Small energy for small things: plasma nanoscience for a sustainable future

Kostya (Ken) Ostrikov[1,2]

[1]*Plasma Nanoscience Center Australia (PNCA), CSIRO Materials Science and Engineering, P.O. Box 218, Lindfield NSW 2070, Australia*
[2]*Plasma Nanoscience, School of Physics, The University of Sydney, Sydney NSW 2006, Australia*
Kostya.Ostrikov@csiro.au

In this talk, I will discuss the issues related to one of the grand science challenges recently highlighted by the US Department of Energy on *nanoscale control of energy and matter.* This grand science challenge is related to the grand societal challenge related to *a sustainable future.* Plasma Nanoscience-based research related to the challenges that are critical for renewable energy and energy-efficient technologies for a sustainable future will be the focus of this presentation [1]. I will discuss how one can approach the problem of directing energy and matter at the nanoscale using the fundamental approaches of Plasma Nanoscience [2].

The aim of this research is to discover the most effective controls for deterministic nanoscale assembly based on precise *control of matter and energy at nanoscales* under far-from-equilibrium conditions. This control includes generation and manipulation of the plasma-generated building units and their arrangement into arrays of nanostructures with the required properties using effects not available in other nanofabrication techniques.

The effects that will be considered are related to ionization, charges, electric and magnetic fields, polarization, alteration of surface energy in specified regions, etc. It will be discussed how the resulting nanoscale objects of different materials systems and dimensionalities can be produced and processed more quickly and more uniformly in size and distribution, even without using pattern delineation techniques that presently dominate in nanofabrication technologies but are rapidly nearing their physical limits. The examples will be related to quantum dots, nanotubes, nanowires, graphene, nanowalls, and other nanoparticles of desired shapes and structures, both free-standing and surface-bound.

This research is carried out in three dimensions. It allows one to relate the targeted applications, the advanced nanomaterials (carbon, silicon, metal, oxides/nitrides and hybrid nanomaterials) for these applications, and the most suitable (e.g., hot/cold, low/high-pressure, thermal/non-equilibrium, etc.) plasmas and processes to produce these materials and device elements. The results of theoretical modeling, numerical simulations, and experiments on nanomaterials synthesis, characterization and applications will be presented. It will be shown how the outcomes of this research may lead to faster, very clean, human-health-friendly, and energy-efficient nanoscale synthesis and processing technologies. Examples of advanced (e.g., smart and responsive) functional materials for next-generation devices and systems for renewable energy (e.g., solar cells, batteries, supercapacitors), environmental (e.g., gas sensing), medicine and health care (drug delivery, cancer therapies, biosensing), and human nutrition (pathogen inactivation in food, water purification) applications will be used as well.

I will also present our recent advances on the applications of low-temperature, weakly ionised gases in renewable energy technologies and cancer therapies. The examples will include precisely tailored production of nanostructured functional materials for energy conversion (e.g., photovoltaic solar cells of the third generation) and (bio-, gas-) sensing devices as well as treatment of living cells and tissues for effective cancer therapies. I will show how Plasma Nanoscience makes it possible to localize and control energy and matter at micro- and nanoscales, and how this small energy can control the formation and responses of small (non-living and living) things such as carbon or silicon nanostructures for solar cells or sensors and human hepatocellular carcinoma (HepG2) cancer cells. As mentioned above, control of energy and matter at nanoscales is an ultimate challenge that is critical for the development of renewable energy, energy-efficient fabrication, biomedical, and environmental technologies for a sustainable future. This presentation will also aim to show how physics, chemistry, biology, and related engineering disciplines can interact to produce a significant scientific and societal impact.

References:

[1] K. Ostrikov, U. Cvelbar, and A. B. Murphy, J. Phys. D.: Appl. Phys. 44, 174001 (2011).
[2] K. Ostrikov, J. Phys. D.: Appl. Phys. 44, 174003 (2011).