Emerging miniaturized energy storage devices for microsystem applications: From design to integration

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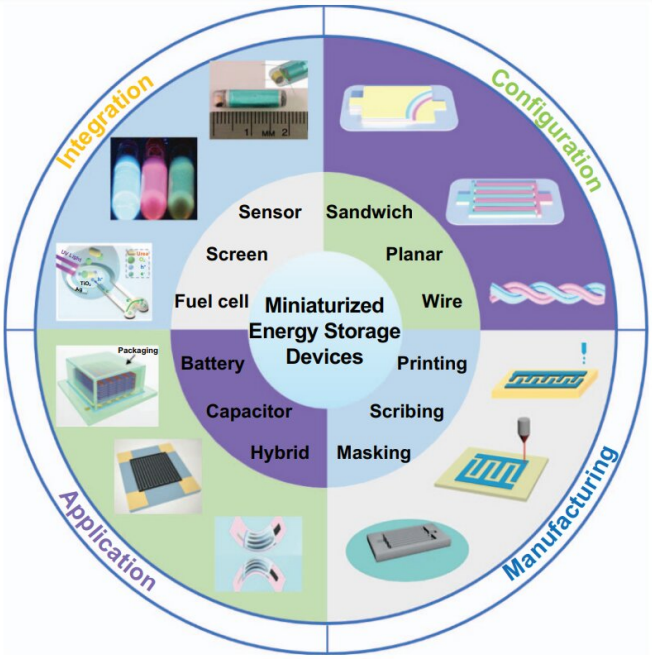

Configuration design, microelectrode manufacturing, typical applications, and on-chip integrated microsystems. Credit: Huaizhi Liu et al

The ever-growing demands for integration of micro/nanosystems, such as microelectromechanical system (MEMS), micro/nanorobots, intelligent portable/wearable microsystems, and implantable miniaturized medical devices, have pushed forward the development of specific miniaturized energy storage devices (MESDs) and their extreme manufacturing processes. Typically, MESDs are a type of miniaturized power supply with the electrode size in the range of micrometer, which cannot only serve as a compatible energy source for micro/nanosystems but also integrate with micro/nanodevices directly to satisfy the need for integration, intelligence, ultracompactness, and extremely lightweight. Thus, the MESDs are considered to be preferable compact energy sources for uninterrupted powering of integrated microsystems.

In a new paper published in the *International Journal of Extreme Manufacturing*, a team of researchers, led by Dr. Huigao Duan and Dr. Guanhua Zhang from the State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, College of Mechanical and Vehicle Engineering, Hunan University, People's Republic of China, provided a comprehensive overview of the background, fundamentals, device configurations, manufacturing processes, and typical applications of MESDs. Additionally, recent advances of MESDs, as well as their functional integration are systematically summarized. This review discussed the on-chip integrated microsystems consisting of miniaturized energy storage units and a range of practical micro electronic devices. Finally, the authors made a further prospect to better promote the development and practical application of miniaturized energy storage devices and integrated microsystems.

MESDs mainly include classic microbatteries (MBs), microsupercapacitors (MSCs), and newly developed microhybrid metal ion capacitors (MHMICs). In particular, the compact size of MESDs with compatible performance and the capability of satisfying extreme customization requirements, such as achieving high output voltage (in series), high output current (in parallel), and high output power (multiple series), makes them preferable for powering miniaturized, flexible/wearable electronics and integrated micro/nanosystems. In addition, easy integration with specific microelectronic devices on a compliant substrate makes MESDs the most suitable candidate for a power supply with an irreplaceable

position as energy storage components for miniaturized electronic devices and integrated microsystem applications.

The on-chip integration of specific functions into MESDs can endow them with more impressive properties, making them suitable and accessible for microsystem applications. An ideal on-chip integrated system based on MESDs should not only possess high electrochemical performance with good durability but also be well endowed with the desired properties for specific purposes. In this field, MESDs integrated with energy harvesters, screen displays, fuel cells, transmitters, and functional electronics such as electrochromic and miscellaneous sensors have been extensively studied and are promising to be applied in the future integrated microsystems.

From the recent advances and achievements of MESDs, it is worth noting that the challenges are not only to enhance the electrochemical property, such as high energy density and high power density in a limited footprint with a durable lifetime, but also to integrate with multifunctional properties, matching up with multiple demands of microelectronic devices and microsystems. In order to better promote the development of MESDs, Mr. Huaizhi Liu, Dr. Guanhua Zhang, Dr. Huigao Duan et al. identified a few critical challenges in the future research as follows:

1. Exploring high-performance and multifunctional active materials for microelectrodes.
2. Developing easy-to-operate, low-cost, time-saving, highly safe, environmentally friendly, and scalable microelectrode fabrication technologies.
3. Optimizing the device configuration and the intricate connections among the structure design, electrolyte selection, and electrochemical property.
4. Achieving self-powering, multifunctional on-chip integrated microsystems consisting of energy harvesting, energy storage, and energy consumption devices.

Considering the promising prospects, researchers still need to explore more possibilities to perfect the development and application of MESDs. Engineers need to seek to apply them to practical uses, such as wearable devices, implantable devices, and micro/nano systems. While there is still a long way toward making it a reality, the potential of MESDs is truly tantalizing.

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