Highly efficient and high capacity-performing nanoarchitectures for free standing electrodes in all solid-state Li-S batteries

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With growing demands for lower cost energy storage alternatives which exhibit high capacities over multiple cycles, Li-S battery systems present a promising class of materials for widespread practical applications. However, challenges remain in realizing this technology including, for example, avoiding the dissolution of the intermediate polysulfide species which results in the loss of active material and decreased ionic conductivity. One way to tackle this is to avoid the use of liquid electrolytes and move to an all solid-state battery configuration, which also considerably improves the safety features of these cells. Here, we report a fast, facile synthesis of $Li_3PS_4/Li_2S/C$ nanoarchitectures designed to work as free-standing cathodes in all solid-state Li-S batteries. A novel microwave-assisted approach is used to develop nanostructured Li_2S, which, using a simple solution-based procedure, could be incorporated in a range of $Li_3PS_4/Li_2S/C$ three-phase nanostructured architectures in which Li_3PS_4 homogeneously coats Li_2S and C nanoparticles. Our fabrication process is scalable and cost-effective, affording precise control over composition thereby allowing tunability over the mechanical and electrical properties of the cathode. An all solid-state battery employing $Li_3PS_4@Li_2S/C$ as a free-standing cathode showed capacities up 840 mAh g^{-1}, with exceptional cycling stabilities also noted at faster rates (~440 mAh g^{-1} retained at 100 µA/cm^2 up to 400 cycles). The promising battery performance of these composites is attributed to enhanced electrode electronic and ionic conductivity and excellent compatibility between the solid components, reflected in the preservation of the electrode integrity and the build up of very low interfacial resistances upon cycling. This work highlights how nanoscale design can improve performance of functional materials and provide optimized composites as cathodes for all solid-state batteries.

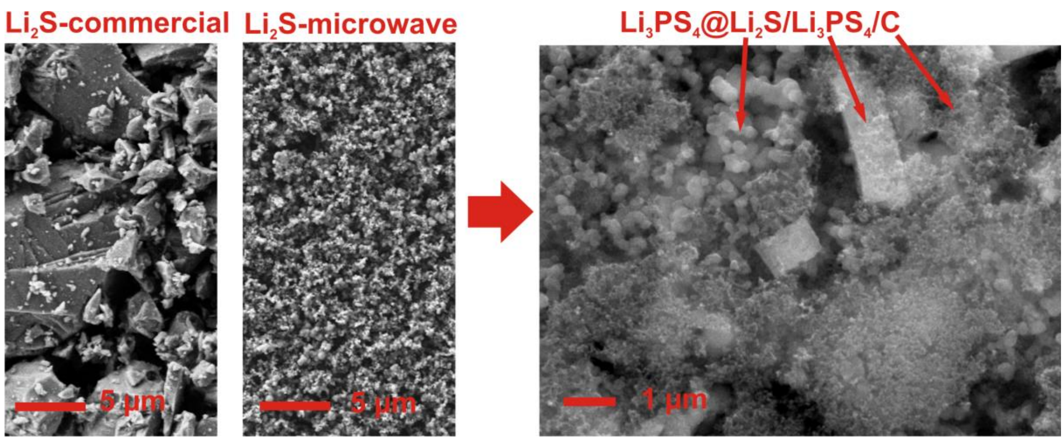

Figure. Morphologies of microwave-synthesized Li_2S, commercial Li_2S and one of the $Li_3PS_4/Li_2S/C$ nanocomposites.