High-power energy storage enabled by 2D layered materials

Minghao Yu, Xinliang Feng
Center for Advancing Electronics Dresden (cfaed) & Faculty of Chemistry and Food Chemistry, Technische Universität Dresden, Mommsenstrasse 4, Dresden, Germany
minghao.yu@tu-dresden.de

Electrochemical energy storage technologies have been brought into the spotlight as they provide elegant and efficient approaches to store, transport, and deliver energy harvested from sustainable energy resources.[1, 2] Typically, supercapacitors and batteries differ in electrochemical mechanisms, hence featuring almost opposite energy and power characteristics. However, the demand for power and energy supply is equally imperative in actual use and is keen to expand in the future. Thus it is highly desirable to design new electrode materials or rationally re-construct the recognized electrode materials for energy storage devices to mitigate the power-energy tradeoff.

2D layered materials are a class of materials with strong atom bonding in the basal plane and weak van der Waals (vdW) interaction between layers. These materials are equipped with versatile physical, chemical, electronic properties, as well as broad structural diversity. Importantly, the weak vdW interaction between the stacked layers enables layered materials with diverse possibilities for rational structure engineering, such as exfoliation into 2D nanoflakes, interlayer expansion with guest molecules, and hybrid structure construction. These structure engineering strategies are highly desired for layered materials to tailor their intrinsic properties (*e.g.,* electronic structure, conductivity, and redox capability) and electrochemical behaviours (*e.g.,* ion desolvation energy, solid-state ion diffusion kinetics, charge-storage mechanism) for diverse energy storage devices.[3]

Here, we will present our recent efforts in exploring 2D layered organic/inorganic materials for high-power energy storage applications.[3, 4] We will show 2D redox-active carbon-rich frameworks as promising electrode alternatives for high-power energy storage devices by demonstrating 2D polyarylimide covalent organic framework (COF) as the first COF anode for Zn-ion aqueous batteries[5] and dual-redox-site 2D conjugated metal-organic framework as a high-capacitance and wide-potential-window pseudocapacitive electrode. Moreover, we have demonstrated several interlayer engineering strategies for inorganic 2D layered materials to regulate the ion transport behaviors and boost the power-energy performance of the assembled energy storage devices.[6, 7]

References

[1] Wang G, Yu M, Feng X. Carbon materials for ion-intercalation involved rechargeable battery technologies. *Chem. Soc. Rev.* **50**, 2388-2443 (2021).
[2] Yu M, Feng X. Thin-Film Electrode-Based Supercapacitors. *Joule* **3**, 338-360 (2019).
[3] Zhou J, Lu X, Yu M. Structure engineering of van der Waals layered transition metal-containing compounds for aqueous energy storage. *Mater. Chem. Front.* **5**, 2996-3020 (2021).
[4] Yu M, Dong R, Feng X. Two-Dimensional Carbon-Rich Conjugated Frameworks for Electrochemical Energy Applications. *J. Am. Chem. Soc.* **142**, 12903-12915 (2020).
[5] Yu M*, et al.* A High-Rate Two-Dimensional Polyarylimide Covalent Organic Framework Anode for Aqueous Zn-Ion Energy Storage Devices. *J. Am. Chem. Soc.* **142**, 19570-19578 (2020).
[6] Zhang H*,* Yu M*, et al.* Interlayer Engineering of alpha-MoO3 Modulates Selective Hydronium Intercalation in Neutral Aqueous Electrolyte. *Angew. Chem. Int. Ed.* **60**, 896-903 (2021).
[7] Yu M*, et al.* Interlayer gap widened alpha-phase molybdenum trioxide as high-rate anodes for dual-ion-intercalation energy storage devices. *Nat. Commun.* **11**, 1348 (2020).

LiCoO 2 enabled industrial-scale production and enabled the commercial lithium-ion battery.Â For a Li-ion storage coupled with photovoltaics and an anaerobic digestion biogas power plant, Li-ion will generate a higher profit if it is cycled more frequently (hence a higher lifetime electricity output) although the lifetime is reduced due to degradation.[90]. Lithium nickel manganese cobalt oxide (NMC) cells come in several commercial types, specified by the ratio of component metals.Â Various materials have been introduced but their voltage is high leading to a low energy density.[171] Low voltage of material is the key requirement; otherwise, the excess capacity is useless in terms of energy density. Negative electrode. Technology. From mobile devices to the power grid, the needs for high-energy density or high-power density energy storage materials continue to grow.Â Advances and phenomena enabled by nanomaterials in energy storage. Nanostructuring often enables the use of conventional materials that cannot be used in the microcrystalline state as either cathodes or anodes.Â The example of MXenes has shown that both double-layer and redox capacitance can be used at very high current rates, with just ~20% electrochemical performance loss when going from 10 to 100,000 mV sâˆ'1 cycling.Â Another way to enable fast transport of electrons and ions is through the creation of 2D heterostructures, which allow the combination of highly conducting and highâ€"energy density 2D materials. Two-dimensional materials for energy production and storage. Application of Diamond in Energy Research. Oxide materials and their application in energy research.Â Resume : Unique two-dimension (2D) nanosheets possess great advantages over their bulk counterparts owing to their high surface area-to-volume ratio and high-density unsaturated atoms exposed on the surface, so as to exhibit substantially distinctive physical and chemical properties, especially in many catalytic regions.1 Pd-based monometallic or multimetalic nanosheets have drawn specially increasing attention as the excellent catalysts. This enables them to provide multiple power and energy services. 35 This operational flexibility makes the flow battery very attractive for grid scale applications. 36 37 2.6.Â - Corrosive materials - High operating. temperatures - Thermal management. requirement.Â 1 Storage systems can be owned by the utility companies or independent storage providers, 2 who can either have direct access and trade in the wholesale energy, capacity, balancing and 3 ancillary services markets or have a contractual agreement with a utility company or a third-4 party to whom they provide their services. From mobile devices to the power grid, the needs for high-energy density or high-power density energy storage materials continue to grow. Materials that have at least one dimension on the nanometer scale offer opportunities for enhanced energy storage, although there are also challenges relating to, for example, stability and manufacturing.Â The nanomaterials approach represents the most powerful solution to the aforementioned problems (89, 95). Thin layers of 2D materials, such as MXene (42), or electrospun carbon nanofibers (96) at the separator on the cathode side can serve as barriers for polysulfide transfer across the separator.