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Effect of POSS-PEG hybrid nanoparticles on cycling performance of polyether-LiDFOB based solid polymer electrolytes for all solid-state Li-ion battery applications

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ABSTRACT

For the first time, the consequences of organic-inorganic hybrid nanoparticle polyhedral oligomeric silsesquioxane-polyethylene glycol (POSS-PEG($n = 4$)) on the physicochemical and electrochemical properties of poly(ethylene oxide) (PEO)-lithium difluoro(oxalato)borate (LiDFOB) based nanocomposite solid polymer electrolyte (NSPE) membranes were systematically prepared and utilized as an active separator for battery applications. The thermal stability and structural properties of the prepared NSPE membranes were analyzed by means of differential scanning calorimetry (DSC), thermogravimetry (TG) and X-ray diffraction (XRD) analyses. The morphological changes by POSS-PEG in polymer electrolyte membranes were investigated by field emission scanning electron microscopy (FE-SEM) and transmission electron microscopy (TEM). The incorporation of POSS-PEG greatly enhanced the ionic conductivity, mechanical integrity and compatibility. The maximum ambient temperature ionic conductivity was found to be in the range of 7.28×10^{-5} S/cm for 40 wt% POSS-PEG. Finally, the solid state lithium cell was assembled as Li/NSPE/$LiCoO_2$. The cell delivered a maximum discharge capacity of 187 mAh g^{-1} at 0.1C-rate with very good capacity retention up to 50 cycles. The test results indicated that the electrolyte is found to be a better candidate than those reported earlier.

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Introduction

The high-performance lithium-ion battery (LIB) technology has played an important role in promoting the portable electronic devices and electric vehicles due to their high energy and power densities [1,2]. Generally, the electrolytes used in LIBs can be divided into solid, gel and liquid electrolytes. Compared with traditional liquid and gel electrolytes, solid electrolytes have several advantages such as high energy density, flexible geometry, no-leakage of electrolyte, thus higher safety [3,4]. From the last three decades, many of the lithium ion conducting solid polymeric networks have been prepared and characterized [5]. Unfortunately, solid polymer electrolytes (SPEs) offer very low ionic conductivity of the order of 10^{-7} S/cm at ambient temperature that excludes their practical applications [6] and gel polymer electrolytes (GPEs) drop their mechanical strength when they are plasticized [7]. In order to overcome and improve the properties of solid polymer electrolytes with better safety and long term stability, the incorporation of nanomaterials in polymer system has introduced by researchers and scientific communities. Also, the studies on nanocomposite solid polymer electrolyte (NSPE) membranes reveal that these can lead to the assembly of safe and reliable batteries [8].

Among different polymer hosts studied, the polyether, poly (ethylene oxide) (PEO) can easily complex with lithium salts. The monomer ethylene oxide (EO) units of PEO have a high donor number for Li^+ and high chain flexibility, which are important for improving ion transport. In addition, PEO has a high dielectric constant and strong Li^+ solvating ability. Therefore, PEO-based SPE

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