Nanoscale

EDITORIAL

View Article Online
View Journal | View Issue

Cite this: *Nanoscale*, 2026, **18**, 10456

DOI: 10.1039/d6nr90042a

rsc.li/nanoscale

Introduction to advanced semiconductor nanocrystals

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Angshuman Nag is a Professor of Chemistry at the Indian Institute of Science Education and Research (IISER) Pune, India. He completed his Master of Science in Chemistry at IIT Guwahati (2003) and Ph.D. at IISc Bengaluru (2009), followed by postdoctoral research at IISc and University of Chicago. He started his own research group at IISER Pune in the year 2012. His research is focused on developing novel semiconductors for optoelectronic properties.

Klaus Boldt

Klaus Boldt studied chemistry in Hamburg, Germany, from where he also obtained his PhD in 2011, working in the group of Horst Weller on the spectroscopy of semiconductor nanocrystals. After working as a postdoc in the groups of Paul Mulvaney (Melbourne) and Alexander Eychmüller (Dresden), he started his own research group at the University of Konstanz in 2015. Since 2022, he has been a professor of physical chemistry at the University of Rostock, where he is interested in the synthesis and spectroscopy of complex nanoheterostructures.

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Introduction

The field of semiconductor nanocrystals has witnessed a remarkable transformation, evolving from fundamental curiosity to a cornerstone of modern nanotechnology. The themed collection on "Advanced semiconductor nanocrystals" in *Nanoscale* brings together a curated collection of cutting-edge research highlighting the latest advances in synthesis, characterization, and application of these versatile materials. Recent breakthroughs have enabled unprecedented control over nanocrystals' size, shape, and anisotropy, as well as the development of complex heterostructures and precise doping strategies. These advances have unlocked unique quantum confinement effects, resulting in tunable optical and electronic properties that are unattainable in bulk materials. However, the versatility of this material class comes not only from the possibility to tune physical properties, but also from the processability. Nanocrystals can be processed as an ink and then coated, printed, or annealed, much like polymers, providing a sustainable alternative to solid-state device fabrication.

The research featured in this collection demonstrates the broad impact of semiconductor nanocrystals across multiple domains:

Optoelectronics: solution-processed quantum dots for laser and blue light-emitting diodes, offering economical and color-tunable alternatives to traditional devices.

Energy conversion: innovative nanocrystal-based photocatalysts and heterostructures for efficient hydrogen production and water splitting.

Sensing and detection: high-responsivity photodetectors and UV detectors based on novel nanocrystal architectures.

Quantum technologies: materials with tailored band structures and carrier dynamics, paving the way for quantum computing components.

Jannika Lauth

Jannika Lauth is assistant professor for physical chemistry at the University of Tübingen and at the University of Hannover, specializing in 2D semiconductors, ultrafast spectroscopy, and nanomaterials. She received her doctorate from the University of Hamburg and completed postdoctoral work in Delft and Hamburg. Lauth has led research groups in Oldenburg and Hannover and is the spokesperson of the young Physical Chemists (yPC) in the German Bunsen Society. Her work focuses on colloid chemistry and advanced spectroscopy techniques.

Highlights from the collection

Innovation in colloidal synthesis

New methods for producing tungsten oxide nanocrystals doped with organic cations,[1] and flow-reactor synthesis of CdSe nanoplatelets,[2] exemplify the drive toward scalable and tunable nanomaterial fabrication.

Hybrid and heterostructured materials

The design of S-scheme heterostructures and ternary composites, such as $ZnIn_2S_4$/MoS_2 [3] and PANI/GO/α-Fe_2O_3,[4] showcases the synergy between different semiconductor materials for enhanced catalytic and optoelectronic performance.

Surface chemistry and defect engineering

Studies on interface engineering in CdS quantum dots,[5] surface modification using proteins,[6] and multidentate coordination in perovskite solar cells[7] highlight the importance of defect passivation and surface modification for optimizing device efficiency and help to design NPs for biomedical applications.

Environmental and societal impact

The development of electrocatalysts from waste-derived materials and the upcycling of CO_2 into valuable products reflect the field's commitment to sustainability.[8]

Summary and future prospects

The research presented in this collection underscores the transformative potential of advanced semiconductor nanocrystals. The advances showcased in this collection deepen our understanding of semiconductor nanocrystals and chart a course toward their integration into next-generation technologies. We invite readers to explore the diverse and innovative contributions defining this dynamic field's forefront. As the community continues to unravel the fundamental mechanisms governing these materials, new frontiers in energy, electronics, and quantum information science are within reach. Integrating nanocrystals into practical devices will require continued synthesis, surface chemistry, and device engineering innovation.

References

1 O. Kendall, L. V. Melendez, M. N. Guven Bicer, M. Wilms, J. Van Embden, D. E. Gómez, A. Calzolari, D. Prezzi and E. Della Gaspera, *Nanoscale*, 2025, **17**, 7030–7034.
2 J. I. M. Funk, B. Sochor, S. Koyiloth Vayalil and H. Weller, *Nanoscale*, 2024, **16**, 21309–21316.
3 H. Bhatt, M. S. Patel, T. Goswami, D. K. Yadav, A. S. Patra and H. N. Ghosh, *Nanoscale*, 2025, **17**, 7908–7916.
4 I. Ahmad, M. S. Athar, M. Muneer, H. M. Altass, R. Felemban and S. A. Ahmed, *Nanoscale*, 2025, **17**, 3822–3836.
5 S. Das, B. Bhattacharyya, A. Mohanty, P. Mukherjee, A. Mukherjee, A. Dutta,

A. Pandey, P. Mahadevan, R. Viswanatha and D. D. Sarma, *Nanoscale*, 2025, **17**, 276–286.
6 B. Otange, T. Katenkamp, H. Böhler, M. Rütten, L. Lang, F. Schulz, W. J. Parak and T. Beck, *Nanoscale*, 2025, **17**, 1997–2003.
7 H. Baishya, M. J. Patel, R. Das Adhikari, D. Yadav and P. K. Iyer, *Nanoscale*, 2024, **16**, 21804–21816.
8 Y. Hu, X. Wang, J. Liu, X. Lu, L. Huang, Y. Jiang, L. Zhao, J. Li, Z. Yin, J. Cui, W. Zhu and Y. Wang, *Nanoscale*, 2025, **17**, 5056–5063.