3-D Nanofilm Cathode for Secondary Lithium-Air Battery Applications

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The nexus of electrochemical activity in secondary Li-air batteries, the ideal air cathode will facilitate the diffusion of reactant oxygen, ions and electrons to/from reaction sites throughout the electrode surface. The air cathode will host an oxygen reduction reaction (ORR) upon discharge and the breakdown of ORR products through an oxygen evolution reaction (OER) during charge. The air cathode is thus an essential factor in determining the performance of Li-air batteries.

Current approaches combine high surface-area carbon powder with catalyst and binder materials as a composite. Unfortunately, the pore volume is limited, the pore structure is tortuous and pore diameter is significantly (ca. 50%) microporous. Cumulatively, these serve to impede O_2 diffusion and promote clogging by ORR products limiting energy and cycle life. Further, catalytic efficacy is hindered by low catalyst surface area, poor catalyst distribution, and reliance on a mono-catalyst to promote multiple reactions. Power density is further limited as the magnitude of current density that can be accommodated is low due to the lack of activated (bound) oxygen species. This leads to a build-up of ions near the cathode and a more sloping discharge profile. This approach also leaves the carbon exposed to surface reactions that degrade the carbon at potentials required to induce OER.

Ionova Technologies is developing binderless, 3-dimensional nanofilm-based air cathode structures to address these shortcomings. Our approach conformally coats a mesoporous 3-D carbon structure with a nanoscale layer of novel low cost bifunctional catalysts. The carbon structure acts as a support for nanoscale catalysts and as a facilitator of electron, ion and O_2 transport. It provides >2x increase in pore volume vs. powder composite in a through-connected pore structure dominated by desirable mesopores to promote gas diffusion while providing a large, accessible reaction surface that is much less susceptible to pore blockage by reaction products. The specific surface area of the 3-D nanofilm catalysts is ca. 30x larger vs. the most promising published nanowire catalyst morphology. This will promote a higher rate capability and therefore a higher power density compared to the current composite cathodes by availing a higher number of activated oxygen species due to the corresponding increase in active sites. The use of mixed metal oxide catalysts specifically targeting ORR and OER will provide reduced charge/discharge voltage hysteresis and improved cycle life as the presence of different functional sites on the catalyst serve to facilitate the two reactions. Since the carbon is conformally coated, it is protected against the degradation effects of the OER process.