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# Inorganic-blended Separator for High Power HEV Battery

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**Abstract**

Inorganic-blended separator (IBS) newly developed by Asahi Kasei was evaluated by means of wettability measurement, Hybrid Pulse Power Capability (HPPC) test, and rate discharge capability test. The results of wettability showed IBS could absorb electrolyte more rapidly and plentifully than the conventional separator. From these results, IBS is expected to contribute to the productivity improvement of the cell manufacturing and longer cycle-life of the cell. The results of HPPC test at the current of 5C indicated the battery with IBS had higher discharge and regenerative pulse power capability than with the conventional separator. The averaged battery size factor of IBS to meet the USABC minimum power assist was 5% smaller than that of the conventional separator. This data indicates the possibility that battery manufacturers can reduce the material cost per cell as well as 5% of total cell numbers per a battery pack. The results of rate discharge capability test indicated the cell with IBS showed 90% of 1C rate discharge capability at the 30C rate, while the conventional separator showed 17%. It is expected that there is the higher gap in the BSF at the higher current HPPC because of the significant difference in the discharge capacity at 30C. Moreover, IBS generated less heat than conventional one because of low electric resistance. The less-heat-generation property of IBS has a possibility of offering the design margin of the cooling system of the battery pack as well as the longevity of the cell. Therefore, IBS has promising properties for HEV battery separator.

*Keywords: inorganic-blended separator, polyolefin, lithium-ion battery, HEV*

## 1. Introduction

Polyolefin-based micro-porous membrane has been widely used for the Lithium-ion battery (LIB) separator because of its fine, small, continuous porous structure for performance, and high mechanical strength for insulation property. The manufacturing process for micro-porous membrane is separated into wet process and dry process.

Asahi Kasei group has been researching and developing the micro-porous membrane technologies, especially by means of phase separation between polymer and solvent (i.e. wet process), since the early 1970's. Before launching the separator for secondary LIB in 1990, we manufactured the separator for lead-acid battery in 1975, for primary lithium battery in 1987, by improving the phase separation technologies. We have been improving the separator for LIB in terms of performance and safety since 1990. Currently, we are the world's leading separator manufacturer, known for the product name HIPORE™ [1]. Our advantage is the design capability of separator's properties, such as thickness, pore size, porosity, permeability, and mechanical strength, to meet our customers' demands.

With increasing demand for lithium-ion based hybrid/electric vehicle, we have been developing the separator specifically designed for lithium-ion HEV battery with considering power and safety. Figure1 shows our R&D directions of the separator for HEV. As the best solution for HEV application, we recently developed inorganic-blended separator (IBS) and released at LLIBTA-08, Tampa [2]. IBS has excellent properties of low ionic resistance, good wettability, high thermal stability and high mechanical rigidity. The battery with IBS is expected to have an excellent high power capability because of its low ionic resistance.

This paper presents the advantages of IBS in terms of the membrane properties, the cell manufacturing, and the battery performance.

## 2. Characteristics of IBS

### 2.1 Experimental

For the wettability test, a strip of separator (10mm in width × 50mm in length) was soaked into mixed solvent of ethylene carbonate/ethyl methyl carbonate/dimethyl carbonate (EC:EMC:DMC = 1:1:2). The apparatus is shown in Figure 2. Vessel was sealed in order to prevent the solvent from volatilization. A conventional separator having thickness of 25µm, porosity of 43% and puncture strength of 400g was used as reference.

