IOP Publishing Journal of Physics D: Applied Physics
J. Phys. D: Appl. Phys. **50** (2017) 200201 (3pp) https://doi.org/10.1088/1361-6463/aa694a

Editorial

Biological applications of electromagnetically active nanoparticles

Guest Editors

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Gathering a collection of articles dedicated to the general field of 'nanoparticles and biological applications' would have been an unsurmountable task because of the so many different types of nanoparticles that have been developed over the last 20 years for different purposes and the tremendous amount of related applications in biosciences. It is even hard to consider the number of reported achievements as belonging to a consistent sub-field of science as they are truly multidisciplinary by embracing a diversity of aspects of chemistry, physics, modeling, biology and medical science. Yet, when Dr Tom Miller, Publisher of *J. Phys. D: Appl. Phys.*, solicited us some years ago with an idea of preparing a special issue on the biological applications of nanoparticles, we took it as a challenging idea: how to gather a collection of articles and reviews while providing an original view on this flourishing field? Obviously, an approach highlighting a cross-disciplinary aspect was needed. While being broad enough but at the same time not too specific in order to interest a broad enough audience of physicists, we proposed the concept of 'electromagnetically active' nanoparticles as a common denominator to this collection. What did we mean by this term? We believe that those bearing physical properties that are generally speaking driven by electromagnetic fields deserved a particular focus in the context of biological applications, and could be viewed as belonging to a larger family of approaches as compared to standard classifications which are generally restricted to optical or magnetic properties for instance. In this context, this collection gathers developments and applications of nanoparticles with diverse properties such as for light microscopy imaging or magnetic resonance imaging, but also for biomedical purposes like in diagnostic, sensing, photothermal or magnetic hyperthermia therapies. Through some selected examples, it thus illustrates the great variety of nanoparticles in different applied physical fields and their active development in biology and medical science. We hope that the readers will realize how resourceful electromagnetically active nanoparticles are and that they will find new inspiration for their own field and might discover some state-of-the art scientific and applications driven questions exposed in this issue.

In their paper, El Rouby *et al* [1] propose a hybrid nanostructure based on sodium titanate nanotubes that are decorated with gold nanoparticles in order to promote photocatalytic properties for pollutant degradation. They nicely show that coupling plasmonic properties of gold nanoparticles to semiconducting nanotubes allows reinforcing the inherent physical properties of the nanotubes through a plasmonic electron transfer from the noble metal to large band-gap semiconductors, in order to exploit a broader range of the electromagnetic spectrum for improved photocatalytic degradation. By performing the synergistic integration of the adsorptive and photocatalytic properties of hybrid nanocomposties, this article provides a representative example on how the detailed understanding and the coupling of photophysical properties of nanoscale objects can be manipulated to design and create nanocomposites with enhanced properties for advanced applications. There are other ways than relying on electron transfer properties to make use of the energy stored by nanoparticles following electromagnetic field absorption. In particular, converting absorption of electromagnetic waves into heat using nanoscale absorbers is a highly investigated approach for curing purposes. This approach aiming at creating local hyperthermia however needs a fine understanding regarding the dose of light needed to create locally controlled temperature elevations. Because the physics of heat transport at the nanoscale and in cellular environments does not always follow the same scaling laws than in macroscopic environments [2] there is high demand for designing new methodologies to precisely probe temperature elevations at the nanoscale. In their paper, Hemery *et al* [3]

1361-6463/17/200201+3$33.00

describe a new approach to probe the temperature at the surface of magnetic iron oxide nanoparticles and further gain new understanding of local temperature elevations when a magnetic field is applied and of the creation of stationary gradients that can be maintained between the surface of nanoparticles and the bulk solvent, a phenomenon sometimes referred to as 'cold hyperthermia'. The authors used the grafting of thermosensitive polymer chains to the nanoparticle surface followed by the measurement of macroscopic properties of the resulting nanoparticle suspension and comparison to a calibration curve built up by macroscopic heating. This approach provides an interesting strategy for estimating the response of magnetic nanoparticles when a radiofrequency magnetic field is applied and more generally for understanding the behavior of other thermogenic nanoparticles. For many applications, such as in cancer treatment where magnetic nanoparticles are aimed at being used to create hyperthermia, it is also important to develop robust strategies to target the nanoparticles to specific areas to be cured. In their paper, Moros *et al* [4] propose a strategy to engineer magnetic nanoparticle surfaces to obtain specific immunotargeting of cadherin expressing cells. Magnetic nanoparticles are also known to be able to stimulate specific enzymatic-like activities following electromagnetic field absorption, representing a promising route for analyte sensing (glucose, or ascorbic acid for instance). To this end, nanoparticle surfaces must however be made multifunctional. In this context, a new synthetic route is proposed by Mumtaz *et al* [5] to obtain dopamine capped mixed ferrite nanoparticles that have distinct peroxidase-like activity. The development of nanoscale sensors for local protein concentrations in solution is also an important field of research as demonstrated by Morris *et al* [6] who designed single and branched conducting polymer nanowires that can work in highly saline biological media under applied electric fields. Fluorescent nanoparticles, i.e. those capable of emitting light under the application of electromagnetic waves, have also become increasingly important for many bio-applications such as for sensing, imaging and diagnostics. This is because fluorescence provides an exquisite sensitivity (down to the single molecule level), high resolution with the advent of super-resolution microscopy that was awarded the Nobel Prize in chemistry in 2014 (see review in this journal [7]), ease of operation, need for non-sophisticated instrumentation, and compatibility with living samples. A lot of effort is still being made to obtain bright and photostable, fluorescent nanoparticles that are nontoxic and detectable in thick tissues. In their article, Daniel *et al* [8] propose an original strategy based on the design of fully organic nanoparticles to obtain biocompatible multicolor nanoparticles which can be tracked individually in biological environments.

Finally, this collection includes an extensive review dedicated to the promises of gold nanostructures, as an archetypical biocompatible optically active nanomaterial for the management of a single important pathology. In their review, Si *et al* [9], took the very interesting view point of presenting a variety of different state of the art approaches based on the use of gold nanoparticles dedicated to diabetes care in terms of sensing, drug delivery, imaging and therapy.

Acknowledgments

LC acknowledges support from the Centre National de la Recherche Scientifique (CNRS), the France-BioImaging national infrastructure (ANR-10-INBS-04-01), IdEx Bordeaux (ANR-10-IDEX-03-02), the Agence Nationale de la Recherche (ANR) (ANR-14-OHRI-0001-01 & ANR-15-CE16-0004-03). MTD acknowledges the LABEX AMADEus program (under the contract ANR-10-LABX-42). SL thanks the Robert A Welch Foundation (C-1664) and the National Science Foundation (CBET-1438634) for support.

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