CeFEMA

Center of Physics and Engineering of Advanced Materials

Newsletter May 2019

Editorial

Luís Amaral
João Figueirinhas

The CeFEMA newsletter intends to be a showcase for good examples of the recent and high-quality activity in research and engineering in materials science, condensed matter physics and strongly interacting systems happening at CeFEMA. The current number features the work of four CeFEMA members working in the areas of electrochemistry and energy storage, nuclear physics and condensed matter physics, whose research is having a significant international impact in the respective fields.

A novel energy storage system for low earth orbit spacecrafts

Mónica Afonso

monica.afonso@omnidea.net

The increasing interest on low earth orbit (LEO) missions prompted the growth of the small satellites market segment. Besides telecommunication, micro satellites have recently started to be used for scientific purposes in constellations for communication or observation. This new class of small satellites is comprised by cube units. The challenge of such missions is the availability of adequate energy storage technologies onboard the small spacecraft occupying the smallest volume possible inside the units.

Omnidea Lda. Aerospace Technology is developing an electrochemical energy storage system to be combined with the electric propulsion system aiming the market segment of 20-50 kg satellites. The product corresponds to a new concept of a low cost, high performance and safe hybrid propulsion system. The device is projected to work in discharge mode during eclipse time and in charging mode during the sunlit period, furnishing electric power as well as propellant for deorbit manoeuvre.

The current project entitled "Multifunctional systems", is integrated in the "Artes competitiveness & Growth Element", European Space Agency, ESA ARTES programme. The electrochemical part is being performed using the facilities of the Materials Electrochemistry Group integrated at CeFEMA-IST in collaboration with Professor Doutor César Augusto Sequeira with whom Omnidea Lda. has a long-term agreement on scientific and technological cooperation.

Omnidea Lda is a part of the Omnidea Group constituted by Omnidea Lda. (PT), Omnidea-RTG (DE), Armilar (PT) and Pleione (GR), all dedicated to the aerospace industry. Its mission is to carry out R&D in aerospace technology and energy systems, with special emphasis on the transference of technology between these two markets. This heritage dates back to the foundation of the company initially installed in an ESA incubator.

The company has been based in Viseu, Portugal since 2006, operating on Caparica facilities of Nova University of Lisbon Engineering school and is composed of a multidisciplinary team of highly qualified professionals with comprehensive engineering backgrounds, providing solutions to the challenges inherent to the aerospace industry, namely in the development of propulsion systems, airborne platforms and advanced manufacturing technologies.

"Our mission is to contribute to the expansion of human society's frontier."

"Our society is a global system nowadays, through the universal laws of physics it tends to become homogeneous. Therefore, the only way to ensure a general growth is to keep constantly expanding the boundaries of our activity."

Nuclear Physics explains formation of elements in the Universe

Lídia Ferreira

flidia@tecnico.ulisboa.pt

The development in recent years of Radioactive Ion Beam Facilities (RIBS), lead to a new era of discoveries in Nuclear Physics. The creation of exotic nuclei far from stability allowed to observe novel phenomena, and opened the door to a domain completely unexplored [1]. New instrumentation techniques had to be implemented, and at the same time, new theoretical models had to be developed to interpret these observations, that were beyond our well established interpretation of stable nuclei.

The purpose of these studies were not only to be able to find the limits of bound matter by mapping the nuclear chart where according to theoretical estimates above 3000 nuclei, bound to proton and neutron emission, are still to be found. It was also to observe important details of their structure, used to discover how the nucleosynthesis processes for the formation of the elements in the Universe evolved [2].

The heavy elements present in Nature, were created in stellar explosions, through nuclear reactions with nuclei at the limits of stability.

In particular, the formation of the elements during the hot hydrogen burning rp process, involves nuclei at and beyond the proton drip line, and are visible in x-ray bursts.

However, there are some nuclei, the "waiting points", that due to competition with beta decay, slow down the flow of the rp process, and consequently decrease the production of heavier elements, strongly affecting the burst observables.

A recent experiment, carried out at the RIB factory of the RIKEN Nishina Center in Japan, lead to the observation of two previously unknown isotopes 72Rb and 77Zr, and measurement of their half-lives [3]. The nucleus 73Rb was too fast for the present detection apparatus to be observed, but an upper limit for the ground-state half-life could be deduced.

Both 72Rb and 73Rb nuclei, lie beyond the limits to proton stability, so, they are proton radioactive. In the case of 73Rb, it decays to 72Kr, which is a waiting point. It could be bypassed by a two proton capture reaction creating a new pathway, but this depends on the specific nuclear structure of 73Rb, which was revealed by the theoretical interpretation of the results from this experiment. The theoretical analysis has proved that 72Kr is a strong waiting point in the path of the rp process, thus helping our understanding of the formation of the elements in this region of the nuclear chart.