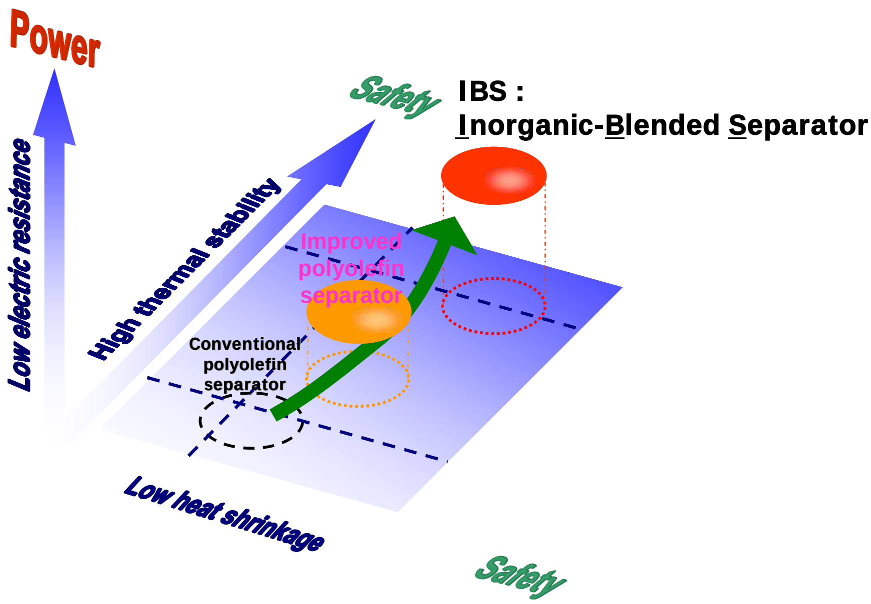


Figure 1: R&D directions of the separator for HEV

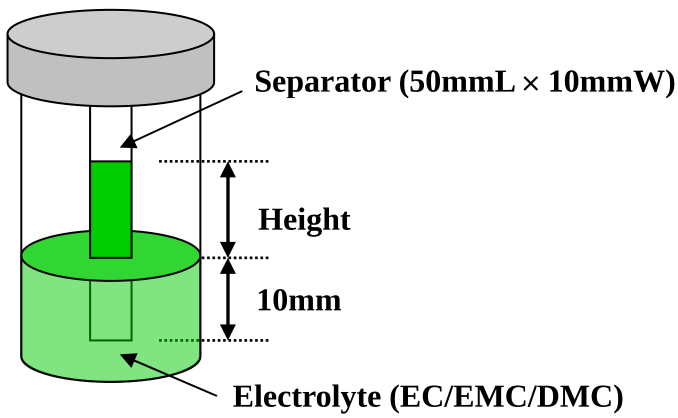


Figure 2: Apparatus for wettability test

## 2.2 Typical properties of IBS

Table 1 shows the typical properties of IBS grade family. These innovative separators have two major characteristics: 1) high permeability and high porosity for higher battery power, and 2) high mechanical strength for insulation integrity.

## 2.3 Surface image of IBS

Figure 3 shows the surface image of IBS by scanning electron microscopy. The characteristic points of IBS structure are as follows: 1) A fine inert inorganic filler disperses homogeneously in the fibril structure; 2) Fibrils interconnect each other to form the solid, isotropic structure. The unique structure of IBS gives the excellent properties.

Table 1: Typical properties of IBS

| Grade | Typical properties | | | | | |
|---|---|---|---|---|---|---|
| | Thickness (μm) | Porosity (%) | Air permeability (sec/100cc) | Puncture strength (g) | Tensile strength ( $kg/cm^2$ ) | |
| | | | | | MD | TD |
| IBS - A | 20 | 69 | 40 | 450 | 1400 | 450 |
| IBS - B | 25 | 68 | 50 | 500 | 1100 | 500 |
| IBS - C | 25 | 60 | 120 | 600 | 1500 | 700 |

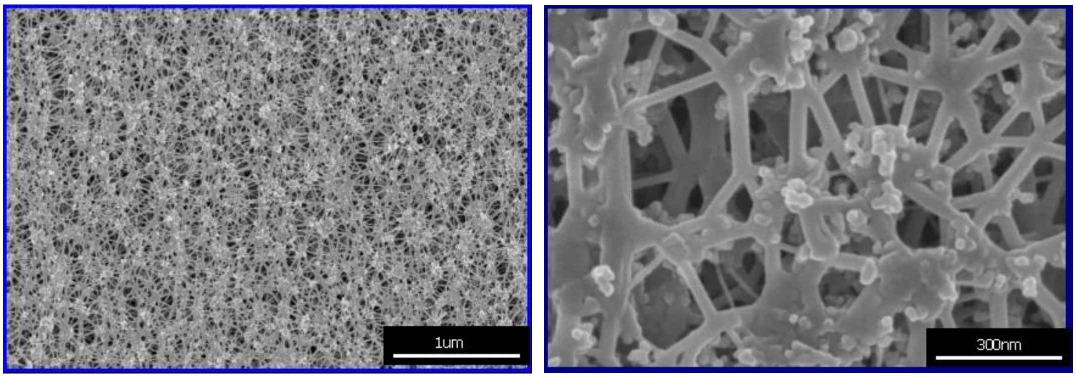


Figure 3: Surface image of IBS

### 2.4 Wettability of IBS

Figure 4 shows the results of wettability test. Results indicate that IBS can absorb: 1) the electrolyte of 5 mm high 10 times faster; 2) the electrolyte 3 times more plentifully in 30 minutes than the conventional separator. This absorption performance comes from the fine dispersed inorganic-filler, which has good wettability with electrolyte, and the pore structure designed for electrolyte permeation. This advantage contributes to the productivity improvement of the cell manufacturing with reduction of the electrolyte injection time.

