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## Introduction to new horizons in materials for energy conversion, optics and electronics

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In conjunction with the Emerging Investigator Forum celebrating the 120<sup>th</sup> anniversary of Southeast University, we herein present a collection of articles focused on the energy conversion, optics, and electronics applications of (nano)materials.

Renewable energy systems have gained popularity due to climate protection and

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sustainability issues.<sup>1</sup> However, the intermittency caused by natural renewable energy sources disrupts the balance of the energy system and can put considerable strain on electrical systems.<sup>2</sup> Thus, such artificial systems should be carefully envisioned, strategized, produced, optimized, and monitored to keep them highly efficient, safe, stable, and cost effective.

Energy materials, engineered at nanometer length scales, present unique physicochemical properties that make them more

suitable to be explored in diverse manners, paving the way towards renewable energy systems with continuous breakthroughs.<sup>3–5</sup> Meanwhile, theoretical calculations, such as machine learning methods, have been widely applied to solve complex problems.<sup>6,7</sup> This collection focuses on energy conversion, optics, and electronic applications of (nano) materials and provides an overview of the most impactful experimental approaches and theoretical methods for energy conversion and storage, intending to connect different



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Professor Jinlan Wang is currently an endowed chair professor in the School of Physics at Southeast University. She obtained her PhD from Nanjing University in 2002, followed by a three-year Post-doctoral experience at the Chemistry Division, Argonne National Laboratory. Her group is one of the pioneers devoted to data-driven functional material design, and her research interests also cover electrocatalytic mechanism and catalyst design, growth mechanism and surface/

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Professor Yuanjian Zhang received his BS from Nanjing University in 2002 and completed his PhD at the Changchun Institute of Applied Chemistry, Chinese Academy of Sciences in 2007. Subsequently, he joined the Max-Planck Institute of Colloids and Interfaces (Germany) as a postdoctoral researcher. From 2009–2012, he worked at the National Institute for Materials Science (Japan) as an ICYS researcher. He joined the faculty at Southeast University (China) in

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communities and identify common challenges in the field.

Part of the Editor's collection is an exquisite study by Qichong Zhang, Kuibo Yin, Litao Sun and coworkers that provides a promising strategy to rationally construct high-performance flexible vanadium-based cathodes for next-generation wearable aqueous zinc-ion batteries (<https://doi.org/10.1039/D2NH00349J>). They fabricated 3D geometrically-promoted N-doped carbon/defect-rich  $V_2O_{5-x} \cdot nH_2O$  (DVOH@NC) fibrous cathodes *via* an *in situ* electrochemical activation strategy. The DVOH@NC cathodes brought unexpected electrochemical performance improvements with their impressive capacity ( $711.9 \text{ mA h cm}^{-3}$  at  $0.3 \text{ A cm}^{-3}$ ) and long-term durability (95.5% retention after 3000 cycles). Moreover, the oxidative formation of the DVOH@NC host with enhanced electronic/ion conductivity and its reversible electrochemistry were investigated using insightful electrochemical tests and density functional theory. The assembled deformable fibrous battery with remarkable flexibility demonstrated great advantages in the solar-driven self-powered system and smart wearable electronics.

Semiconductors, especially one-dimensional  $TiO_2$  nanofibers fabricated by electrospinning, have received considerable attention in the past two decades, for a variety of basic applications toward energy conversion and storage. However, their safe use and easy recycling are still hampered by

their inherently subpar mechanical performance. Part of this collection is a contribution by Yunqian Dai and coworkers that demonstrates a proof-of-concept for the continuous and controlled production of flexible oxide nanofibers, hastening the transition of  $TiO_2$ -based nanomaterials from the lab to the lab (<https://doi.org/10.1039/D2MH01255C>). They used Al ions to soften rigid  $TiO_2$  molecules and regulate the dynamics of  $TiO_2$  crystallization, growth, and aggregation, strengthening electrospun  $TiO_2$  nanofibers from the molecular to macro scale. The modified nanofibers had the highest tensile breaking strength (2.24 MPa) and highest anatase content (47 wt%) ever reported after being calcined at  $900 \text{ }^\circ\text{C}$ . More interestingly, the authors dynamically visualized the oriented deposition of amorphous Al species, which significantly delays the sintering of  $TiO_2$  nanocrystals, at the grain boundary of  $TiO_2$  nanocrystals through *in situ* TEM observation, for the first time. This finding provides essential insight for the rational design of thermally stable oxide nanomaterials. With the aid of origami art for the first time, flexible  $TiO_2$  nanofibrous membranes were constructed into high-temperature resistant microreactors. It was endowed with a  $PM_{2.5}$  filtration efficiency of 99.97% after 300+ minutes of use and is able to effectively degrade adsorbents and therefore become a regenerated system by taking full advantage of residual heat and/or sunlight irradiation. These results provide new insights for the

functionalization of semiconductors with reliable thermal, mechanical, and chemical stabilities.

These are just a couple of the many recent papers published in this themed collection focused on materials for energy conversion, optics and electronics. We hope that you will find them an interesting read!

## References

- 1 T. Bolsen, *Nat. Energy*, 2022, 7, 1003–1004.
- 2 J. M. Gonzalez, J. E. Tomlinson, E. A. M. Ceseña, M. Basheer, E. Obuobie, P. T. Padi, S. Addo, R. Baisie, M. Etichia, A. Hurford, A. Bottacin-Busolin, J. Matthews, J. Dalton, D. M. Smith, J. Sheffield, M. Panteli and J. J. Harou, *Nat. Sustainable*, 2023, 6, 415–427.
- 3 H. Lu, J. Tournet, K. Dastafkan, Y. Liu, Y. H. Ng, S. K. Karuturi, C. Zha and Z. Yin, *Chem. Rev.*, 2021, 121, 10271–10366.
- 4 X. Hu, D. Zuo, S. Cheng, S. Chen, Y. Liu, W. Bao, S. Deng, S. J. Harris and J. Wan, *Chem. Soc. Rev.*, 2023, 52, 1103–1128.
- 5 H. Hosono and M. Kitano, *Chem. Rev.*, 2021, 121, 3121–3185.
- 6 Z. Yao, Y. Lum, A. Johnston, L. M. Mejia-Mendoza, X. Zhou, Y. Wen, A. Aspuru-Guzik, E. H. Sargent and Z. W. She, *Nat. Rev. Mater.*, 2022, 8, 202–215.
- 7 C. Lampe, I. Kouroudis, M. Harth, S. Martin, A. Gagliardi and A. S. Urban, *Adv. Mater.*, 2023, 2208772.



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