



## Production of Alkali Sulfide Cathode Materials for Next Generation Rechargeable Batteries

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**Summary:** A method to produce hierarchically structured alkali sulfide cathode materials.

**Description:** Meeting the demands of advanced consumer electronics and electronic vehicles requires next generation rechargeable batteries with greater specific-energy and energy-density than current lithium ion batteries. Alkali sulfide ( $M_2S$ ,  $M = Li$  and  $Na$ ) cathodes have great promise for enabling a number of “beyond-lithium” technologies, including metal-sulfur, graphite-sulfide, and silicone-sulfide batteries. Significant efforts have been invested to develop  $M_2S$  cathodes.  $M_2S$  nanoparticles serve as a good model system as their small dimensions and high specific surface area enables higher capacity, greater cycling stability, and faster charging/discharging kinetics, but face the challenge of achieving both high specific-capacity and capacity-density. In addition the current methods for production of  $M_2S$  nanoparticles are energy intensive and not viable on a commercial scale. A number of practical challenges also exist when  $M_2S$  nanoparticles are directly used in batteries.  $M_2S$  hierarchical structures ( $M_2S$ -HSs) have the potential to overcome many of these limitations. The  $M_2S$  hierarchical structures developed in this work are composed of micrometer-sized secondary clusters of  $M_2S$  nanoparticles that are wrapped in a carbon scaffolding. These secondary structures have the benefits of both nanoparticles (improved cyclability and high specific capacity) and of bulk materials (high capacity density). The secondary structures are wrapped within a carbon-scaffold to form hierarchical structures and electrical interconnectivity among primary nanoparticles is created producing an effective electrode material.

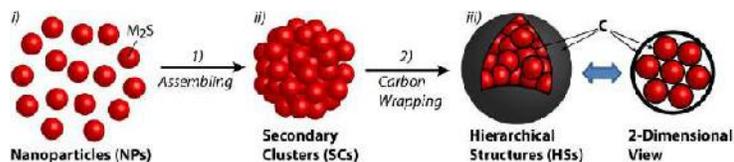
### Main Advantages of this Invention:

- The  $M_2S$  secondary structures are produced through a one-step process, without the need to first synthesize  $M_2S$  nanoparticles. The reaction is thermodynamically favorable, spontaneous, rapid, and complete, and proceeds at room temperature and pressure. The auxiliary reagents can be recycled without any treatments, enabling a continuous process for manufacturing.
- A polymer coating on the secondary structures is applied and is resistant to the solvent used to form the carbon-scaffold.
- The carbon scaffold enables electrical interconnectivity among the primary nanoparticles, facilitates M-ions transport throughout the whole structure, and blocks the electrolyte and prevents the formation of detrimental species inside of the hierarchical structures.
- Method completely consumes the reactant  $H_2S$ , which is a major industrial pollutant.

### Potential Areas of Application:

- Batteries
- $H_2S$  removal

**ID number:** 16020



**Intellectual Property Status:** US provisional patent filed.

**Opportunity:** We are seeking an exclusive or non-exclusive licensee for implementation of this technology.

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