Supporting information

A facile route for the fabrication of polypropylene separators for lithium ion batteries with high elongation and strong puncture resistance

Jian Kang[1], Dandan Chen[1], Bijin Xiong [2,*], Nan Zheng[3], Feng Yang[1], Ming Xiang[1], Zhuo Zheng[1]

[1] State Key Laboratory of Polymer Materials Engineering, Polymer Research Institute of Sichuan University, Chengdu 610065, China
[2] School of Chemistry and Chemical Engineering, Huazhong University of Science and Technology (HUST), Wuhan 430074, China
[3] Institute of Polymer Optoelectronic Materials and Devices, State Key Laboratory of Luminescent Materials and Devices, South China University of Technology, Guangzhou 510640, China.

* Corresponding author. E-mail: bjxiong@hust.edu.cn

(1) Essential work of fracture (EWF) measurement

The essential work of fracture (EWF) approach was used to investigate the fracture resistance behavior of the separators with and without white oil treatment, so as to explore the role of white oil treatment in the toughness and fracture behavior of the separator. According to previous elegant works cited in the main manuscript, the separators of were cut into the square samples (20x20 mm) for double edge notched tension (DEN-T) specimen (20 mm in width and 15 mm in gauge length) with several ligament lengths (2, 3, 4, 5, and 6 mm) for EWF measurement. Two samples were selected in this section, the original separator (SWO-0) and the separator immersed in the white oil bath for two hours under room temperature (SWO-2H). The tensile loading was performed by DEN-T at room temperature and at a crosshead speed of 0.003/min according to the European Structural Integrity Society (ESIS) protocol. Load-displacement (*P* to *V*) curves were recorded, and the fracture energy was calculated from the area under these curves. The fracture parameters were determined by plotting the specific work of fracture (w_f) as a function of the ligament length (*L*) using following equation.

$$w_f = \frac{W_f}{A} = w_e + \beta w_p L \quad \text{(s1)}$$

where W_f denotes to the total energy involved during the ductile fracture (the plastic deformation fully developed around the ligament region before to the crack growth) of the pre-cracked separator, *A* is the area of the ligament cross-section of the separator, w_e and w_p are the specific essential work of fracture and specific non-essential work of fracture respectively, while β is a shape factor to determine the volume of outer plastic zone. The obtained results were shown in Fig. S1 and Table S1.

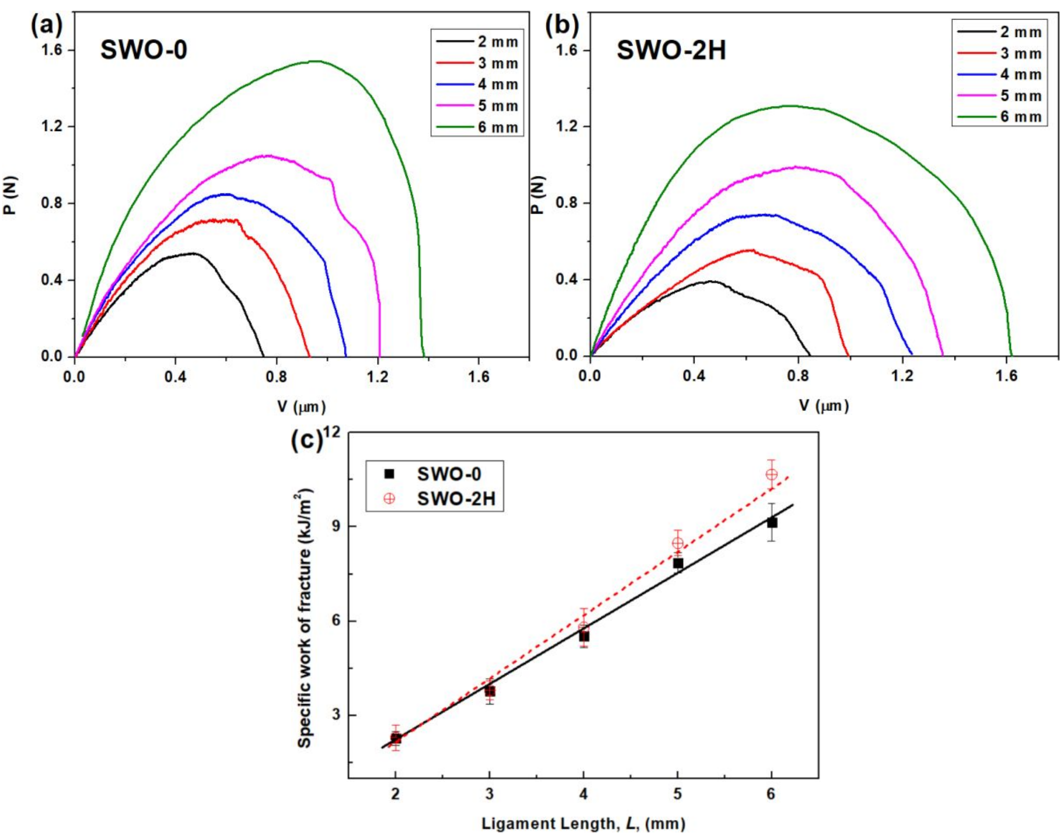

Figure S1 Load–displacement curves for the DEN-T specimens of the separators (a) SWO-0 and (b) SWO-2H, and (c) the specific work of fracture against ligament length of the separators.

