Nanoscale

EDITORIAL

Cite this: *Nanoscale*, 2024, **16**, 19936

DOI: 10.1039/d4nr90169j

rsc.li/nanoscale

Introduction to micro- and nano-motors

Li Zhang, *[a] Martin Pumera, *[b,c] Samuel Sánchez *[d,e] and Xing Ma *[f]

An introduction to the *Nanoscale* and *Journal of Materials Chemistry B* themed collection on micro- and nano-motors that features a series of articles discussing the virtue of their small size and controllable mobility, while highlighting the revolutionary potential applications.

The initial concepts of micro- and nano-motors (MNMs) were inspired by Richard Feynman's famous 1959 lecture, "There's Plenty of Room at the Bottom", which laid the theoretical foundation by suggesting the possibility to manipulate molecules using small machines at the nanoscale. During the past two decades, the field has experienced rapid development, with significant advancements in regard to propulsion mechanisms, material design, integration of multifunctionality, imaging and motion control, and fundamental aspects of active matter. Moreover, due to their remarkably small dimensions and precisely controllable mobility, MNMs have shown unprecedented potential in various applications, particularly in sensing, biomedicine, and environmental management, among others. The field of MNMs is vivid, emerging and highly interdisciplinary, and represents a rapidly growing area of research, including materials science, physics, chemistry, and biomedical engineering.

In this context, the cross-journal collection featured in *Nanoscale* and *Journal*

[a]*Department of Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong SAR, China. E-mail: lizhang@cuhk.edu.hk*
[b]*Future Energy and Innovation Laboratory, Central European Institute of Technology, Brno University of Technology, Purkynova 123, Brno, Czech Republic. E-mail: martin.pumera@ceitec.vutbr.cz*
[c]*Faculty of Electrical Engineering and Computer Science, VSB – Technical University of Ostrava, 17. Listopadu 2172/15, Ostrava, Czech Republic*
[d]*Institute for Bioengineering of Catalonia (IBEC), The Barcelona Institute of Science and Technology (BIST), Baldiri I Reixac 10-12, 08028 Barcelona, Spain. E-mail: ssanchez@ibecbarcelona.eu*
[e]*Institució Catalana de Recerca i Estudis Avançats (ICREA), Psg. Lluís Companys, 23, Barcelona, Spain*
[f]*Sauvage Laboratory for Smart Materials, School of Materials Science and Engineering, Harbin Institute of Technology (Shenzhen), Shenzhen 518055, China. E-mail: maxing@hit.edu.cn*

Li Zhang

Li Zhang is a Professor in the Department of Mechanical and Automation Engineering and a Professor by Courtesy in the Department of Surgery at The Chinese University of Hong Kong (CUHK). He is also a project leader in the Multi-scale Medical Robotics Center (MRC), InnoHK, at the Hong Kong Science Park. Dr Zhang's main research interests include small-scale robotics and their applications for translational biomedicine. Dr Zhang is elected as a Fellow of the IEEE, Royal Society of Chemistry, Asia-Pacific Artificial Intelligence Association, and The Hong Kong Institution of Engineers, a member of the Hong Kong Young Academy of Sciences, and an Outstanding Fellow of the Faculty of Engineering at CUHK.

Martin Pumera

Professor Martin Pumera is the Head of the Advanced Nanorobots and Multiscale Robotics Laboratory at Technical University Ostrava and Chief Investigator of the Future Energy & Innovation Lab at CEITEC, Brno, Czech Republic. He founded the Center for Advanced Functional Nanorobots at UCT Prague, where he served as a director (2017–2023). He was a tenured group leader at the National Institute for Materials Science, Japan, in 2006. In 2010, Martin joined Nanyang Technological University, Singapore, where he worked as a tenured associate professor for almost a decade. Prof. Pumera has diverse research interests in nanomaterials and microsystems, in the specific areas of micro- and nanomachines, quantum materials, machine intelligence and 3D printing.

