From Sulfur to Selenium: Bridging Concepts in Lithium Battery Design

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To satisfy the growing energy demands of modern applications, research efforts have traditionally centered around sulfur-based battery chemistries, owing to sulfur's high theoretical energy density and cost-effectiveness. Despite these advantages, the commercialization of Li–S batteries has been limited by persistent challenges such as drastic volumetric expansion during cycling, poor electrical and ionic conductivities of sulfur and its discharge products, and the sluggish redox kinetics of intermediate polysulfides. These limitations often result in poor cycling stability, irreversible loss of active material, and the formation of passivating layers that hinder performance.

In recent years, lithium–selenium batteries have gained attention as a promising alternative among chalcogen-based systems. Selenium offers a higher volumetric capacity and much better intrinsic conductivity compared to sulfur. Nevertheless, Li–Se batteries still face critical hurdles, particularly large volume fluctuations during charge and discharge, as well as uncontrolled accumulation of Li 2 Se on the electrode surface. Building on the knowledge gained from Li–S battery research, our work focuses on addressing these challenges by studying the reversible conversion reactions and tackling capacity loss caused by imperfect re-oxidation of Li_2Se. In this presentation, we will first review the progress made with sulfur-based batteries, then explore strategies to enhance the performance of Li–Se systems. Special attention will be given to the use of electrocatalysts that improve Li 2 Se conversion and increase active material utilization.

Rezan Demir-Cakan received her Ph.D. degree in 2009 from the Max Planck Institute of Colloids and Interfaces. Between 2009 and 2012, she conducted postdoctoral research in the group of Prof. Jean-Marie Tarascon, where she focused on rechargeable lithium batteries, particularly lithium–sulfur systems. She is currently a Professor in the Department of Chemical Engineering at Gebze Technical University. Her research activities center on the design and synthesis of nanostructured energy materials for advanced battery systems, with particular emphasis on sodium-ion, lithium–sulfur, and aqueous electrolyte zinc-ion batteries. Rezan Demir-Cakan has been the recipient of several prestigious awards, including the French Embassy Research Fellowship (2018, 2023), the Turkish Academy of Sciences Outstanding Young Scientist Award (TÜBA-GEBİP, 2018), the L'Oréal–UNESCO "For Women in Science" Award (2016), the Science Academy's Young Scientist Award (BAGEP, 2015), the IMLB Young Researcher Award (2012), and the Japan Carbon Award (2008). Since 2014, she has served as an expert evaluator for energy-related calls within EU-funded programs (H2020, Horizon Europe), and she currently coordinates the EU-funded project TwinBat.