A possible reason for the deterioration of the cell performance after hundreds of charge-discharge cycles is that the separator inside the cell becomes less porous to absorb the electrolyte and permeate ions by the compressive force from the negative electrode in charging and depositions from the materials. Therefore, a good wettability of IBS can contributes to a longer cycle-life of the cell.

## 2. Cell evaluation

### 3.1 Experimental

18650-sized 1.1Ah-capacity cell was used to evaluate the cell performance. The specific data of the cell is shown in Table 2. HPPC test was carried out at the current of 5C according to FreedomCAR Battery Test Manual for Power-Assist Hybrid Electric Vehicles. Rate capability test with fresh cell was performed at 25 °C, and the surface temperature of the cell was measured to estimate the heat generation behavior during discharge. A conventional separator having thickness of 25µm, porosity of 43% and puncture strength of 400g was used as reference.

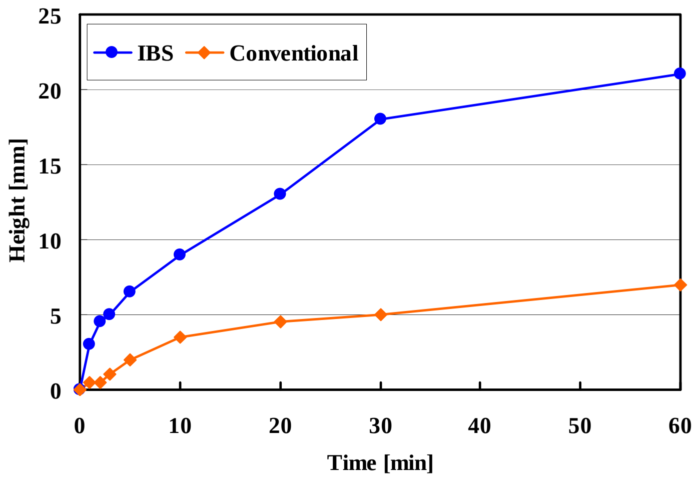


Figure 4: Results of wettability test

Table 2: Specific data of cell for each test

| Test | HPPC / Rate capability |
|---|---|
| Cathode | $LiFePO_4$ |
| Anode | Carbon |
| Electrolyte | 1M-$LiPF_6$/EC/EMC/DMC |
| Type | 18650 |
| Capacity | 1.1Ah<br>(3.6V-2.0V) |

### 3.2 HPPC test

HPPC test results indicated that IBS-B had better discharge and regenerative pulse power capability than the conventional separator because IBS-B had lower ionic resistance. (Test results are not shown)
The averaged battery size factor (BSF) to meet the USABC minimum power assist was calculated from results of 14 cells. The averaged BSF of IBS was 948 and that of the conventional separator was 999, 5% higher than that of IBS. This data indicates the possibility that battery manufacturers can reduce the material cost per cell as well as 5% of total cell numbers per a battery pack.

### 3.3 Rate capability test

Rate capability test at high discharge rate was carried out in order to rate the ability for high power application, such as heavy-duty HEV. Figure 5 shows the result of discharge rate capability test with IBS-B and the conventional separator. Discharge capability of IBS at 30C rate was 90% of 1C discharge rate capacity, while that of the conventional separator was 17%. Obviously, IBS has excellent capability for high power application. From two observations of HPPC test and rate capability test, we expect the higher gap in the BSF at the higher current HPPC because the current in HPPC test was 5C. This expectation is supported by the significant difference in the discharge capacity at 30C.