[1] J. Erler, et. al., Nature 486 (2012) 509-512.
[2] Thoennessen, M. & Sherrill, B., Nature 473 (2011) 25.
[3] H. Suzuki, L. Sinclair,P.-A. Söderström, G. Lorusso, P. Davies, L. S. Ferreira, E. Maglione, et al. Phys. Rev. Lett.119 (2017) 192503.

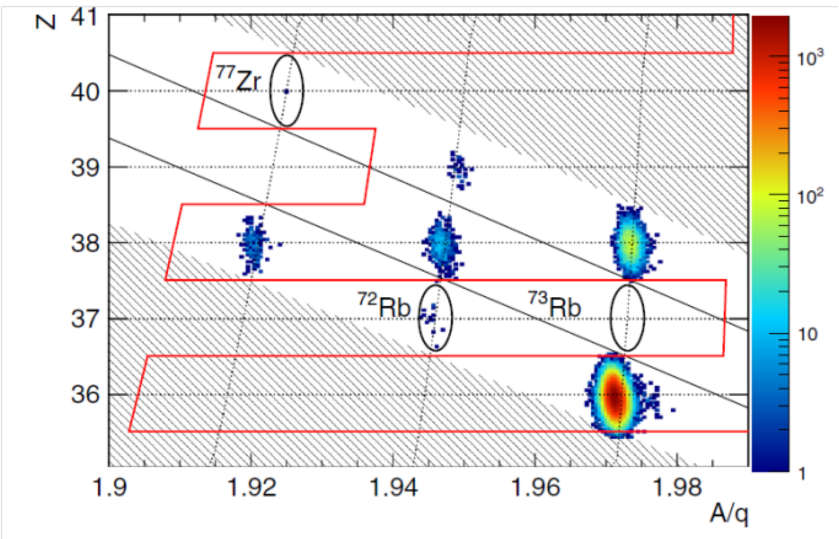


Fig 1. Discovery of 77Zr and 72Rb, from Ref 3. Proton drip-line in red.

Progress in electrochemical energy conversion and storage

César Sequeira

cesarsequeira
@tecnico.ulisboa.pt

In modern society, our lives are crucially dependent on energy and currently the dominating global energy is mainly supplied by traditional fossil fuels, e.g., oil, natural gas, and coal. However, fossil fuels are non-renewable and provide a net-emission of carbon dioxide (CO_2) into the atmosphere, which already results in visible changes of the world's climate. Owing to the excessive use of fossil fuels, ever-increasing environmental issues, and a globally growing population, there is a high demand for renewable alternatives and clean energy sources. Sunlight, wind and tidal energies are regarded as preeminent environmentally friendly, renewable energy sources, and their ability to meet people's future energy needs has been well documented. One of the challenges confronting their large scale usage is their intermittent nature, and thus a need to equilibrate their output or store the energy for later use. Given the intermittent changes by the atmospheric conditions, the development of efficient storage technologies is important to enable the growth of renewable electricity towards a situation where they can be the primary energy supply.

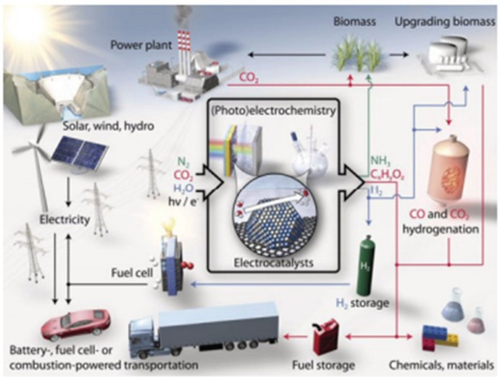
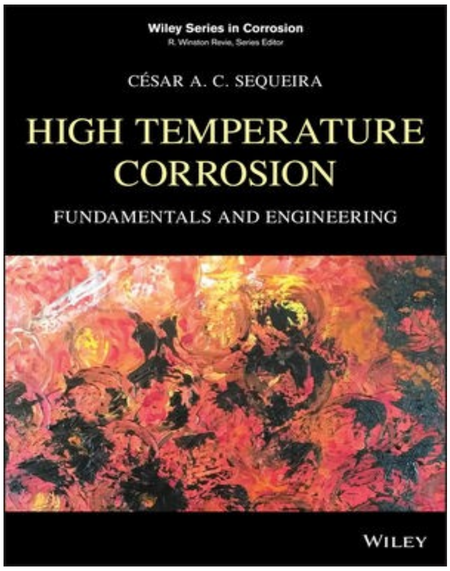


Figure 1

In this context, one perspective approach of the Materials Electrochemistry Group at CeFEMA is to develop electrochemical technologies enabling efficient conversion of molecules in Earth's atmosphere (e.g., H_2O, CO_2, and N_2) into chemical fuels (e.g., hydrogen, hydrocarbons, and ammonia) via the integration of such systems with renewable electricity.