Table S1 Parameters of the specific work of fracture of the separators

Sample	w_e (kJ/m^2)	βw_p (kJ/m^3)
SWO-0	0.83	1.23
SWO-2H	0.54	1.49

As can be seen from Fig. S1, after the white oil treatment, the load–displacement curves for the DEN-T specimens of SWO-2H is quite different from that of SWO-0, to be more exactly, longer displacement before total failure and the lower loading force of SWO-2H can be seen compared with SWO-0. Moreover, an adverse impact to the specific work of fracture w_e can be observed after the white oil treatment, meanwhile, an increase of the specific non-essential work of fracture (βw_p) can be seen, which might be attributed to the plasticization effect of the white oil. Therefore, the results of EWF measurement here might suggest that under the influence of the white oil treatment, the polymer separator behaves as a less rigid material, therefore, the size of plastic zone ahead of crack tip as well as the fracture toughness of the separator have been increased.

(2) Contact angle test

The contact angles (CA) of the separators were tested on a contact angle instrument (K100, KRÜSS, Germany). The separators were dried in an air-circulating oven at 60 ^{o}C for 24 h before testing. Next, a water droplet of 4 mL was placed on the top surface of each separator. Then, the contact angle of the droplet with the surface of the separator was measured. Five repeated trials were carried out for each sample.

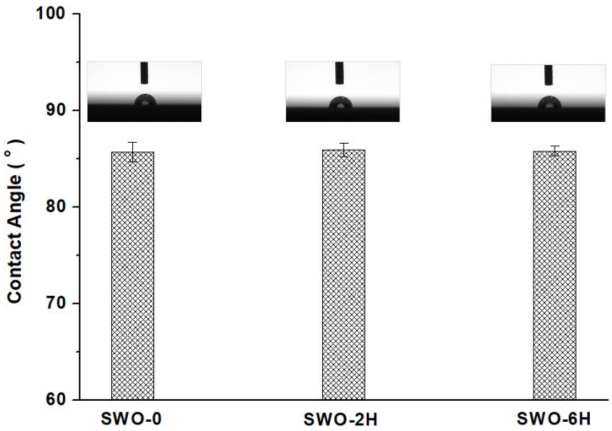

Figure S2 Contact angles of the separators before and after the white oil treatment.

(3) Differential scanning calorimetry

Calorimetric experiments were carried out on differential scanning calorimeter (Mettler Toledo DSC3+, Mettler Toledo Corp., Switzerland), under the protection of nitrogen atmosphere (50 mL/min). To ensure reliability of the results, the temperature scale was calibrated using indium as the standard. The heating rate is 10 °C/ min.

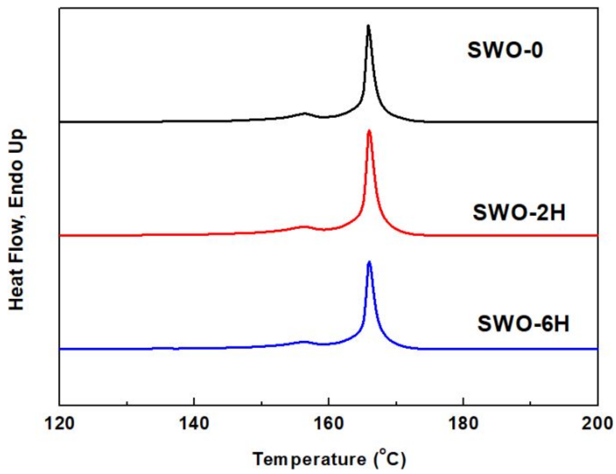

Figure S3 DSC melting curves of the separators before and after white oil treatment.

(4) Thermal shrinkage

The dimensional stability, represented by thermal shrinkage, was determined by exposing the separators with the size of 10 cm x 10 cm in an oven at 120 °C for 1 h. After that, dimensional variations of the samples were carefully calculated by *Eq. s2*:

$$Shrinkage(\%) = \Delta l / l_0 \tag{s2}$$

where Δl represents the dimensional change in length in the stretching direction (MD), and l_0 is the original length. The thermal shrinkage in transverse direction of all the samples cannot be detected.

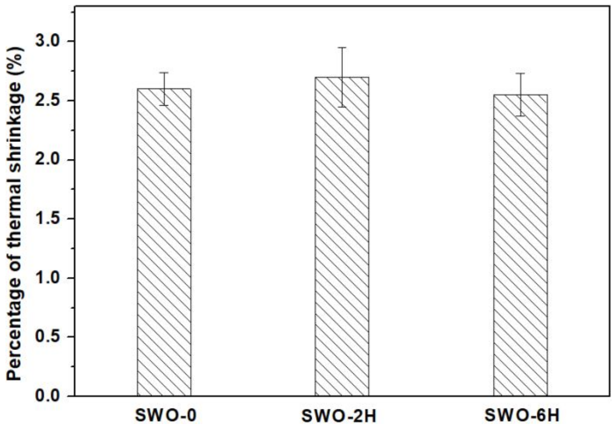

Figure S4 Thermal shrinkage along machine direction of the separators before and after white oil treatment.