Defense Announcement

High Energy and High Power Magnesium Batteries

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Degree: PhD, Materials Engineering

Date: 07/18/2019 **Time: 10 am – 12 pm**

Location: MREB 320

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Magnesium batteries are emerging as an attractive candidate for energy storage in terms of safety, energy density, and scalability because Mg metal has ideal properties as a battery anode: high volumetric capacity, low redox potential, dendrite-free plating, and earth-abundant resources. One persistent challenge is the lack of high-performance cathodes, since Mg^{2+} ingress into and diffusion within cathodes are kinetically sluggish. The main objective of this dissertation is to demonstrate new research approaches that could effectively overcome these barriers and eventually lead to high-performance Mg batteries.

In this dissertation, I proposed two strategies to achieve this goal, including Mg-Na hybrid batteries and Mg-organic batteries. First, I developed an Mg-Na hybrid battery, which can circumvent the intercalation of Mg^{2+} by using a Na-insertion cathode in a Na^{+}/Mg^{2+} hybrid electrolyte.

The second strategy was to utilize organic compounds as Mg battery cathodes. I first revealed that previously reported organic cathodes all operated on an MgCl-storage chemistry sustained by a large amount of electrolyte that significantly reduced cell energy. I then demonstrated Mg batteries featuring an Mg^{2+}-storage chemistry using chloride-free electrolytes. The observed specific energy (243 Wh kg^{-1}), and cycling stability (87%@2500 cycles) of Mg-storage cells consolidated polymers as promising cathodes for Mg batteries.

Finally, I reported a quinone molecule, pyrene-4,5,9,10-tetraone (PTO), that can circumvent sluggish Mg^{2+} diffusion through a dissolution-precipitation reaction, and its intrinsic ion-coordination charge storage mechanism without involving bond-breaking and bond–formation, making it has potential to achieve high power. By coupling PTO cathode with a high-performance electrolyte, $Mg(CB_{11}H_{12})_2$ in DME/G2, I created an Mg battery with a specific energy of 563 Wh kg^{-1} and an ultra-high power of 30 kW g^{-1}.