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Pierre Braunstein

***Synthesis and Applications in Chemistry and Materials*** (ed. A. J. L. Pombeiro, K. T. Mahmudov and M. F. C. Guedes da Silva), **Series on Chemistry, Energy and the Environment**, vol. 11–14, World Scientific Publishing (March 2024): a review

Volume 27 (2024), p. 197-204

Online since: 18 September 2024

<https://doi.org/10.5802/crchim.332>

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Book review

# *Synthesis and Applications in Chemistry and Materials* (ed. A. J. L. Pombeiro, K. T. Mahmudov and M. F. C. Guedes da Silva), Series on Chemistry, Energy and the Environment, vol. 11–14, World Scientific Publishing (March 2024): a review

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**Abstract.** Critical review of four new volumes in the book series “Series on Chemistry, Energy and the Environment” (World Scientific Publishing, Singapore): *Synthesis and Applications in Chemistry and Materials*, 4 volumes, 2100 pages (March 2024). <https://doi.org/10.1142/13309>.

- Volume 11: *Metal Coordination and Nanomaterials*
- Volume 12: *Enzymatic and Organic Systems*
- Volume 13: *Metal Complex Catalytic Systems and Materials*
- Volume 14: *Biomass and Waste Valorisation, Functional Materials, Energy Conversion and Supercritical Systems*

These volumes were edited by Armando J. L. Pombeiro (Universidade de Lisboa, Portugal), Kamran T. Mahmudov (Universidade de Lisboa, Portugal) and M. Fátima C. Guedes da Silva (Universidade de Lisboa, Portugal).

**Keywords.** Chemistry, Synthesis, Materials.

*Manuscript received 2 September 2024, accepted 9 September 2024.*

The well-established series of books on “Chemistry, Energy and the Environment”, edited by Karl M. Kadish (Univ. of Houston, USA) and Roger Guilard (Université de Bourgogne, France) aims at emphasising the multidisciplinary character of chemistry and its numerous interfaces with energy- and environment-related fields. Four new volumes have recently been dedicated to the “Synthesis and Applications in Chemistry and Materials”, edited by Armando J. L. Pombeiro, Kamran T. Mahmudov and M. Fátima C. Guedes da Silva from the University of Lisbon (Portugal), Armando J. L. Pombeiro acting as the set editor. The approach followed by the editors has been to highlight research carried out in

Portugal and by international teams that have developed longstanding collaborations with Portugal. The topics cover very important and diversified areas of chemistry where progress has been particularly significant over the past 20 years. The editors have been able to collect a total of 50 chapters with 168 authors from 63 international institutions and offer an up to date and most informative panorama of chemistry and material sciences in their diversity and relevance.

Volume 11, the first in this set of four volumes deals with metal coordination and nanomaterials (480 pages). Part I focuses on the “Synthesis of metal coordination compounds and applications”

and contains 4 chapters. The first chapter, by C. Pettinari et al. from the University of Camerino (Italy), summarises in 42 pages the major achievements of the long-standing collaboration between the chemists in Camerino and their colleagues in Lisbon. It highlights their achievements in the use of scorpionates, pyrazolone and arylhydrazones of barbituric acid as ligands in coordination chemistry, and the formation of coordination polymers and metal organic frameworks. The synthesis and structural characterization of numerous metal compounds have led to interesting applications in homogeneous and heterogeneous catalysis and to the study of their antitumour and antimicrobial activity. The second chapter in this volume (31 pages), by K. T. Mahmudov and co-authors from Lisbon, deals with tetrel bonding in coordination chemistry. The authors analyse the occurrence, structural features and consequences of these weak interactions between the electron density deficient side of a covalently bonded tetrel atom (C, Si, Ge, Sn or Pb) and a nucleophilic region in the same or another molecular entity. The occurrence of tetrel bonding can have a significant impact on the structure, catalytic or physical features of the corresponding molecules. These interactions offer interesting extensions to the better-known hydrogen, halogen, and chalcogen bonds. The next chapter (30 pages) focuses on a collaboration between scientists in Lisbon and in Wroclaw (Poland) and offers a comprehensive review of the synthesis, chemical properties of copper complexes and coordination polymers bearing the well-known, water soluble monodentate, cage-like phosphine 1,3,5-triaza-7-phosphatricyclo[3.3.1.1]decane (PTA, also known as 1,3,5-triaza-7-phosphadamantane) and their applications as catalysts, in azide-alkyne cycloaddition reactions, nitroaldol condensation, and benzyl alcohol and catechol oxidation and as antitumour agents. Chapter 4 (35 pages) by M. Woźniczka and M. Swiatek (Medical University of Lodz, Poland) deals with cobalt complexes of hydroxamic acids, reduced Schiff base ligands and their solution behaviour. The study of equilibria in solution as a function of pH is relevant to the bioactivity of the complexes.

