as the sensing platform. The quantitative detection of the target DNA can be achieved by measuring the fluorescence intensity of the probe. For the fluorescence quenching testing, the results showed that the CoBDC NRBs exhibit better performance than the bulk CoBDC MOFs materials (Fig. 1g). Compared with the existing materials of DNA detecting, the CoBDC NRBs also exhibited very good sensitivity for the target DNA (Fig. 1g and h).

Overall, this work represents very important progress in MOF chemistry and 2D nanoscale materials through the facile and straightforward approach to preparing ultrathin 2D MOF materials. This pioneering work will significantly facilitate the development and implementation of 2D multifunctional MOF materials for diverse applications that will be beyond those developed on gas separation, catalysis, sensing and membrane devices in the future.

Conflict of interest statement. None declared.

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National Science Review
7: 3–5, 2020
doi: 10.1093/nsr/nwz159
Advance access publication 21 October 2019

MATERIALS SCIENCE

Scalable and safer printed Zn//MnO_2 planar micro-batteries for smart electronics

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The rapidly growing field of miniaturized smart electronics has forced us to search for compatible microscale power sources with reliable electrochemical performance, various form factors, manufacturing scalability, and safety [1–5]. Among the several power sources reported to date, planar micro-batteries, which are characterized by geometrical superiority over simple-stacked ones, have recently garnered considerable attention due to the simple miniaturization, facile serial/parallel integration, mechanical flexibility, and removal of conventional separator membranes [6]. Lithium-based thin-film micro-batteries have been extensively investigated; however, the complex manufacturing processes and flammable organic electrolyteinduced safety concerns pose a formidable barrier to their practical applications. To address this issue, aqueous-based non-lithium planar micro-batteries are suggested as a promising alternative beyond the aforementioned lithium-based ones. They can be fabricated through various printing

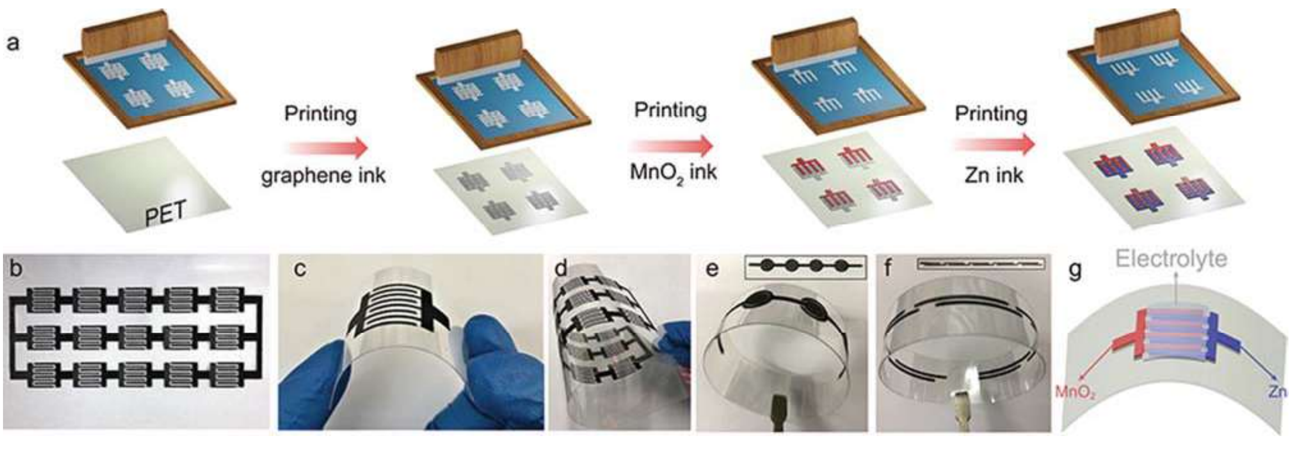

Figure 1. (a) Schematic of fabrication of printed Zn//MnO_2 micro-batteries. (b) An energy storage pack of Zn//MnO_2 micro-batteries connected in a tandem fashion of 5 series × 3 parallel. (c–f) Photographs of shape-designable Zn//MnO_2 micro-batteries under different bending states, e.g. (c) an individual interdigital Zn//MnO_2 micro-battery, and (d) the tandem energy storage packs via self-connection of (c) interdigital Zn//MnO_2 micro-batteries in 5 series × 3 parallel bended at 180°, (e) four concentric-circle-shape, and (f) five linear-shape Zn//MnO_2 micro-batteries in series, under flat and bent (180°) states. (g) Schematic of the bent Zn//MnO_2 micro-battery with electrolyte.

techniques including inkjet, screen, gravure, and 3D printing [7].

A recent study published in *Natl. Sci. Rev.* by Wu. *et al.* [8] reported a new class of screen-printed, aqueous Zn//MnO_2 planar micro-batteries as a breakthrough approach. The Zn//MnO_2 planar micro-batteries, which were based on interdigital patterns of Zn ink as an anode and MnO_2 ink as a cathode, with high-conducting graphene ink as a metal-free current collector, showed outstanding electrochemical performance, aesthetic diversity, mechanical flexibility, and modularization.

The Zn//MnO_2 micro-batteries were fabricated by a low-cost and scalable screen-printing technique as illustrated in Fig. 1a. The screen-printing enabled seamless integration of the Zn//MnO_2 micro-batteries with various complex-shaped planar geometries, resulting in the fabrication of multiple parallel interdigitated micro-batteries via in-series/in-parallel connections (Fig. 1b), individual micro-batteries (Fig. 1c), flexible patterns with multiple connections (Fig. 1d), and flexible tandem concentric circular (Fig. 1e) and linear-structured micro-batteries free from conventional metal-based interconnectors (Fig. 1f). The planar Zn//MnO_2 micro-batteries employed neutral aqueous electrolytes (Fig. 1g). They delivered a high volumetric capacity of 19.3 mAh/cm^3 and, notably, a volumetric energy density of 17.3 mWh/cm^3, outperforming those ($\leq$10 mWh/cm^3) of conventional lithium thin-film batteries. The Zn//MnO_2 micro-batteries also provided long-term cyclability, high capacity retention of 83.9% after 1300 cycles at a current density of 5 C, which far exceeds those of stacked Zn//MnO_2 batteries reported to date. Furthermore, the Zn//MnO_2 planar micro-batteries exhibited exceptional flexibility without capacity loss under serious deformation and high voltage/high capacity through facile serial and parallel connection of bipolar cells. The serial or parallel Zn//MnO_2 planar micro-batteries were assembled with unit cells one by one, which were packaged by dropping electrolyte onto the project area of interdigital microelectrodes.

The low-cost, environmentally benign Zn//MnO_2 micro-batteries with in-plane geometry presented in this study hold great promise as a high-performance, safe, flexible, and shape-versatile printed microscale power source that can be directly integrated with various miniaturized electronics. This study will be of broad interest to scientists and engineers involved in nanotechnology, chemistry, material science, and energy storage, and contributes to enriching development perspectives and directions of planar microscale power sources for potential use in future microelectronics. Research directions on printable batteries are currently focused on (i) synthesis of highly conducting and stable battery component inks with tunable rheological properties associated with electrochemical performance, (ii) design of battery shapes and configurations with fully printable techniques, (iii) development of industrially scalable printing techniques, and (iv) monolithic/seamless integration of printable batteries with electronic devices [2,9].

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National Science Review
7: 5–6, 2020
doi: 10.1093/nsr/nwz092
Advance access publication 21 July 2019