Fibrous glass electrodes for all solid-state batteries

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Abstract

In recent years there is notable advance in rechargeable energy storage devices driven by geopolitically forced decline from fossil fuels. Main focus is on lithium-ion batteries utilized in almost all aspects of human life ranging from small electronic devices and EPS to electric transportation vehicles. However prevalent construction designs have several problematic areas. High price, high weight, relatively short lifetime under high power drain and most importantly safety. They contain highly flammable electrolytes, toxic materials and in case of thermal runaway release toxic and corrosive fumes. These problems can be addressed by utilizing all solid-state battery systems. Major drawbacks are generally solid materials low conductivities, therefor best solution is using thin layer materials ranging from tens of nanometres to several micrometres. There are several promising new materials especially silicon to be used as anode with reversible capacity almost 10 times higher than currently utilized graphite electrodes. Main issue with silicone is high expansion levels during lithiation, almost 300%. This again can be however addressed by transferring to submicron or nano dimensions.
Also, large number of solid electrolytes have been developed, where several high ion conductive types of glass can even surpass bulk polymer materials.
Very convenient method of producing thin-sheet nanomaterials is electrospinning. Thaks to recent development in upscaling production, it has become viable method to produce materials with electrochemical purity in amounts sufficient for industrial production unlike other nanomaterial production methods. It has been reported that it is possible to obtain fibres as thin as 2 nm in diameter. It is possible to prepare complex materials through sol-gel methods, however introducing highly active particles into spinning solutions has proven to be more convenient and more importantly cheaper option. It also allows to use recycled materials or even byproduct unused earlier. There are however several major issues. Spinning solutions, a processing conditions must be optimized to supress particle agglomeration and sedimentation, premature condensation, even particle distribution, and reaching uniform fibre distribution.

This study is focused on characterising morphology and properties based on processing and postprocessing conditions with 29Si NMR, XPS, XRD, EIS, laser confocal and electron microscopy. For this study glassfibre thin-sheet mats via sol-gel based on SiO2 filled with recycled active materials, were prepared from TEOS and PVP mixtures. PEMs were separated from EOL EV batteries, silicon from EOL monocrystalline solar cells. Next step

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of production is high pressure compacting followed by high temperature calcination in controlled atmosphere. Produced fibres retain its flexibility and functionality even after short exposure up to 1000$\circ$C.
Based on material testing, this technology seems promising in creating safer, energy and cost-effective batteries for EV application.

This work is supported by Skoda Auto a.s. and the project "The Energy Conversion and Storage", funded as project No. CZ.02.01.01/00/22_008/0004617 by Programme Johannes Amos Comenius, call Excellent Research.

Keywords: electromobility, recyclation, battery, glassfiber, nanofiber