Part II in volume 11 deals with “Polynuclear Metal Assemblies, MOFs and Applications”. It begins with Chapter 5 (30 pages) on “Photoluminescent MOF sensors: on the road to cancer diagnostics” and is

written by F. Figueira et al. from the University of Aveiro (Portugal). Photoluminescent Metal-Organic Frameworks have emerged as promising candidates for the development of sensors capable of detecting cancer biomarkers with high sensitivity and selectivity. This chapter reviews the various strategies reported in the literature for the synthesis and modification of photoluminescent MOFs and their role in sensing cancer biomarkers. The following chapter (28 pages) by M. Aureliano from the University of Algarve (Portugal) is a joint effort with co-authors from this university, the National Institute of Technology Karnataka in Bangalore (India), the Algarve Biomedical Centre Research Institute in Faro (Portugal), the Champalimaud Centre for the Unknown in Lisbon and the University of Vienna (Austria). It summarizes the structures, catalytic applications, antimicrobial and anticancer activity of polyoxovanadates, with a special emphasis on decavanadates which are the most studied polyoxovanadates in biology. Chapter 7 (42 pages) by D. S. Nesterov from the University of Lisbon, deals with “Heterobimetallic Polynuclear Complexes: Synthesis from Zero-Valent Metals or their Oxides, Magnetic and Catalytic Applications”. The syntheses and structures are clearly organized as a function of the nuclearity of the metal complexes and this is followed by a summary of their magnetic and catalytic properties, the latter being focused on alkane oxidation with  $H_2O_2$  and with *m*-chloroperoxybenzoic acid. The following chapter (35 pages) by A. J. L. Pombeiro and co-authors from the Russian Academy of Sciences in Moscow (Russia), the University of Russia in Moscow, the University of Lisbon, the Baku State University (Azerbaijan) and covers the “Synthesis, Structure and Catalytic Application of Cage Metallasilsesquioxanes”. These molecules display a range of architectures and possess interesting magnetic and photophysical properties; they have found numerous applications in catalysis and material sciences where they can be used as precursors to hybrid materials and composites. They can also be associated with additional P,P- or N,N-ligands, which impact their structures and catalytic properties, such as the homogeneous oxidation of organic compounds and the tandem oxidation or amidation of benzyl alcohol with primary and secondary amines to yield benzamides. As part of a collaboration between the Universities of Lisbon and Peoples’ Friendship University of Russia (RUDN) in

Moscow, Chapter 9 (32 pages) by A. Paul et al. addresses hydrothermal and solvothermal methods in MOF chemistry. This field of research has grown considerably over the years and the authors have rightly focused on selected aspects, such as the synthesis and structure of MOFs of different dimensionalities containing Zn(II), Cu(II), Co(II), Ni(II), Cd(II), Cr(III), Fe(III), Al(III), Ln(III) and Zr(IV) ions, and the influence of solvents, temperature, reagents stoichiometry and pH.

Part III in this volume is dedicated to Nanomaterials. Chapter 10 (56 pages) provides a detailed account on the use of “Gold nanoparticles as a tool for combinatorial nanomedicine”. P. V. Baptista and co-authors from various institutions in Lisbon highlight significant, recent advances made in this field of growing importance and all the benefits of gold nanoparticles in cancer medicine, although several issues remain to be solved before their large-scale use can be envisaged in cancer diagnosis and therapy. Chapter 11 (24 pages) presents applications of “Gold- and silver-based catalysts for liquid-phase selective oxidation of alcohols” and reports investigations carried out in Tomsk (Russia) and Lisbon by E. Pakrieva et al. In addition to their size, the nature of the support and the composition of the nanoparticles in the case of binary systems play a major role in the catalytic performances. The last chapter in this volume (76 pages) deals with “Sustainable redox catalysts with molybdenum complexes and nanoparticles” and reports joint efforts by C. D. Nunes and co-authors from the universities of Lisbon and Reading (UK). Experimental data are analysed in combination with DFT studies. The mechanisms of the catalytic oxidation of alkenes are discussed and the results include the direct use of molecular precursors, their immobilization on MCM-41-type supports, which can result in improved enantioselectivity, and the properties of MoO<sub>2</sub> and MoO<sub>3</sub> nanoparticles. A section is devoted to the electrochemical reduction of CO<sub>2</sub> to CO and examines the mechanisms related to the use of Mo(II) or Mo(0) precursor complexes. The photo-assisted electrocatalytic conversion of CO<sub>2</sub> is considered as a promising research area.

