Regulation of two-dimensional nanomaterials for lithium-ion batteries

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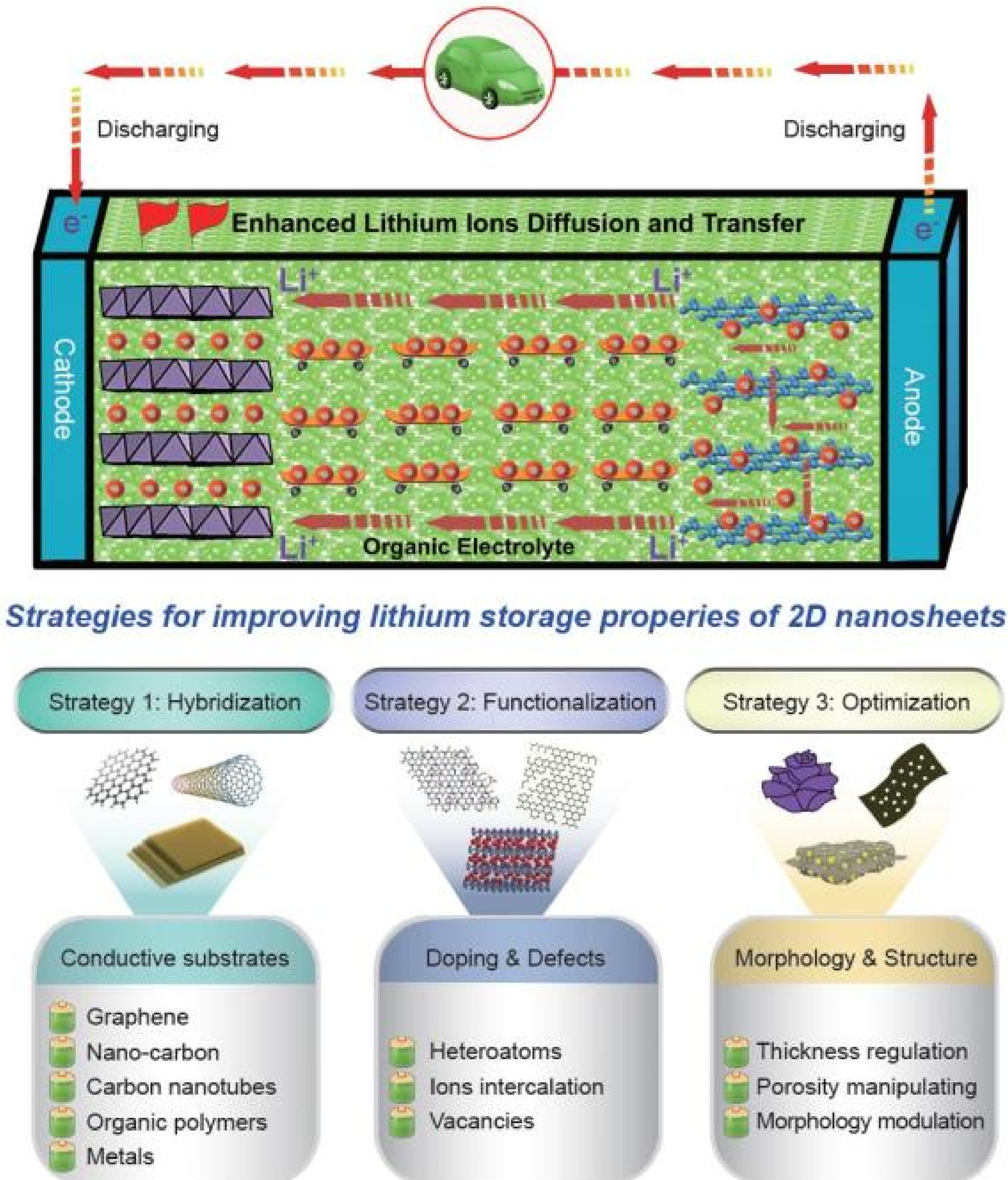

Strategies for improving the lithium storage properties of 2D nanosheets. Credit: ©Science China Press

Li-ion batteries (LIBs) are advantageous energy storage devices due to their higher specific energy density, lower self-discharge, and lower memory effect. Among the components of batteries, electrode materials play a key role in enhancing electrochemical properties. Thus, the development of advanced electrode materials for high-performance LIBs is a major objective in related research fields.

Two-dimensional (2-D) nanomaterials, including graphene, transition metal oxide (TMO) nanosheets, transition metal dichalcogenide (TMD) nanosheets, etc., are composed of one or several monolayers of atoms (or unit cells). They have outstanding physical and chemical properties in contrast to their bulk counterparts. The integration of 2-D nanomaterials with energy storage devices could overcome major challenges driven by ever-growing global energy demands. Unfortunately, the direct use of these sheet-like materials is challenging due to a serious self-agglomerating tendency, relatively low conductivity, and obvious volume changes over repeated charging-discharging cycles.

In a new review paper published in *National Science Review*, scientists from Australia at Queensland University of Technology and University of Wollongong summarized recent progress on the strategies for enhancing the lithium storage performance of 2-D nanomaterials. These strategies for manipulating the structures and properties are expected to meet the major challenges for advanced nanomaterials in energy storage applications. Co-authors Jun Mei, Yuanwen Zhang, Ting Liao, Ziqi Sun and Shi Xue Dou identified three primary strategies: hybridization with conductive materials, surface/edge functionalization, and structural optimization.

"The strategy of hybridization is the most common for TMOs/TMDs-based nanocomposites, in which some conductive nanostructures, e.g. nano-carbon, carbon nanotubes (CNTs), graphene, organic polymers, metallic nanoparticles, etc., are introduced to hybridize with TMO/TMD nanosheets to improve the overall conductivity and accommodate the volume expansion of metal oxide or sulfide nanomaterials during the repeated charging/discharging cycles," the researchers report.

"The second strategy is edge/surface functionalization, which can be achieved by atom/ion doping or defect engineering at the edges or on the surfaces of the 2-D nanomaterials. The implantation of heteroatoms or ions into 2-D nanomaterials helps to modulate the electronic structure, the surface chemical reactivity, or the interlayer spacing of the 2-D nanomaterials, and further enhances the lithium ion storage capacity," they write. "The third strategy of structure optimization is often realized by controlling some structural parameters during fabrication, such as thickness, size, pores, or surface morphology, which have significant impacts on the structure-dependent properties and the electrochemical performance, and are beneficial for alleviating the inevitable self-restacking and exposing more active sites."

The scientists conclude, "These effective strategies for improving the lithium storage of 2-D nanomaterials will be good reference points for scientists and researchers in the related fields of materials, chemistry, and nanotechnology, who are looking forward to developing superior next-generation rechargeable batteries".

More information: Jun Mei et al, Strategies for improving the lithium storage performance of 2D nanomaterials, *National Science Review* (2017). DOI: 10.1093/nsr/nwx077

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