High Energy Density Lithium/Sulfur Batteries for NASA Space Missions

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By virtue of their high specific energy, energy density, long cycle life and good low temperature performance, lithium-ion batteries have contributed to several space missions, by either significantly enhancing or enabling some of the recent missions with their unique characteristics. However, NASA's future planetary missions, including planetary rovers, planter landers, planetary probes, CubeSats, Unmanned Aerial Vehicles (UAV) etc., require battery technologies with higher specific energies, even with shorter cycle life. Likewise, the Department of Defense (DoD) is interested in these rechargeable battery technologies for several soldier and navy applications. The lithium/sulfur system is deemed the most viable future technology, because of its high theoretical specific energy (3-4x vs Li-ion). High specific energies of 400 Wh/kg have often been realized in practice. However, despite several years of development, this system hasn't matured yet, mainly due to the challenges from the soluble polysulfides, which results in a 'redox shuttle' affecting cycle life, and a deposition of lithium sulfides and impedance growth at the Li anode.[1-3] Several attempts were reported in the literature with novel cathode designs, e.g., hierarchical porous carbon structures to sequester sulfur and its reduction products, and also with electrolyte solutions to minimize their solubility. Good cycle life was achieved in some of these cases, but the sulfur loadings in the cathodes are much lower (1-2 mg/cm^2) than desired for realizing high specific energy., i.e., $\geq$ 12 mg/cm^2 per side or $\geq$6 mAh/cm^2.[4,5] Recently, our group[6] and few others[7] have been developing new sulfur composite cathodes blended with transition metal sulfides (e.g., titanium and molybdenum disulfide), which assist in the trapping of polysulfides within the cathode and improve the cycle life of Li-S cells. In addition, we have demonstrated similar improvements in cycle life with the use of ceramic-coated separators, e.g., Tonen separators coated with alumina and aluminum fluoride,[8] and with Li anodes protected with polymeric and ceramic coating. Finally, we have developed an in-situ method to detect soluble polysulfides in the electrolyte, which confirms the reduced shuttle effect with the cathode and separator modifications.

References

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