Volume 12 (460 pages) in this set deals with enzymatic and organic systems and contains two parts: Part IV contains 3 chapters on enzymatic and related systems and materials and Part V, with 8 chapters, deals with organic synthesis and applications.

Chapter 13 (35 pages) by L. B. Maia et al. from Lisbon deals with “Molybdenum enzymes: an unexploited biotechnological treasure and a challenge for medicine” and details the use of molybdenum in biology, landscapes for molybdoenzymes biotechnological applications and molybdoenzymes and human health disease. In particular, the enzymes belonging to the sulfite oxidase, xanthine oxidase, dimethylsulfoxide reductase and nitrogenase families are discussed. Promising perspectives are identified in these important areas. In the next chapter (40 pages), L. Cerofolini, C. F. G. C. Geraldes and co-authors report results obtained in the framework of a collaboration between Universities in Florence (Italy), Coimbra (Portugal) and Lisbon on “Paramagnetic NMR of transition metal derivatives of human carbonic anhydrase: implications for enzyme catalysis and sustainability”. The authors illustrate the application of NMR tools in the structural and dynamic characterization of the enzyme active site, often complementing results obtained from single crystal X-ray diffraction analysis. Chapter 15 (31 pages) by M. M. Q. Simões et al. from Aveiro and Porto (Portugal), discusses “Metalloporphyrins as oxidative catalysts: synthesis of high-value-added compounds” and details the use of *meso*-pentafluorophenylporphyrin and derivatives as oxidation catalysts under homogeneous and heterogeneous conditions, the oxidation of organosulfur compounds, of indole and benzofuran derivatives of industrial significance and the immobilisation of porphyrin catalysts. This comprehensive contribution highlights several strategies that were developed to improve the activity and robustness as well as the recyclability or water solubility of the catalysts.

Part V begins with a presentation in Chapter 16 (47 pages) by P. S. M. Amado et al. from universities in Algarve, Faro, Liverpool (UK) and Lisbon, of the various catalysis-based methodologies applied to the synthesis of nonsymmetrical 1,2,4,5-tetraoxanes and of bridged 1,2,4,5-tetraoxanes, both families having a considerable relevance in medicinal chemistry. In Chapter 17 (23 pages), A. J. Burke and A. Moutayakine from various institutions in Evora, Coimbra (Portugal), and Islas Canarias (Spain), discuss “Catalytic routes to 1,2,3-triazoles: new developments and applications”. Access to these molecules, which find applications in several areas, in particular in drug discovery, was based on click-chemistry approaches

involving initially Huisgen's cycloaddition reaction. Innovations in the biomedical fields, in supramolecular chemistry and electronic chemicals are also detailed. In Chapter 18 (33 pages), F. Siopa and C. A. M. Afonso, from the Faculty of Pharmacy in Lisbon, show that pyridinium salts are valuable synthetic building blocks to access, by photochemical activation, bicyclic aziridines and aziridine-beta-hydroxycyclopentanones of relevance in particular in the medical sector. Applications to total synthesis are also mentioned. The "Metal-based synthesis of flavonoid-related compounds" is discussed in Chapter 19 (56 pages) by V. L. M. Silva et al. from Aveiro and Oviedo (Spain). Flavonoids are a family of polyphenolic metabolites that can be found in plants and fruits and are endowed with low toxicity and unique mode of physiological action. The authors provide a detailed analysis of metal-promoted reactions and metal-catalysed reactions giving access to the synthesis of such compounds and allowing further studies on structure-activity relationships. In Chapter 20 (56 pages) A. M. de Matos and A. Pilar Rauter from the University of Lisbon discuss "Catalytic processes towards the synthesis of sugar-based molecules with therapeutic interest" and nicely illustrate the efficiency of catalysis to produce such molecules, in particular for addressing stereoselective reactions. It is significant that improved catalysis-based synthetic routes have been developed for oseltamivir (the so-called Tamiflu), remdesivir, the first antiviral approved for COVID-19 treatment, and the C-glucoside drugs approved for the treatment of diabetes type 2, the gliflozins. Natural methacrylate polysaccharides and proteins form a versatile group of modified macromolecules and in the next Chapter (28 pages), D. H. A. Rocha and J. F. Mano from the University of Aveiro present an overview of "Methacrylated natural macromolecules as precursors of hydrogels for biomedical applications", such as tissue engineering, therapeutic delivery, and stem cells modulation. Chapter 22 (43 pages) by C. D. Maycock and M. R. Ventura from Lisbon describes "Approaches to asymmetric compounds using natural products". They discuss the use of quinic acid, tartaric acid, the synthesis of carbohydrates and access to autoinducer-2 (AI-2), which is produced by phylogenetically distinct bacteria, and analogues. Clearly, a constant effort is needed to develop asymmetric multistep organic synthesis, an important sector to the pharmaceutical