Figure 1 illustrates the available catalytic conversion pathways for renewable fuels. The universal feedstock can be potentially converted into chemical fuels with a zero net-emission and would enable a sustainable supply of energy without any net change in the atmospheric conditions. Our group in CeFEMA studies electrocatalytic processes for energy conversion and storage, for the development of battery, fuel cell and electrolyzer devices. Our approach is focused on testing lower cost electrocatalysts with the required characteristics to split water into H_2 and O_2 [1], as well as perform CO_2 reduction [2], and BH_4^- oxidation [3] with high conversion efficiency. We have also initiated secondary studies on alcohol electrooxidation, H_2O_2 reduction for liquid fuel cells [4] organic electrosynthesis [5], solid state diffusion [6], and cancer electrochemotherapy [7], just to name a few. Šljukić and Sequeira recently published 2 books [8,9], and Sequeira is acting as Guest Editor of 3 Special Issues on "Latest progress for proton exchange membrane fuel cells", "Membrane separators for batteries and fuel cells", and "Palladium based nanoalloys for electrochemical reactions", to be published in Energies, Membranes, and Nanomaterials, respectively.

HIGH TEMPERATURE CORROSION: FUNDAMENTALS AND ENGINEERING



[1] L Amaral et al., ACS Appl. Energy Mater. 2018; 1:4731-4742
[2] MR Gonçalves et al., Electrochim Acta 2013; 102:388-392.
[3] RCP Oliveira et. al., Electrochim Acta 2018; 269:517-525.
[4] DSP Cardoso et. al., PCCP 2018; 20:19045-19056.
[5] DSP Cardoso et. al., Org Process Res Dev 2017; 21:1213-1226.
[6] CAC Sequeira, L Amaral, Trans Non-ferrous Metals Soc. China 2014;24:1-11.

[7] CAC Sequeira, DSP Cardoso, Cienc. Tecnol. Mater. 2014;26:126.
[8] IS Simatovic, BS Paunkovic. Electrochemistry theory and application, Fac Phys Chem, Belgrade, 2018, ISBN 978-86-82139-71-3.
[9] CAC Sequeira. High temperature corrosion: fundamentals and engineering. John Wiley & Sons Ltd, New York, 2019.

Perturbing topological states

Pedro Sacramento

pdss@cefema-gt.tecnico.ulisboa.pt

Concepts from topology have enabled the understanding of outstanding properties of several physical systems, including condensed matter materials. One such example is the robustness to sample geometry or effects of disorder, of the Hall conductance of a two-dimensional electronic system in the presence of a high magnetic field. Indeed, the quantization of the Hall conductance at low temperatures is associated with a topological number, the first Chern number. Other examples are the relevant role of temperature excited vortices in the Kosterlitz-Thouless transition, or the appearance of a topological term that distinguishes different types of one-dimensional spin lattices. The field has had a significant boost with the extension of topological properties to some superconducting materials and insulators. Associated with the topological properties is the appearance of edge states in a finite system, that are often robust to perturbations. These zero energy states have interesting properties such as being dissipationless and, as consequence, in topological insulators there are conducting states at the borders of the material. In the context of superconductors they are a realization of hermitian Majorana modes that braid in a nontrivial way, and have been proposed as elements for quantum computation.

Some topological properties are the result of some symmetries in the Hamiltonian, and, if the perturbations do not break those symmetries, the states are robust. In some other systems the robustness is the result of states that are strongly entangled and of long range, such that local perturbations do not change the topological nature. These arguments hold if we consider the systems in (or close to) equilibrium.

Considering perturbations that strongly deviate the system from equilibrium, may affect the robustness of the topological states. One motivation is to infer the effect of uncontrolled noise in the system. Another motivation is to understand the effect of controlled perturbations and how they may be used to induce different phases, with potential new applications. Some of the work that I have carried out has focused on different types of time perturbations on topological systems. Often sudden or aperiodic perturbations affect the edge states, but it is possible to tailor the perturbation to control their existence and even their revival. Periodic perturbations, on the other hand, lead, in some cases, to generation of nontrivial topological states, absent in the unperturbed system.

[1] Fate of Majorana fermions and Chern numbers after a quantum quench, P.D. Sacramento, Physical Review E 90, 032138 (2014).
[2] Edge mode dynamics of quenched topological wires, P.D. Sacramento, Physical Review E 93, 062117 (2016).
[3] Edge and bulk localization of Floquet topological superconductors, T. Cadez, R. Mondaini and P.D. Sacramento, Physical Review B 99, 014301 (2019).

CeFEMA
Center of Physics and Engineering of Advanced Materials

TÉCNICO LISBOA

LISBOA UNIVERSIDADE DE LISBOA

Contacts

Instituto Superior Técnico. UL
Av. Rovisco Pais, 1
1049-001 Lisboa

Office: Physics Building, 3rd floor
Telephone number: +351 218419092
cefema@cefema.tecnico.ulisboa.pt
http://cefema.tecnico.ulisboa.pt