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Water-Reactive Metals and Fusible Alloys for Next Generation Electrochemical Energy Conversion and Storage Applications

Abstract: In this talk, I will discuss recent work by our group in developing alternative material systems for energy storage applications. The talk will be divided into two parts: 1) Water-reactive nanoporous metals. Selective leaching, commonly known as dealloying, removes sacrificial element(s) from an alloy to produce a bulk, nanoporous material. While much of the research in this field focuses on precious nanoporous metals, we study earth-abundant non-precious water-reactive nanoporous metals. We have developed a novel air-free eco-friendly electrolytic dealloying processes to create nanoporous aluminum (NP-Al) and nanoporous magnesium (NP-Mg) with recovery of the sacrificial element during the dealloying process.[1,2,3] A promising application of these materials is the generation of hydrogen by hydrolysis. We have demonstrated that nanoporous Al can react with *pure water* (without addition of reaction promoters) to create hydrogen gas for on-demand hydrogen generation.[1,2] 2) Fusible alloys. The increased demand for lithium-ion batteries (LIBs) has placed a considerable strain on lithium and cobalt resources used in commercial LIBs. Alternative battery technologies including rechargeable magnesium-ion batteries (MIBs) and sodium-ion batteries (SIBs) are desirable to support LIBs. Our group has developed a novel class of *self-healing* MIB and SIB anode materials based on fusible alloys that undergo solid-liquid transformations at low temperatures upon charging and discharging. We have demonstrated the concept in MIB using micron-sized Mg-Ga solid alloy particles, which undergo a solid-liquid phase transformation as Mg is reversibly stored in Ga at 40^{o} C.[4] The solid-liquid phase change significantly reduces the accumulation of stress within the anode, preventing the detrimental pulverization that would normally arise during a solid-solid phase transition. This new type of solid-liquid anode material significantly shifted the state-of-the-art in MIBs, outpacing the longest MIB cycle life on record by approximately five times: they cycled over 1000 times at a higher charge-discharge rate.[4]

(1) Corsi, J. S.; Fu, J.; Wang, Z.; Lee, T.; Ng, A. K.; Detsi, E. **Hierarchical Bulk Nanoporous Aluminum for On-Site Generation of Hydrogen by Hydrolysis in Pure Water and Combustion of Solid Fuels**. *ACS Sustain. Chem. Eng. 23*, **2019**. https://doi.org/10.1021/acssuschemeng.9b00481

(2) Lee, T.; Fu, J.; Basile, V.; Corsi, J.; Wang, Z.; Detsi, E. **Activated Alumina as Value-Added Byproduct from the Hydrolysis of Hierarchical Nanoporous Aluminum with Pure Water to Generate Hydrogen Fuel**. *Renew. Energy 155,* **2020**. https://doi.org/10.1016/j.renene.2020.03.072

(3) Fu, J.; Corsi, J. S.; Welborn, S. S.; Basile, V.; Ng, A. K.; Detsi, E. **Eco-Friendly Synthesis of Nanoporous Magnesium by Air-Free Electrolytic Dealloying of Magnesium-Lithium Alloy with Recovery of Sacrificial Lithium**. *Under Review.*

(4) Wang, L.; Welborn, S. S.; Kumar, H.; Li, M.; Wang, Z.; Shenoy, V. B.; Detsi, E. **High-Rate and Long Cycle-Life Alloy-Type Magnesium-Ion Battery Anode Enabled Through (De)Magnesiation-Induced Near-Room-Temperature Solid–Liquid Phase Transformation** *Adv. Energy Mater.* 9, **2019**. https://doi.org/10.1002/aenm.201902086