industry. The last chapter in this volume is Chapter 23 (45 pages), by A. M. M. Faisca Phillips from the University of Lisbon, which deals with "Enantioselective organocatalysis in the synthesis of phosphonates". Some phosphonates are endowed with important biological activities, and are used as antiviral compounds, as antibiotics, for the treatment of bone diseases and as radiopharmaceuticals, just to name a few applications in the medical sector. They are also used as agrochemicals and in polymeric materials. Their synthesis can be achieved through various steps and the author nicely details their formation resulting from carbon-phosphorus or carbon-carbon bond formation. Applications of organocatalysis to phosphonate chemistry is growing.

Volume 13 (373 pages) in this set is entitled "Metal complex catalytic systems and materials" and contains two parts. Part VI deals with "Metal complexes and supported materials" and begins with Chapter 24 (42 pages) in which K. V. Luzyanin and M. A. Kinzhalov from the Universities of Liverpool (UK), Lisbon, St Petersburg and Tomsk (Russian Federation) discuss "Enabling catalytic applications of aminocarbene ligands through rational design". Carbene ligands are increasingly applied in homogeneous catalysis because of the relatively easy tunability of their electron-donor and steric properties. This chapter focuses on the use of acyclic diaminocarbenes and the catalytic applications of their metal complexes, in particular of palladium, platinum and gold, for a number of important transformations. Chapter 25 (31 pages) by P. T. Gomes and colleagues from Lisbon is entitled "Catalysis with earth-abundant metal complexes of iminopyrrolyl ligands" and features the main catalytic achievements and considerable potential of such complexes in alkene polymerization, hydrofunctionalization and azide-alkyne cycloaddition. The authors also provide mechanistic insights and structure-reactivity relationships that should open the way for further developments. The next Chapter (54 pages) by M. N. M. Milunovic et al. from the University of Vienna (Austria) and the University of Lisbon, deals with "Oxidation, hydrocarboxylation and cross-coupling reactions catalysed by transition metal complexes with macrocyclic and related open-chain carbonyl and carboxylate ligands". The search for efficient and environmentally friendly methods to catalytically functionalize C-H, C-OH and C-C bonds

