The 134th GREEN Seminar

Sustainable Li-Ion Batteries: Materials Innovation for a Cobalt-Limited World

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Optimizing lithium-ion battery technology remains critical to overcoming the range, cost, and thermal management challenges associated with advancing Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs). LIBs have dominated the market due to their high energy density (150-250 Wh kg^{-1}), operating voltage (>3.7 V), and long cycle life (> 1000 cycles). Commercial cathodes in use are $LiCoO_2$ (LCO), $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA), $LiNi_xMn_yCo_{1-x-y}O_2$ (NMC), and $LiFePO_4$. Cobalt plays a leading role in commercialised LIBs because of its high voltage, structural stability, and good Li^+ ion diffusivity during charge-discharge. However, experts doubt that cobalt scarcity will halt LIB manufacturing growth in the near future. Besides, Ni-rich layered oxides, such as NCA, $Li_{1.2}Mn_{0.55}Ni_{0.15}Co_{0.1}O_2$, and $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$, are gaining popularity as cathode materials for EVs due to their higher capacity (~200 mAh g^{-1}) than LCO (~150 mAh g^{-1}). Though the redox activity of nickel occurs at a higher potential *vs.* Li^+/Li, resulting in a higher energy density, the issues of storage (formation of residual lithium compounds inhibits performance), structural instability at high voltages, and thermal and cycle stability have limited its application. Additionally, no cobalt-based cathodes, such as LMFP ($LiMn_{0.8}Fe_{0.2}PO_4$, 4.1 V) and LNMO ($LiNi_{0.5}Mn_{1.5}PO_4$, 4.7 V), are proposed as ideal cathodes for next-generation LIBs and Solid-state Lithium batteries. Ni-rich, Co-less layered/spinel oxide-based, high-voltage olivine cathodes could meet the demand for next-generation LIBs with energy densities beyond 250 Wh kg^{-1}. In addition, dual-carbon (ion) batteries are poised to play a leading role in the next generation of LIBs. Given these developments, alternative applications of graphite in energy storage systems are vital for maintaining its relevance and fostering circularity. A particularly promising avenue is its use as a cathode in dual-ion batteries (DIBs), where graphite can intercalate anions, resulting in high voltage, enhanced safety, and sustainability.

The presentation will focus on the development of the current Li-based rechargeable batteries in our laboratory and the prospects of LIBs.

Venue: Auditorium, 1F, NanoGREEN/WPI-MANA Bldg., Namiki-site

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