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News & Views

Commentary on the special topic: nanoenergy and nanosystem

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In the internationally renowned journal—Science China Technological Sciences—a good selection of articles dedicated to the field of micro-/nanotechnologies have reported several advanced technologies in nanoenergy and nanosystems. Five papers written with great care by international experts are targeting to address technical challenges in self-powered chaotic signal generators and new batteries based on nanomaterials. I read these papers and found them interesting and beneficial to researchers working in the above-mentioned areas.

The paper written by Zhang et al. [1] has analyzed the power consumption of a chaotic circuit. Chaotic circuits are key elements in communication and neural systems, where they serve functions of adding extra protections to the communicated signals and simulations of brain working mechanism. The power consumption of such circuits is extremely important particularly in applications such as portable and implanted devices, where it is almost impossible to perform in vivo battery replacement, drastically reducing the lifetime of the devices. In the paper, rigorous theoretical analysis of power consumption of the chaotic circuits was conducted. It has been shown in the paper that the total power of the linear elements equals the power stored in the nonlinear resistor. Therefore, the power consumption of the whole device can be obtained from the sum of the power dissipated in the linear elements. Evidence is shown in Fig. 3 of this paper, which depicts the calculation results of the power level of the nonlinear resistor, and the power level of all the linear elements. For parameters chosen to demonstrate this approach, 2.45 mW was calculated to maintain the circuit working in the chaotic state. In addition, the paper reviewed recent technical advancements in nanoscale energy generators.

In this special topic, there are several experimental papers in the field of chemical batteries with improved performances using nanomaterials. The performances of Li-ion batteries have been improved by implementing Cu_2O nanowire synthesized by hydrothermal method in the article written by the group led by Professor Yafei Zhang [2]. The paper presented a novel approach taking advantage of the superior properties of Cu_2O such as enhanced conductivity and charge–recharge cycle stability. Notable characteristics reported for the newly developed Li-ion battery include the value of capacity exceeding 400 mAh/g for the cycle number up to 100. Detailed experimental procedure of fabricating Cu_2O nanowires has also been described, benefiting researchers who intend to follow this approach. It is noted that fabricating anodes for Li-ion batteries using hydrothermal method is a very popular process [3].

Another paper in this special session reported a new technology using nanocomposites to improve the performances of the Li-ion battery by addressing challenges of multi-cycle stability and the capacity [4], with the similar aim as in Ref. [2]. In Zhao's work, SnO_2–CuO/graphene nanocomposites were synthesized via a two-step method. In the first step, the CuO nanorods were loaded on the graphene nanosheets, followed by coating SnO_2 nanoparticles. It was reported that after 30 cycles, the capacity can be maintained at 584 mAh/g. Obviously, capacity and multi-cycle stability are key problems in Li-ion batteries, and both papers demonstrated reasonable improvements to these performances through different novel approaches. Again, detailed chemical process of preparing nanocomposites was presented in the paper. Moreover,

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nanocomposites were characterized through scanning electron microscope (SEM) and X-ray diffraction (XRD). The improved performance was predicted owing to graphene nanosheet structure (GNS) and the synergistic effect among the SnO_2 nanoparticles, CuO nanorods, and GNSs, which was supported by analyzing previous published references.

A paper written by a research group in Lanzhou University has again targeted at the Li-ion batteries to increase capacity for multiple charge–discharge cycles [5]. Excellent performances have been reported with the capacity reaching more than 600 mAh/g after 100 charge–discharge cycles. The physics behind this significant improvement was thought to be the good electrical conductivity of the multi-wall carbon nanotube (MWCNT), which can provide fast transport channels for MnO_2 in the electrochemical reactions. The nanomaterial used in this paper was the tubular nanocomposite with interconnected MnO_2 nanoflakes coated on MWCNTs, which was synthesized using the hydrothermal method. The nanocomposite essentially combines the high capacity of MnO_2 and high conductivity of MWCNTs. The synthesized nanocomposites were subsequently examined using SEM and XRD. Electrochemical performances of the device were also tested and analyzed. Comparison of the pure MnO_2 electrodes and the MWCNTs@MnO_2 was made in the results shown in Fig. 2b therein. Amazingly, the new nanocomposite material has quadrupled the capacity from around 150 mAh/g to above 600 mAh/g. It is worth mentioning that in the first charging process, using the nanocomposite, the capacity reached as high as 1,233.6 mAh/g. The reason why there is a big difference between the first charge and after multiple charge–recharge cycles has not been revealed. Similar approaches of implementing graphene to the anode materials can be seen in Refs. [6, 7]. Microstructure reconstruction of the cathode of Li-ion batteries has also been made in Ref. [8].

Finally, a paper aiming to improve the operating bandwidth of the MEMS vibrational energy harvesters has been presented [9]. Energy harvesting devices converting mechanical energy to the electricity through piezoelectric materials have attracted great interests from global researchers. The current status in this area is reasonably mature after research and development in recent 20 years. One of the challenges limiting the technology from being further commercialized is the frequency mismatch between the excitation frequency and the resonant frequency of the mechanical structures. Tremendous papers have been published to increase the resonant band of the mechanical structures to ameliorate the power conversion efficiency, i.e., designing complex multi-degree-of-freedom structures [10]. In Ref. [9], the power density of the device reached 0.81 $\mu W/cm^3$ at resonant frequency of 20 Hz. The low resonant frequency is certainly an advantage; the power density of the device is still not large enough to be utilized in the real applications. Future work is needed to improve the power density.

It has been a joy to read these high-quality papers published in the special issue in the journal of Science China Technological Sciences. Out of the five articles, three of them reported up-to-date technologies on Li-ion batteries using advanced nanomaterials with the aim of increasing the capacity for multiple charge–recharge cycles. One article filled the gap in the development of chaotic circuits by analyzing its power consumptions. A MEMS energy harvesting device designed to widen the bandwidth has also been reported. With the fast development in micro- and nano-technology in recent decades, it is timely and imperative to publish this special issue. More interesting works in the related fields is anticipated in the near future.

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