represents a very active field of modern research, because such reactions are part of most important processes in nature and in industry. In this context, the authors explore the efficiency of various transition metals such as Fe, Cu, Zn, Mn, Ni, V, Pd and Co to achieve these important targets. They focus on the oxidation of alkanes, the oxidation of primary and secondary alcohols and the hydrocarboxylation of linear and cyclic alkanes, as well as on carbon-carbon cross coupling reactions, such as Suzuki-Miyaura, Henry and Knoevenagel condensation. In Chapter 27 (40 pages), A. M. Trzeciak from the University of Wrocław (Poland) provides an account on “Palladium complexes with non-phosphorus ligands as catalysts of Suzuki-Miyaura coupling”. This reaction is commonly used in industry for the production of biaryl compounds involved in pharmaceuticals, natural products and agrochemicals. The nature of the pre-catalyst is discussed as a function of its nuclearity, oxidation state as well as of the ancillary ligands that allow a fine-tuning of the properties of the palladium centre. Among the non-phosphorus ligands used, *N*-heterocyclic carbenes play an increasing role and are included in this chapter. Zeolite-embedded metal complexes have been used for numerous catalytic applications and Chapter 28 (33 pages) focuses on “Zeolite-encapsulated metal complexes towards sustainable catalysis”. After a brief overview of zeolite-*Y*-encapsulated transition metal complexes, the authors B. K. Kundu and S. Mukhopadhyay from the University of Cincinnati (USA) and the Indian Institute of Technology Indore (India) discuss the design of intrazeolite complexes and their use as sustainable catalysts, in particular in oxidation and asymmetric catalysis. Chapter 29 (48 pages) discusses “The role of heterogeneous catalysts in C–H and C–OH activation” and the authors, M. A. Andrade et al. from the University of Lisbon begin by describing the most used supports and detail major achievements in these two classes of catalytic reactions. Diverse user-friendly heterogeneous materials have emerged as supports for metal complexes, which facilitates the development of recyclable catalysts featuring a broad substrate scope. Emphasis is rightly placed on the high selectivities that could be achieved with these systems. In Chapter 30 (21 pages), L. Kustov and coll. from Moscow (Russian Federation) discuss the “Ring opening of mono- and polycyclic hydrocarbons” in the context

of increasing the cetane number of diesel fuels. Platinum, rhodium, iridium and ruthenium catalysts deposited on various carriers are used for these reactions. The size of the metal particles and the occurrence of strong metal-support interactions are critical for the selectivity of such ring opening reactions.

The second part of this Volume 13, Part VII, is dedicated to the activation of unsaturated molecules. It begins with Chapter 31 (30 pages) on the “Uranium chemistry based on a bis(aryloxy) cyclam ligand: a synthetic pursuit to activate relevant unsaturated molecules”. L. Maria et al. from the University of Lisbon and the Lawrence Berkeley National Laboratory (USA) discuss first the synthesis and properties of bis(aryloxy) cyclam uranium(III) and uranium(IV) complexes, then the activation of saturated N–N bonds, the activation of oxygen-transfer reagents, the activation of carbon dioxide and the covalency in uranium–ligand multiple bonds, analysed by <sup>15</sup>N NMR spectroscopy and computational studies. Combining synthetic, spectroscopic and computational approaches provides great opportunities for the development of this research field. In Chapter 32 (36 pages), S. Weber et al. from the Universities of Vienna (Austria) and Lisbon discuss the development “From stoichiometric textbook reactions to catalytic applications of manganese carbonyl alkyl complexes”. Stoichiometric reactions such as carbonylation, reactions with various nucleophiles and cyclometallation are examined first. The catalytic transformations discussed include hydrogenation and hydrofunctionalization reactions, demonstrating the potential of this earth-abundant metal in catalysis. The last chapter in this volume, Chapter 33 (33 pages) by M. Sutradhar et al. from the University of Lisbon and Peoples’ Friendship University of Russia (RUDN) (Russian federation) discuss collaborative efforts towards the “Conversion of volatile organic compounds to useful building blocks by mild catalytic oxidation”. The transformation of toxic volatile organic compounds, such as toluene, xylene, ethylbenzene, styrene and *n*-hexane, into valuable oxygenated products by selective oxidation, constitutes an area of high current interest. Such transformations can be achieved using both homogeneous and heterogeneous catalysis.

Volume 14, the last in this set of four volumes, covers in more than 700 pages the important topics of “Biomass and waste valorisation, functional

materials, energy conversion and supercritical systems”, and the chapters are distributed in six parts. Part VIII, dedicated to biomass valorisation, begins with Chapter 34 (60 pages), by R. Bertani and co-authors from the Universities of Lisbon, Padova and Palermo (Italy), which provides an overview of “Bioenergy in Portugal” and comparisons with the situation in Italy. It includes a literature survey of the valorisation of selected biomasses and the utilisation of green metrics for a better evaluation of greener treatment methods and sustainability issues. Chapter 35 (48 pages) by M. M. Antunes and A. A. Valente from the University of Aveiro, deals with “Zeolitic catalysts for carbohydrate biomass-related conversion processes”. The increasing use of sustainable vegetable biomass conversion processes owes much to recent developments based on heterogeneous catalysis. This chapter discusses the conversion of saccharides to furanics and derivatives, synthetic strategies towards modified zeolites, publication records on zeolites/zeotypes, and selective reactions of carbohydrates/furanics over zeolites/zeotypes.