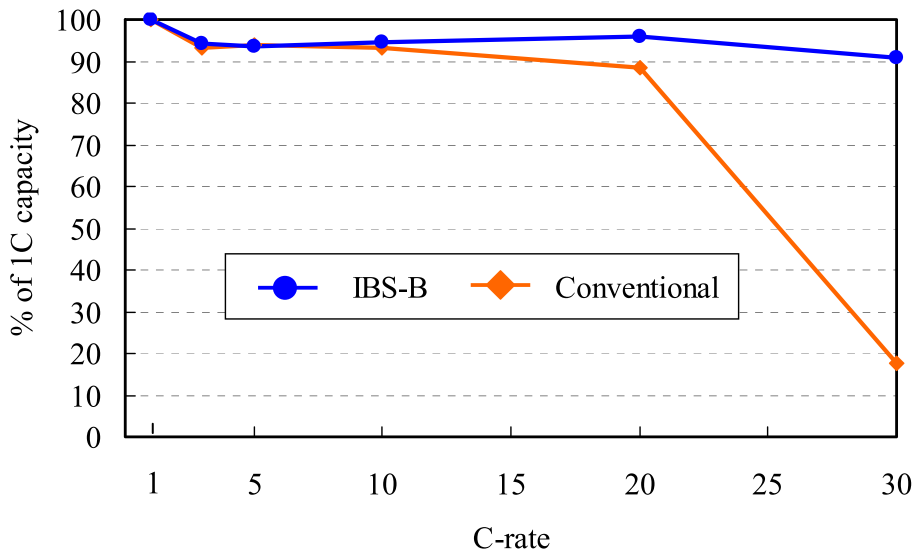


Figure 5: Result of rate capability test

### 3.4 Heat generation during discharge

Figure 6 shows the temperature increasing behavior at 20C discharge. IBS generates less heat than conventional separator at discharge because of lower internal resistance. Temperature of the cells at 1000mAh was 35.7°C for IBS, while 38.2°C for the conventional separator. Furthermore, IBS generated less heat at a pulse discharge in HPPC test than the conventional separator, though the amount of heat was small. We expect that heat generation from one cell become significant in the battery pack/system, so the less-heat-generation property of IBS can offer the design margin of the cooling system of the battery pack/system as well as the longevity of the cell.

## 4. Summary

Inorganic-blended separator (IBS) from Asahi Kasei HIPORE™ has the fine, isotropic structure, and good wettability. The evaluation of the cell using LFP/Carbon system with IBS showed an excellent high power, high rate capability and less-heat-generation property.
These results indicate that IBS has a great possibility for HEV battery separator, and provide solutions for our customers. In addition, AsahiKasei has been developing advanced separators for EV and PHEV battery. AsahiKasei will provide solutions for EV and PHEV battery as well as HEV battery.

## 5. References

[1] http://www.asahi-kasei.co.jp/hipore/en/index.html
[2] Hiroshi Hatayama, *Proceedings of the Forth International Symposia on Large Lithium Ion Battery Technology and Application, 2008.*

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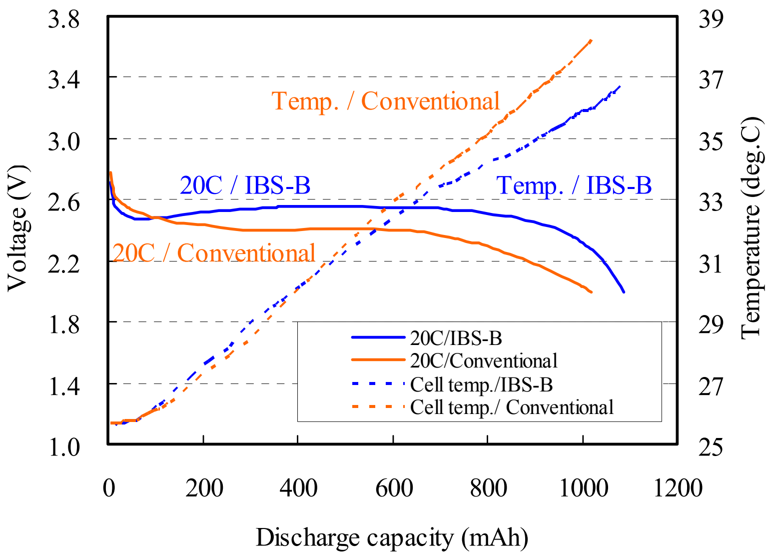


Figure 6: Temperature increasing behavior at 20C discharge