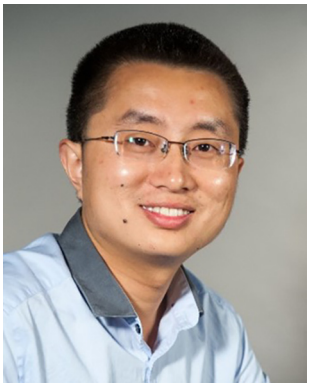
of Materials Chemistry B aims to present a comprehensive overview of the current advancements in micro- and nanomotors, with a particular focus on their application across a broad spectrum of fields and disciplines. For instance, a review by Chen *et al.* opens the themed collection – with a cover image – summarizing the evolution of enzyme nanomotors from single motors to swarms (**https://doi.org/10.1039/D3TB02457A**). Oral *et al.* review the *in vivo* applications of micro/nanorobots, especially focusing on preclinical studies conducted with animal models (**https://doi.org/10.1039/D3NR00502J**). Jiang *et al.* introduce intelligent sensing based on micro/nanomotors in their article (**https://doi.org/10.1039/D3TB01163A**). Liang *et al.* summarize the current progress in active therapy based on byproducts produced or generated during the motion process of micro/nanomotors (**https://doi.org/10.1039/D2NR05818A**). The review articles in this collection provide a comprehension of the current development and challenges of MNMs, as well as highlighting the inspirations to bridge the gap between laboratory research and clinical applications.

In addition to the inspiring reviews, there are also reports on original research work. Patiño *et al.* reported their findings on the protein corona formation around self-propelled enzyme nanomotors (**https://doi.org/10.1039/D3NR03749E**). In their work, they elucidate how active particles interact with biological media and maintain their self-propulsion after protein corona formation, which may pave the way for the use of these systems in complex biological fluids in biomedicine. Mohammadnezhad *et al.* demonstrate light-driven nanomotors with reciprocating motion and high controllability based on interference techniques (**https://doi.org/10.1039/D3NA00678F**). The interferometric method discussed in their work can also be used in light-driven nanomotors to reach high controllability. Chen *et al.* reported ultrasound-propelled nanomotors for efficient cancer-cell ferroptosis (**https://doi.org/10.1039/D3TB02041J**). This work is a significant step toward accelerating cellular internalization and inducing cancer-cell ferroptosis in an active way by utilizing nanomotors.

The themed collection is dedicated to showcasing the state-of-the-art developments in the design and fabrication of MNMs, the mechanisms that drive their propulsion, advanced imaging techniques, safety considerations, and their diverse applications. By bringing together cutting-edge research from these interconnected domains, the collection seeks to foster interdisciplinary collaboration that is crucial for addressing the critical challenges facing the development of MNMs. Moreover, it aspires to showcase the advancement of these technologies toward practical implementations. Through this initiative, the collection endeavors to promote the translation of MNMs from the laboratory to real-world applications, thereby unlocking their full potential to impact society.

Samuel Sánchez

Samuel Sánchez is an ICREA Research Professor, Group Leader and Deputy Director at the Institute for Bioengineering of Catalonia, Spain. Samuel has had an international career in different research centers between Japan and Germany. Samuel received several awards (among others): the MIT TR35 Top Innovator Under 35 2014, the Princess of Girona Scientific Award 2015 and the National Research Award for Young Talent 2016, the "Scientific Excellence award 2022" from the Spanish Royal Society of Chemistry, the Banco Sabadell Foundation award for "Basic Science and Engineering award" 2022, and the "Constantes y Vitales Award" to the "Young Talent in Biomedicine". He has been an elected member of the Young Academy of Spain since 2020. His group's main interests are new types of advanced robotics from the nano- to mesoscale, including from self-propelled nanoparticles as intelligent vehicles in biomedicine to the 3D Bioengineering of biohybrid robots and actuators. He is also cofounder, CSO and CEO-interim of the spin-off Nanobots Therapeutics SL.



Xing Ma

Dr Xing Ma is now a full professor at the School of Integrated Circuits, Harbin Institute of Technology (Shenzhen), China. He started his PhD study at the department of Materials Science and Engineering in Iowa State University in the United States and transferred to Singapore in 2011. He obtained his PhD degree from the Materials Science and Engineering School at Nanyang Technological University, Singapore in 2013. He conducted postdoc research at the Max-Planck Institute for Intelligent Systems at Stuttgart, Germany, from 2014 to 2016, and was awarded the Alexander von Humboldt fellowship for his postdoc research. His research interest focuses on smart biomaterials for micro/nano-robots/motors and biosensing devices.