Part IX in this volume is dedicated to the increasingly relevant topic of “Plastic waste valorisation and degradable materials” and begins with Chapter 36 (24 pages) dedicated to “Heterogeneous catalysis in the circularity of plastic”. M. A. N. D. A. Lemos and coauthors from Lisbon discuss in particular the pyrolysis of plastic waste, the catalytic pyrolysis of polyolefins, the catalytic co-pyrolysis of polyolefins in crude oil refinery context and the catalytic upgrading of pyrolysis oils. In Chapter 37 (30 pages), A. C. Fernandes from the University of Lisbon, discusses “Catalytic advances in the valorization of biomass resources and plastic waste”. Important methodologies already exist for the valorisation of biomass resources and plastic waste, but further research is needed in order to develop a bio-based economy. “Hydrocracking of plastics: a pathway for chemical recycling” is discussed in Chapter 38 (48 pages) by C. S. Costa et al. from Lisbon. This technology appears most promising for the conversion of plastic waste into high-quality liquid fuels and other value-added chemicals. The authors examine the chemical recycling routes available and the hydrocracking process as a pathway for plastic waste management. In Chapter 39 (96 pages), W. Zhang and W.-H. Sun from the Beijing Institute of Fashion Technology and the Institute of Chemistry of the Chinese

Academy of Sciences in Beijing (China), respectively, discuss “Progressive metal complex catalysts for ring-opening polymerization of cyclic esters”. The ring opening polymerization of biorenewable monomers can lead to advanced and biodegradable polyesters for sustainable applications. This chapter nicely illustrates the recent progress in using as catalysts metal complexes decorated with auxiliary ligands allowing a fine-tuning of their properties. The ongoing search for suitable catalysts allowing the ring-opening polymerization of cyclic esters is triggered by the desire to replace stannous octoate widely used in industry despite of its toxicity. In this chapter, the sections describing the use of alkali metal complexes, alkaline earth metal complexes, group 13 and 14 metal complexes as well as transition metal complexes as precatalysts are clearly organised according to the nature of the donor atoms and denticity of the ligands.

Functional materials are the subject of Part X, which contains three chapters. “Functional Polymer based nanostructured materials” are examined in Chapter 40 (55 pages) by J. P. Farinha et al. from the University of Lisbon. Functional nanostructured materials possess a wide range of applications and controlling the size and architecture of the polymer chains is of considerable relevance. This chapter details the controlled synthesis and assembly of functional polymer chains, the role of polymer nanoparticles, from building blocks to nanocarriers, as well as silica-polymer hybrid nanoparticles. Despite the advances made over the past few years in this area, a number of challenges remain to be overcome, which should be the subject of future research. Chapter 41 (29 pages) examines “Luminescence in tetra-coordinate boron complexes of iminopyrrolyl ligands.” P. T. Gomes and co-authors from Lisbon and Thanjavur (India) examine the effect of *N*-aromatic and *N*-aliphatic groups on the luminescent properties, the impact of extending  $\pi$ -conjugation, the properties of 5-substituted iminopyrrolyls, the internal heavy-atom effect and that of co-ligands on the luminescent properties of the materials, including their applications to OLEDs. In the last chapter in Part X, Chapter 42 (38 pages), S. S. Balula and co-authors from the University of Porto discuss “Clever strategies to broaden polyoxometalate functionalities: from molecular units to hybrid composites.” Their work has resulted in structural modifications,

modulation and functionalization of discrete units in transition metals- and lanthanides-containing polyoxometalates, depending on the targeted applications. The incorporation of polyoxometalates into porous solid materials represents a successful approach towards improved stabilisation. The properties of porous metal organic frameworks and their advantages over traditional organic or inorganic supports are discussed.

