How contact angle measurements can help to develop overheat protections for lithium ion batteries

The reliability and safety of Lithium-ion batteries (LIBs) has attracted more and more concern owing to its important and rapidly increasing applications in electronics, mobility, and large-scale energy storage. The separator is a key component to achieve a high performance of LIBs by conducting the lithium ions and preserving the electrolyte. Up to now, polyolefin microporous membranes, such as polypropylene, polyethylene, and their composites, are widely employed as commercial separators, since they have good mechanical properties as well as perfect chemical stability. However, this kind of separators show poor dimensional stability at high temperatures and inferior electrolyte wettability, which impact the battery's safety and rate capability. The wettability is an essential performance parameter for LIB separators. Only separators with good wettability can keep the electrolyte effectively and promote the migration of Lithium-ions. Although various methods have been reported to overcome the problems described above, they are still not suitable for practical LIB applications. Potential candidates for improved separator materials are polyimide (PI) nanofibers coated with polybenzimidazole (PBI) and Polyether imide (PEI) which both exhibit thermal stability and flame retardancy. More importantly, PEI possesses a very good wettability owing to the polar ether bonds in the PEI backbone and electrolyte, which endows it with unique value for LIBs. Considering the advantages of PBI/PI and PEI, Wu and team reported a novel tri-layer PBEI separator that exhibits good wettability, super strength, fire resistance as well as a shutdown function under high temperature by an in-situ welding technique (**Figure 1**).

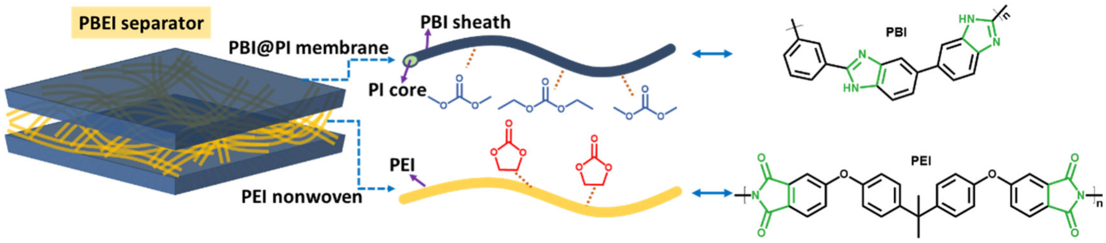

Figure 1. *Schematic principle of the interaction between separator and the electrolyte.*

In this work, a new tri-layer PBEI separator that employs polybenzimidazole-sheath@polyimide-core nanofibers (PBI@PI) as the support structure and melt-processable polyether imide (PEI) nonwoven as the interlayer was manufactured. To evaluate the wettability of the separator, contact angle (CA) measurements were carried out. **Figure 2** illustrates the wetting process and CA results of PBEI separators and commercial Celgard separators, indicating that the wettability of PBEI separator is obviously better than the commercial membranes. As **Figure 1** illustrated, the good wettability of PBEI separators is mainly caused by polar group (such as nitrogen heterocycles, carbonyls and ether groups) of PBI@PI and PEI. Polyolefin separator need to undergo hydrophilic treatment processes while the inherent polar group of PBEI makes hydrophilic treatment unnecessary. Besides, the interaction between the polar group of the PBI and PEI backbone and the polar ether bonds of electrolyte solvent improves the compatibility of PBEI separator with the electrolyte.

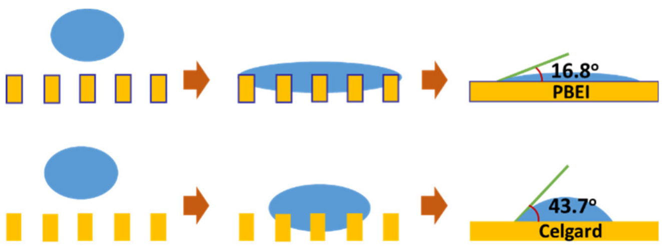

Figure 2. *The wetting process and contact angle measurement of PBEI and Celgard membranes.*

In addition, this work also showed that the PBEI membrane possesses other favourable properties such as a superb strength, outstanding thermal stability and high electrochemical performance. Especially, a shutdown function of PBEI separators that was realized via an *in-situ* welding technique, which can greatly enhance the battery safety and allow it to be use for high-rate and high-power battery applications is beneficial. **Figure 3** shows how lithium ions can transport through the separator under a certain working temperature, however, these lithium ion transport channels in the PEI layer will be blocked when the battery works in a harsh condition (> 235 ^{o}C).

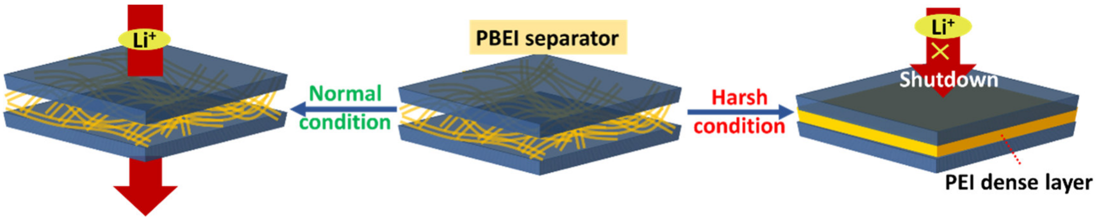

Figure 3. *Illustrations of the shutdown function of PBEI separator under normal conditions and harsh conditions*

Overall, this work reports a practical and new PBEI tri-layer separator with good wettability, superb strength, high electrochemical performance and outstanding thermal stability, which could be applied for high-safety and high-power LIBs. Besides, the melt-processable PEI nonwoven was employed as the shut-down layer, greatly improving the safety of the battery.

The optical contour analysis system OCA (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

In situ welding: Superb strength, good wettability and fire resistance tri-layer separator with shutdown function for high-safety lithium ion battery; Guohua Sun, Bingxue Liu, Hongqing Niu, Fuyao Hao, Nanjun Chen, Mengying Zhang, Guofeng Tian, Shengli Qi, Dezhen Wu; *J. Membr. Sci.,* **2020**, 117509*;* DOI: 10.1016/j.memsci.2019.117509