Overview of High Temperature Sodium Sulphur and Sodium Nickel Chloride Batteries

Introduction

There is a growing interest in low-cost electrical energy storage systems for grid storage applications. The possible shortage of lithium is promoting a renewed interest in sodium-based batteries for large format batteries. The molten sodium battery systems – sodium sulphur and sodium nickel chloride - are mature enough for adoption on a large scale of hundreds of megawatt-hours (MWh). These technologies are already in use for integration into renewable, back-up power and other grid services to provide power during times of high demand. The increase in grid storage capacity is forecast to exceed 1TW by 2030.[(1)]

As the technology develops further it is expected that the use of molten sodium batteries along with sodium-ion batteries will become more widespread and become an important part of the energy storage mix.[(2,3)]

The overall cell reaction is:

NiCl2(s) + 2Na (l) ↔2 NaCl + Ni(s) Ecell ~ 2.58 V at 300 °C

In contrast to the NaS system the cathode does not stay fully liquid, and the cycling may result in nickel chloride coated nickel particles. The battery is maintained at 300C to ensure sufficient sodium ion conductivity through the BASE separator.

NaS batteries deployed in commercial systems have an energy density of up to 400Wh/l and a cycle life of up to 4,500 with an operational lifetime of 15+ years. The performance of Na-NiCl2 batteries is up to 190Wh/l with again 4,500 cycles and an operational lifetime of up to 20 years.
An important part of these cell systems is the BASE separator. β''-alumina has long been recognised as the most suitable sodium-ion conductor separator for high temperature molten sodium batteries.

The β''-alumina is required to operate at these elevated temperatures for several decades and must retain structural and electrochemical performance over this time. β''-alumina is not a pure Al2O3 phase such as the α or γ, but a sodium oxide doped alumina material.

Sodium beta-alumina compounds are commonly recognized as the having the formula Na2O.nAl2O3, in which n is typically between 5 and 11. These compounds deliver high sodium mobility along the conductive planes within the layered structure. Li2O and MgO are often added to aid the formation of the correct layered structure to ensure high sodium conductivity. Oxide impurities, such as calcium, silica and potassium, have been shown to be detrimental to the performance of the BASE by several mechanisms such as grain growth and the formation of non-conducting phases at the grain boundaries.[(8-10)] Reducing the sodium-ion conductivity of the separator has a direct negative effect on cell performance by increasing the overpotential which reduces the cell potential and increases the capacity decline with cycling.

The BASE material can be simply made via a solid-state reaction between powdered α-alumina and sodium oxide at around 1600˚C. Purity of the starting materials is particularly important to ensure that only advantageous compounds are included in the final BASE. AEM 4N α-alumina which has low levels of all metal oxides is an ideal starting material for the manufacture of BASE with the required sodium-ion conductivity and durability for long term cycling and battery life.

References

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