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Sorption Energy Harvesting from Air for Smart Battery Thermal Management

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Fengyue Wang, Ning Xu, and Jia Zhu

A smart battery thermal management (SBTM) strategy is proposed to ensure safer batteries with a long lifetime.

Effective thermal management is essential for the safety and long lifetime of batteries. For example, an ideal working temperature range is between 20 and 40 °C for lithium-ion batteries (LIBs). A team lead by Tingxian Li and Ruzhu Wang offers a smart battery thermal management (SBTM) strategy for cooling or heating batteries at high or low temperatures[1] by taking advantage of the moderate transition temperature, fast water sorption/desorption kinetics, and large sorption capacity of metal−organic framework (MOF)@carbon foam.

Under high operating temperatures, batteries run the inevitable risk of overheating and thermal runaway.[2] Conversely, low ambient temperatures result in slow diffusion kinetics of Li^+ ions and Li metal deposition, thereby degrading the performance of batteries.[3] Therefore, preheating batteries in the start-up stage and their thermal regulation in the operation stage are necessary to ensure high energy densities and a long lifetime.

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Diverse battery thermal management (BTM) systems have been developed to regulate LIB temperatures within an optimal range, i.e., between 20 and 40 °C.[4] Compared to the passive BTM strategies, traditional air-forced cooling and liquid cooling require extra consumption of electricity.[5] Solid−liquid phase change materials (PCMs) that utilize endothermic enthalpies during the phase transformation from solid to liquid states (220−251 kJ kg^{-1} for paraffin wax melting) to cool batteries have been regarded as a potential passive BTM strategy. However, practical applications of PCMs are limited by their unsatisfactory thermal conductivity[6] as well as the large weight of PCMs to cover all of the heat generated from a commercial electric vehicle (EV). For example, 426 kg of paraffin wax is required for the Tesla model S with 7100 18650 LIBs.[7]

In their latest work published in *ACS Central Science*,[1] Li, Wang, and team reported an SBTM system with MOF@carbon foam for both passive heating and passive cooling based on sorption energy harvesting from air (Figure 1). The reversible cycles of water vapor desorption and adsorption enable cooling and heating of batteries. These cycles can keep battery temperatures below 45 °C in hot environments while realizing self-preheating to ∼15 °C in cold environments with an increased battery capacity of 9.2%. The SBTM strategy can switch between battery cooling and battery heating modes automatically by realizing self-regeneration of MIL-101(Cr) between its hydrated and dehydrated states via water vapor sorption or desorption from air. Therefore, it is clear that the SBTM strategy equipped with high energy/power density, near-zero-energy consumption, and low-cost operation represents an exciting self-adaptive smart thermal management approach for electronic devices and batteries.

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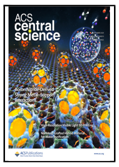

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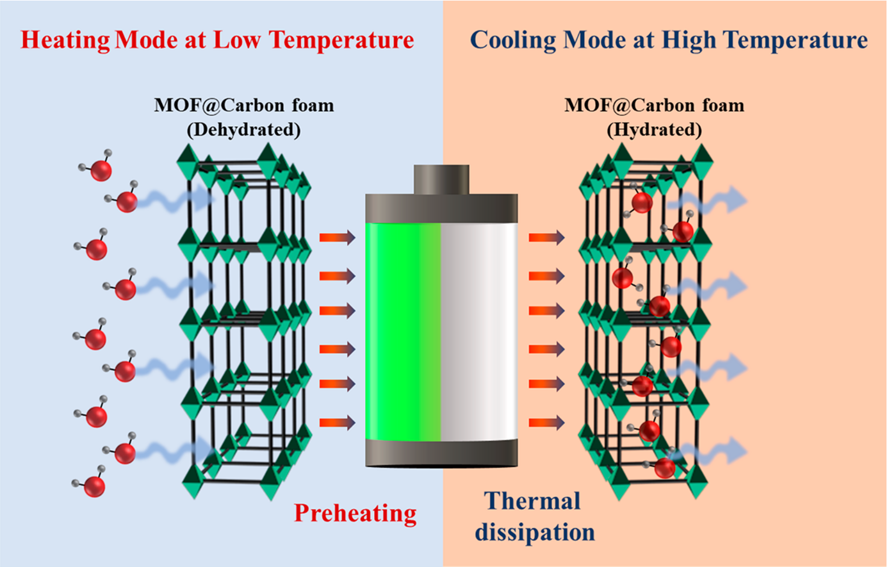

Figure 1. Smart battery thermal management (SBTM) strategy for both passive heating and passive cooling based on reversible water sorption of the metal−organic framework.

