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BATTERIES & SUPERCAPS
Cover Profile

A Functionally Graded Cathode Architecture for Extending the Cycle-Life of Potassium-Oxygen Batteries

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Invited for this month's cover picture is the group of Prof. Vishnu Baba Sundaresan. The cover picture shows a functionally-graded cathode for potassium-oxygen batteries, regulating K^{+}-ion and oxygen transport at the trilayer electrolyte-cathode-air interface. Read the full text of the article at 10.1002/batt.201900025

What prompted you to investigate this topic/problem?

Potassium-oxygen batteries and other metal-air batteries have the potential to transform energy storage devices due to their high energy densities and relatively cheap cathode and anode materials. Despite these advantages, anode passivation due to molecular oxygen crossover during cycling has become a significant hurdle in their application as electrochemical energy storage device. Contemporary methods to protect the anode focus exclusively on modifying the interface between electrolyte and the anode and use expensive materials that offset the cost advantage of potassium-oxygen batteries. We set out to explore alternative strategies and focused our efforts on regulating the concentration of molecular oxygen at the cathode. By using a conducting polymer which demonstrates two orders of higher catalytic activity in oxygen reduction reaction (ORR) when compared with carbon fibers used as cathodes, and by using a microporous geometry at the cathode-electrolyte interface, we demonstrate in this article that the cycle-life of potassium-oxygen batteries is improved significantly.

What new scientific questions/problems does this work raise?

As we set out to investigate the feasibility of using conducting polymer cathodes, swelling of the conducting polymer in DME solvent and volumetric expansion from electrochemical cycling during ORR diminished the electrochemical activity of the conducting polymer. This brought to focus the mechanoelectrochemical properties of the conducting polymer cathode during ORR. The dopant in the conducting polymer was varied and we were able to determine the most plausible choice that increased cycle-life during electrochemical cycling. Subsequently, this material choice was implemented as a functionally graded cathode and we demonstrate that a cycle-life of >100 cycles can be achieved. While this implementation achieves higher cycle-life at low discharge and charge currents, the rate capability of the potassium-oxygen battery is yet to be determined. Our ongoing efforts are focused on improving the mechanical integrity of the conducting polymer in the functionally graded cathode during high discharge rates and higher cathode pressures via experimental mechanoelectrochemistry and multiphysics modelling.

What is in your opinion an upcoming research theme likely to become one of the 'hot topics' in the near future?

We expect that mechanoelectrochemistry of cathodes in metal-oxygen and metal-air batteries will become an important field of study. The choice of materials, topology and morphology of the cathode can significantly influence the performance during electrochemical cycling and hence in its application in energy storage devices. We anticipate that relatively inexpensive materials can support cathode reactions and mechanistic designs of the cathode can enable relatively inexpensive battery architectures.