**Manipulation of internal chemistry of transition metals compounds for enhanced electrochemical processes**

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The nanostructuring and tuning of chemistry at a molecular level have introduced new concepts into mechanisms of charge conversion and storage in electrochemical devices. New insights into molecular nanomaterials are expected to give birth to advanced technologies in next generation devices that can touch the theoretical prediction of electrochemical energy conversion and storage with ability to deliver energy rapidly and efficiently.

Here, we have developed several electrodes/catalysts materials based on transition metal oxides, selenides, phosphides as well as their hybrids with carbon nanostructures through wet chemistry and physical methods to overcome the issues of poor cyclic stability and limited activity through internal chemistry manipulation. The resulted structures have rationally tuned surface chemistries inherited from their defective structures and/or unsatisfied surface atoms as well as strong synergy in hybrids to perform exceptional functionalities. Enhanced catalytic activities/capacities of these materials are observed due to their tunned material features.

We have found very exciting results by achieving highly stable performances for batteries up to 5000 cycles using our self-tunable carbon nanostructures. While achieved high areal capacity for sodium battery up to 4.0 and 7.03 mAh/cm2 for molybdenum and cobalt selenide based 3D heterostructureswith CNTs, moreover, excellent compressibility of hybrid allow high mass loading of 13.9 and 17.04 mg/cm2. Further, we have also developed lightweight flexible electrodes based on polyimide having laser induced graphene on the surface, showed excellent performance by delivering an areal capacity of 280 μAh/cm2, maintained the performance even in fully folded form while separated by the non-conductive polymer. A step forward towards excellent electrochemical energy storage for lightweight and flexible electronics as well as assisting in developing comfortable wearable electronics.

Further, iron and cobalt oxides/phosphides-based catalyst materials delivered the current densities up to 350 mA/cm2 required for the commercialization of water electrolysis at an extremely low voltage of 1.40 V. Thus, water catalysis at low potential with long term stability showing their capability to be deployed in commercial electrolysers. Recently, we also found that by developing 2D heterostructures with the genuine features of unilamellar sheets of two different materials will be very exciting, which can revolutionize various technological fields, especially the energy sector.

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