> The SBTM strategy can switch between battery cooling and battery heating modes automatically by realizing self-regeneration of MIL-101(Cr) between its hydrated and dehydrated states via water vapor sorption or desorption from air.

It is expected that fast charging and frequent use of batteries in capricious climates will require the further development of existing smart thermal management systems. For example, in sorption-based thermal management, the heating or cooling capacity is significantly impacted by water adsorption that is in turn greatly influenced by climate. Temperature and humidity vary greatly in different regions and seasons, which could lead to unstable heating or cooling performance in batteries. Also, a quick charging system for electric vehicles shortens its interval time between running states, which demands advanced sorption-based thermal management systems with faster self-regeneration. While considerable efforts have already been invested in the study of the static and dynamic properties of sorption-based thermal management materials, further improvement is required to enable higher adaptability and faster self-regeneration (within about 15 min that is needed for the Tesla model S to recharge at a supercharger location) for practical integration.

BTM strategies for cooling or heating batteries at high or low temperatures are of great significance in ensuring the performance and safety of Li-ion batteries. With increased charging rates, more aggressive thermal management is needed. A high heat transfer coefficient, large endothermic enthalpies, simplification of integration, and low overall cost will be desired. Furthermore, the mass and heat transfer conditions of the battery pack are different for practical applications; an adaptive battery thermal management system to satisfy the varying cooling or heating load through advanced passive or active control needs to be further developed.

Author Information

Corresponding Author

Jia Zhu − *National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Jiangsu Key Laboratory of Artificial Functional Materials, Nanjing University, Nanjing 210093, P. R. China*; orcid.org/0000-0002-2871-4369; Email: jiazhu@nju.edu.cn

Authors

Fengyue Wang − *National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Jiangsu Key Laboratory of Artificial Functional Materials, Nanjing University, Nanjing 210093, P. R. China*

Ning Xu − *National Laboratory of Solid State Microstructures, College of Engineering and Applied Sciences, Jiangsu Key Laboratory of Artificial Functional Materials, Nanjing University, Nanjing 210093, P. R. China*

Complete contact information is available at:
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REFERENCES

(1) Xu, J.; Chao, J.; et al. Near-Zero-Energy Smart Battery Thermal Management Enabled by ßSorption Energy Harvesting from Air. *ACS Cent. Sci.* **2020**, in press. DOI: 10.1021/acscentsci.0c00570.

(2) Zhu, Y.; Xie, J.; Pei, A.; et al. Fast lithium growth and short circuit induced by localized-temperature hotspots in lithium batteries. *Nat. Commun.* **2019**, *10*, 1−7.

(3) Zinth, V.; et al. Lithium plating in lithium-ion batteries at sub-ambient temperatures investigated by in situ neutron diffraction. *J. Power Sources* **2014**, *271*, 152−159.

(4) Palacín, M. R.; De Guibert, A. Batteries: Why do batteries fail? *Science* **2016**, *351*, 1253292.

(5) Liu, H.; Wei, Z.; He, W.; Zhao, J. Thermal issues about Li-ion batteries and recent progress in battery thermal management systems: A review. *Energy Convers. Manage.* **2017**, *150*, 304−330.

(6) Cottrill, A. L.; et al. Ultra-high thermal effusivity materials for resonant ambient thermal energy harvesting. *Nat. Commun.* **2018**, *9*, 1−11.

(7) Mishra, A. K.; Wallin, T. J.; Pan, W. Autonomic perspiration in 3D-printed hydrogel actuators[J]. *Science Robotics* **2020**, *5* (38), eaaz3918.