8

Multiple experiments were taken under uniform design table and the results were shown above. Lower value are desirable for Y1 and Y4, and higher value for Y2 and Y3. The final result Yj was desided as below by experienced subjection of 4 indicators with fuzzy set method from Lotfi A.Zadeh:

$$Y_j=0.2\times Y_{1j}+0.2\times Y_{2j}+0.2\times Y_{3j}+0.4\times Y_{4j}$$

Where:

$$Y_{1j}=\frac{Y_{i1max}-Y_{i1}}{Y_{i1max}-Y_{i1min}}=\frac{464-Y_{i1}}{464-402}=\frac{464-Y_{i1}}{62};$$

$$Y_{2j}=\frac{Y_{i2}-Y_{i2min}}{Y_{i2max}-Y_{i2min}}=\frac{Y_{i2}-106}{151-106}=\frac{Y_{i2}-106}{45};$$

$$Y_{3j}=\frac{Y_{i3}-Y_{i3min}}{Y_{i3max}-Y_{i3min}}=\frac{Y_{i3}-0.151}{0.228-0.151}=\frac{Y_{i3}-0.151}{0.077};$$

$$Y_{4j}=\frac{Y_{i4max}-Y_{i4}}{Y_{i4max}-Y_{i4min}}=\frac{6.8-Y_{i4}}{6.8-4.6}=\frac{6.8-Y_{i4}}{2.2}$$

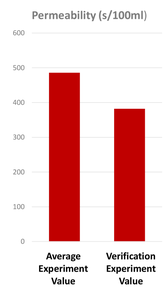
The data was analyzed via DPS (Data Processing System) software by quadratic polynomial regression method and final fomula was calculated as below:

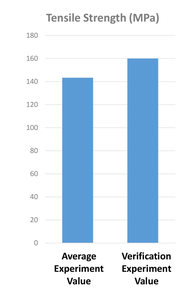
$$Y_j=9.53077235-0.9660210430X_3-0.00007263461561X_1^2+0.0024935753213X_2^2+0.013634611524X_3^2-0.0004728146591X_1X_2+0.0021732959909X_1X_3-0.0006382520039X_2X_3$$

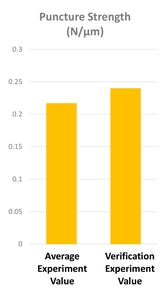
Where, Yj have highest score when X_1=185, X_2=36, X_3=16 and X_4=60 as calculated.

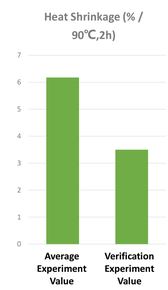
Verification experiment was then taken at 185 ℃, 36 rpm of extrusion speed, 16% of concentration and cooling temperature at 60 ℃. The results show that separators fabricated with designed parameter have improved performance in all 4 key characristics:

General Mechanical Properties of LiB separators:
Thickness：5-40um
Porosity：30-60%
Pore Size：0.03-0.08um
Air Permeability：400-600 S/100mL；
Tensile Strength：≥130MPa；
Impale Strength：≥0.2N/μm；









Conclusion:

The fabrication process of UHMWPE LiB separator was optimized by Uniform Design and ideal parameters was calculated via DPS (Data Processing System) software by quadratic polynomial regression method.
As produced separators have 11.5% improvement on permeability, 25.6% improvement on tensile strength, 24.3% improvment on puncture strength and 36% improvement on heat shrinkage.