Part XI is dedicated to photocatalytic materials and contains three chapters. Chapter 43 (40 pages) deals with the “Sustainable synthesis of oxides for electronics and photocatalysis” and emphasises the advantages of solution-based synthesis methods since they provide a versatile access to metal oxide nanomaterials with properties tailored for specific applications. The authors, R. Branquinho et al. from the NOVA University in Lisbon at Caparica, detail successively the solution synthesis of oxide materials, the solution combustion synthesis of oxides and the hydrothermal synthesis of oxide nanostructures. The outstanding properties of optical semiconductors used as photocatalyst have led to significant progress in photocatalytic synthesis and these and related aspects are discussed in Chapter 44 (34 pages): “Sustainable photocatalytic synthesis assisted by optical semiconductors”, by M. J. Samaio et al. from the University of Porto. The characterization of photocatalysts is first examined, followed by photocatalytic organic synthesis and photocatalytic process intensification. Despite all the recent progress made, large scale applications remain challenging and will require further research. Considering the presence of various antibiotics, such as oxytetracycline, in the aquatic environment and the associated risks, Chapter 45 (16 pages) by M. J. Nunes, J. A. Casas and co-authors from Covilhã (Portugal) and Madrid (Spain) adequately addresses the “Heterogeneous Fenton-like degradation of oxytetracycline by titanium-doped  $\text{SrFeO}_3$ ”. This catalyst appears to be promising since it can be reused after 3 cycles without loss of performances.

Part XII in this volume is dedicated to energy storage and conversion and begins with Chapter 46 (31 pages) on “Biomass derived carbon materials for sustainable energy storage and conversion”. The authors, N. Rey-Rapp et al. from the Universities of Oviedo (Spain) and Porto and the Academy of sciences in Lisbon, provide an overview of the most

promising strategies towards biomass-derived carbon materials with highly efficient performance in energy applications, such as supercapacitors and fuel cells. The “Electrochemical synthesis of porous materials for catalysis” is examined in Chapter 47 (47 pages) by M. F. Montemor et al. from the University of Lisbon. The catalytic applications examined include fuel cells,  $\text{CO}_2$  reduction and the degradation of persistent organic pollutants.

In Part XIII of this volume, supercritical fluid systems are examined, and Chapter 48 (32 pages), by A. V. M. Nunes et al. from Lisbon, discusses “Supercritical  $\text{CO}_2$  as green solvent for sustainable synthesis and catalysis”. Supercritical  $\text{CO}_2$  is considered as an alternative for harmful organic solvents in chemical reactions and this chapter emphasises the importance of phase behaviour and how the unique properties of supercritical  $\text{CO}_2$  can be successfully applied in process intensification strategies. Chapter 49 (22 pages) by L. C. S. Nobre et al. from Lisbon further explores supercritical fluids and offers an overview of recent advances in “Catalysts preparation: a supercritical route”. Despite the growing importance of supercritical fluids, it is fair to say that commercial and industrial applications of supercritical fluid processes for micronization are still limited, in particular owing to the equipment cost. The final chapter of this volume, Chapter 50 (33 pages) by B. P. Nobre et al. from Lisbon, deals with “Supercritical fluid extraction of compounds from microalgae and aromatic plants”. Green extraction processes should make minimum use of toxic solvents, reduce waste production, avoid the presence of toxic solvents in the final product and optimize energy consumption. Supercritical fluid extraction offers such characteristics, and the authors highlight the advantages of using supercritical fluid extraction of valuable compounds from microalgae and of volatile oils from various plants and herbs.

This set of 4 volumes on the “Synthesis and Applications in chemistry and materials” is outstanding in many respects. It offers very well organised, concise and updated information on an impressive diversity of topics of current scientific and societal relevance. These volumes should be made available to Master and PhD students as well as researchers interested in the numerous fields covered and also seeking sources of updated information and references in scientific areas close to their own. The chapters are grouped in a very coherent and rational manner and



are all organised according to a common scheme. The clarity, quality and consistency of the drawings, schemes and figures is remarkable, and the length of the chapters make them very enjoyable to read. Each volume begins with a detailed table of contents and finishes with a most useful index. The editors of this set should be warmly congratulated for having gathered such the collection of outstanding authors, all specialists in their own field, who have produced critical surveys of much interest to a very large scientific community. This set furthermore highlights the numerous, remarkable and often longstanding collaborations between Portuguese and foreign scientists and these scientists should be congratulated for their remarkable endeavour and achievements.

Prof. Pombeiro's constant and well-known enthusiastic commitment to chemistry and the scientific community is reflected on this occasion not only in his role as the set editor, but also as co-author of no less than 6 chapters. Finally, the publisher, World Scientific, should be also congratulated for a very high-quality production.

### **Declaration of interests**

The authors do not work for, advise, own shares in, or receive funds from any organization that could benefit from this article, and have no affiliations other than their research organizations.