President's Science Award 2016

CITATION

Associate Professor LIU Xiaogang
Department of Chemistry, Faculty of Science, NUS
Institute of Materials Research and Engineering, A*STAR

<u>One-line Citation</u>

"For his outstanding research in developing rare-earth-doped nanocrystals that could be used as luminous tags for tracking cancer cells and deciphering various biologically relevant phenomena"

<u>Full Citation</u>

Over the past ten years, Associate Professor Liu Xiaogang has been devoted to developing innovative methods for the synthesis of rare-earth-doped nanocrystals that can emit a palette of visible colors at a wavelength shorter than the excitation wavelength – a phenomenon known as photon upconversion that makes the emitted light to be more energetic than the light absorbed. Owing to their good biocompatibility and small physical dimensions several thousands of these nanomaterials could fit across the width of a human hair, and these nanomaterials can be coupled to proteins or other biological macromolecular systems. They are particularly useful for bioimaging and biodetection because their high energy emissions can be clearly distinguished from background noise. In addition, the ability to excite these nanocrystals under near-infrared light – a spectral range which is less harmful to biological samples and has greater sample penetration depths than conventional ultraviolet excitation – enhances their prospects as a biological tool to control and monitor the activities of individual cells in living tissue. Therefore, the discovery of these nanocrystals allows for tremendous improvements in our ability to study complex biological systems such as proteins or cells that can be made visible over a long period of time without much photodamage, a feat virtually inaccessible by conventional fluorescent imaging techniques.

Despite the enticing prospects, the applications of upconversion nanocrystals in biological and biomedical fields remained unclear in the early days of investigation. One major challenge was to devise methods for making materials with tunable size and shape as well as a spectrum of emitting colors that are highly sought after for measuring multiple analytes in a single run. Another notable challenge was boosting the brightness of the nanocrystal emission at high dopant concentrations. High dopant concentration can lead to better light-harvesting capabilities, but cross-interactions begin to quench the generated light. As it happens, this problem has provided a strong motivation for the materials science community to improve the nanocrystal's light-harvesting capacities.

Indeed, much of the recent resurgence of upconversion came from the widespread research on controlled nanocrystals synthesis, together with the pressing demand for developing next-generation luminescent biomarkers that have very high photostability and long luminescence lifetime. Combined with advanced optical microscopies, these biomarkers could be utilized as a versatile platform for high resolution cell imaging and tumor targeting.

Associate Professor Liu brings together a collaborative and multidisciplinary team which has led to a broad and impactful range of inventions over the past ten years. He has pioneered technologies for finely controlling upconversion emission colour, improving energy conversion efficiency, and interfacing living cells with upconversion nanocrystals. These fundamental breakthroughs have enabled new applications in anti-counterfeiting, volumetric 3D display, stem cell differentiation, optogenetics, drug delivery, and cancer therapy. Very recently, he has demonstrated the use of upconversion nanothermometry as a useful tool to verify Einstein's prediction made in 1907 that the instantaneous Brownian velocity is independent of particle size and shape under infinite dilution conditions. Better understanding of Brownian motion of suspended nanoparticles in non-equilibrium systems would allow improved understanding of thermal conductivity, convective heat and mass transfer in various types of nanofluids.

Associate Professor Liu Xiaogang's work on upconversion nanomaterials has inspired many researchers from a broad spectrum of disciplines, including chemistry, physics, materials and life sciences, and biomedical engineering, to join his efforts to expand the upconversion field worldwide. Recently, the research on photon upconversion has flourished as one of the most exciting fields as there are over 120 research groups in universities and research institutions around the world that make valuable contributions to this field.

Associate Professor Liu's list of accolades include NUS Young Investigator Award (2006), BASF-SNIC (Singapore National Institute of Chemistry) Award in Materials Chemistry (2011), NUS Young Researcher Award (2011), and Royal Society of Chemistry Chemical Society Reviews Emerging Investigator Lectureship Award (2012). Based on The World's Most Influential Scientific Minds 2014 report published by Thomson Reuters, he is among the top 1 percent of those cited in their fields for articles published 2003-13. He has serviced on a number of editorial advisory boards, including the Journal of the Chinese Chemical Society, the Chemistry–An Asian Journal, ChemNanoMat, Nanoscale Horizons, and Advanced Optical Materials. He is currently the associate editor of Nanoscale (Royal Society of Chemistry) and the Journal of Luminescence (Elsevier).

For his outstanding research in developing rare-earth-doped nanocrystals that could be used as luminous tags for tracking cancer cells and deciphering various biologically relevant phenomena, Dr Liu Xiaogang is awarded the 2016 President's Science Award.