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Introduction to fundamental processes in optical nanomaterials

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An introduction to the joint *Nanoscale* and *Chemical Communications (ChemComm)* themed collection focused on fundamental processes in optical nanomaterials that features a series of articles describing the properties of this versatile class of materials while highlighting some of their potential applications.

The importance of the unique material- and size-dependent optical response of nanomaterials is exemplified by the "story" of semiconductor nanoparticles (or quantum dots) that were first prepared by Moungi Bawendi, Louis Brus and Aleksey Yekimov. They were awarded the 2023 Nobel Prize in Chemistry for their discovery.† Synthesis methods that provide quantum dots of well-defined size, shape, composition, and surface chemistry have enabled understanding, control, and ultimately exploitation of the influences of quantum confinement in these materials and facilitated the realization of practical applications. This themed collection provides a glimpse into the design and preparation of a variety of other nanomaterials, fundamental processes that lead to their optical properties, factors that affect these properties, and how they can be probed; many contributions also discuss prototype applications.

Nanomaterial optical properties and their corresponding applications are as diverse as the materials themselves, ranging from optical imaging probes to thermal sensors and photocatalysis. This diversity is well illustrated by contributions related to lanthanide-based emitters. For instance, Calado *et al.* report the interplay of Tb^{III} and Eu^{III} ions within dual-emitting molecular cluster-aggregates (**https://doi.org/10.1039/D3CC03658H**). In their work, precise control over the decay of the Tb^{III} and Eu^{III} excited states resulted in materials that exhibit thermal sensing capabilities. Another example for lanthanide-based optical thermometry is described by Ramos *et al.*, who assessed the application potential of Yb^{III} and Er^{III} co-doped Gd_2O_3 for thermal sensing (**https://doi.org/10.1039/D3NR01764H**). In this study, the authors investigated white light upconversion emission arising from Yb^{III}/Er^{III} in co-doped nanopowders and mechanical mixtures. The versatility of lanthanide-based nanomaterials has also been demonstrated by Kaur *et al.*, namely the photocatalytic capability of dye-sensitized upconverting nanoparticles (**https://doi.org/10.1039/D3NR02845C**). The importance of controlling their composition and structure are further exemplified by Cuau *et al.* (**https://doi.org/10.1039/D3NR03710J**)

Alison M. Funston

Dr Alison Funston is a chief investigator of the ARC Centre of Excellence in Exciton Science and lecturer in the School of Chemistry at Monash University, Melbourne, Australia. She received her PhD from the University of Melbourne in 2002, followed by postdoctoral appointments at Brookhaven National Laboratory (with Dr John Miller, 2002–2005) and the University of Melbourne (with Prof. Paul Mulvaney, 2006–2010). She was appointed at Monash University in 2010 and in 2011 was awarded an ARC Future Fellowship. Her research focuses on the synthesis, assembly and spectroscopy of nanoscale systems, including energy transport and optical properties of well-defined assemblies of metal and semiconductor nanocrystals.

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† **https://www.nobelprize.org/prizes/chemistry/2023/press-release/**

and Liu *et al.* (**https://doi.org/10.1039/D3NR05380F**) who demonstrate the synthesis of Tb^{III}-doped and core/multi-shell nanocrystals, respectively, and show their prototype utility as multi-modal imaging probes.

The community's understanding of silicon nanosheets (silicane) and the tunability of their optical properties is expanded upon in a report by Stavrou *et al.* (**https://doi.org/10.1039/D3NR03497F**). In their contribution the authors describe the synthesis and functionalization of silicane bearing styrene or *tert*-butyl methacrylate moieties. Investigation of the nonlinear optical response (NLO) of these functionalized silicanes revealed enhancements, in both cases, when compared to that of the pristine Si–H terminated systems while providing superior NLO absorption and refraction. New insights into fundamental aspects of silicon nanoparticles (**https://doi.org/10.1039/D3NR04478E**) and the control of superchiral resonances of silicon meta-surfaces (**https://doi.org/10.1039/D3NR05285K**) open routes to novel nanomaterials for optoelectronics, imaging, and sensing applications.

Rounding out this special collection, progress related to metal-quantum dot nanohybrids and their application in fluorescence biosensing is provided by Hildebrandt *et al.* (**https://doi.org/10.1039/D2CC06178C**). In their contribution the authors provide a comprehensive summary of the status of the field while describing the fundamental processes related to plasmonic enhancement and quenching of quantum dot luminescence, prototype applications and future potential for these systems. Seeking novel applications of plasmonic nanostructures, a study by Kashyap *et al.* reveals the prospects of plasmonic nanocatalysts in conducting energy intensive chemical synthesis in a sustainable fashion. Herein, the sole effect of plas-

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Dr Eva Hemmer is an associate professor of materials chemistry at the University of Ottawa. She received her PhD in materials science from Saarland University (Germany) and subsequently worked as a postdoc on lanthanide-based nanoparticles for near-infrared bioimaging at the Tokyo University of Science, Japan. She then became a Feodor Lynen Research Postdoctoral Fellow at the INRS-EMT (Université du Québec, Montreal, Canada), developing lanthanide-based nanothermometers. In 2016, she joined the Department of Chemistry and Biomolecular Sciences at the University of Ottawa, where her group is working on lanthanide-based nanocarriers for biomedical and energy conversion applications.

Arindam Chowdhury

Dr Arindam Chowdhury is a professor in the Department of Chemistry at the Indian Institute of Technology (IIT), Bombay, India. He received his Masters in chemistry from IIT Kanpur in 1997 and a PhD from Carnegie Mellon University in 2002. Following a postdoctoral appointment at Columbia University, USA, he joined IIT Bombay in 2006 where he became a full professor in 2018. His research focus is to probe heterogeneity and elucidate fundamental processes in complex systems using single-molecule fluorescence imaging, dynamics and spectroscopy. His research incorporates physical chemistry with nanomaterials and biomolecular sciences to understand structure and dynamics in semiconductor nanocrystals/heterostructures, soft-materials and biological systems.

Jonathan G. C. Veinot

Dr Jonathan (Jon) Veinot is the Associate Dean Research (Grants and Innovation) in the Faculty of Science at the University of Alberta and a professor in the Department of Chemistry. He also serves as an associate editor for the Royal Society of Chemistry journals Nanoscale *and* Nanoscale Advances. *He and his research team are at the forefront of group 14 (*i.e., *Si and Ge) nanomaterials (*e.g., *quantum dots, nanosheets,* etc.*) research and study their synthesis, properties, and far-reaching applications. His research team has also explored such topics as super-hydrophobic/self-cleaning surfaces, metal oxide nanomaterials and polymers for organic electronic devices; most recently they have initiated studies of a variety of bulk and nanoscale high entropy alloys. Dr Veinot also established and is, the Canadian Director of the Alberta-Technical University of Munich International Graduate for Hybrid Functional Materials (ATUMS).*

monic-heat in driving a high temperature organic transformation is demonstrated (**https://doi.org/10.1039/D3CC04278B**). Catalysis processes at plasmonic nanoparticle surfaces are complicated by ligand effects. Joshi *et al.* show that by harnessing the electron transfer properties of these ligands, their catalytic properties can be improved (**https://doi.org/10.1039/D3NR02829A**). Effects of thermal annealing on the optical properties of plasmonic materials and new synthetic pathways to plasmonic ZrN nanoparticles are presented by Chen *et al.* (**https://doi.org/10.1039/D3NR03522K**) and Protsak *et al.* (**https://doi.org/10.1039/D3NR03999D**).

In addition to molecular, inorganic, and metallic nanomaterials, polymers with optical properties are also showcased in this collection. For example, Suharman *et al.* fabricated thermally tolerant polymer optical resonators from a stereocomplex of poly(L-lactic acid) and poly(D-lactic acid) through the oil-in-water miniemulsion method. The resultant optical resonators preserved their properties up to an elevated temperature of 230 °C (**https://doi.org/10.1039/D3NR05318K**).

This themed collection of contributions related to the optical properties of nanomaterials provides a snapshot of the vast potential of intriguing systems. With the ever-advancing synthesis methods that provide exquisite control over material architectures combined with technological advances in material characterization that facilitate increased understanding of the processes, it is reasonable to expect new materials and applications to emerge.