11-18-2020

Editorial: Carbon- and Inorganic-Based Nanostructures for Energy Applications

Federico Cesano

Jasim Uddin
The University of Texas Rio Grande Valley

Yuanbing Mao
The University of Texas Rio Grande Valley

Muhammad N. Huda
University of Texas at Arlington

Recommended Citation

Cesano F, Uddin MJ, Mao Y and Huda MN (2020) Editorial: Carbon- and Inorganic-Based Nanostructures for Energy Applications. Front. Mater. 7:609576. doi: 10.3389/fmats.2020.609576 frontiers in Materials

EDITORIAL
published: 18 November 2020
doi: 10.3389/fmats.2020.609576

Editorial: Carbon- and Inorganic-Based Nanostructures for Energy Applications

Federico Cesano[1]*, *Mohammed Jasim Uddin*[2], *Yuanbing Mao*[3] *and Muhammad N. Huda*[4]

[1]Department of Chemistry, NIS (Nanostructured Interfaces and Surfaces) Interdepartmental Centre and INSTM Centro di Riferimento, University of Turin, Turin, Italy, [2]Photonics and Energy Research Laboratory, Department of Chemistry, The University of Texas Rio Grande Valley, Edinburg, TX, United States, [3]Department of Chemistry, Illinois Institute of Technology, Chicago, IL, United States, [4]Department of Physics, The University of Texas at Arlington, Arlington, TX, United States

Keywords: nanostructures, nanomaterials, nanocarbons, inorganic nanostructures, low-dimensional materials, energy materials

Editorial on the Research Topic

Carbon- and Inorganic-Based Nanostructures for Energy Applications

The transition from fossil fuels to sustainable energy sources needs more efficient materials and improved technologies. Traditional materials (either pristine or combined to form composites) are restricted by their low efficiency, low performance, short durability, environmental issues, high production costs, and narrow spectrum of applications. In recent years, the research in the field of materials for energy applications has been very active as documented by the number of scientific contributions that is trending with exponential growth (**Figure 1A**).

Furthermore, from a subject area standpoint, the field of "*energy materials*" is very broad and its relevant research is a multidisciplinary and multifaceted activity. For example, the subject area can range from the materials for nuclear reactors harnessing nuclear energy to the materials for chemical energy storage. Even, the safety materials for energy technologies can also be considered as "energy materials." Consequently, an issue on "*energy materials*" may include basic and fundamental scientific studies to more applicative contributions, which are comprised in a wide variety of applications (**Figure 1B**).

For this reason, it is quite difficult to provide a complete overview over the materials for energy. From the operational point of view, materials for energy conversion, transport and storage are typically included. Topics are manifold, multifaceted, and sometimes very diverse. For example, the field of the electrical energy storage is very far from fuel storage. In any case, a very wide and transversal viewpoint in a specific field can make available a remarkable innovation. As a rule, a look must always be directed towards new materials, fabricated experimentally (Uddin et al., 2014), or predicted theoretically (Sarker et al., 2013) and their properties (Zhang et al., 2019). For example, very recently the concept that uses the earth as a heat source and the night sky as a heat sink, known as thermoradiative photovoltaics, has been illustrated (Raman et al., 2019; Deppe and Munday, 2020). Materials for such devices will need a strong absorption and emission in the thermal radiation range, enough transparency to permit optical access to the night sky. Such materials have the potential to revolutionize the photovoltaics technology. Another look must always be oriented towards new characterization techniques and innovative investigation methods. For example, in the specific field of lithium (Li)-ion batteries, the machine learning assisted statistical analysis together with experiment-informed mathematical modelling have been shown very recently by Jiang et al. (2020). The authors have correlated the degree of particle detachment cathodes with the charging rate and particle sizes. Alternatively, X-ray nano-computed tomography dual-scan superimposition technique has been adopted by (Lu et al., 2020) to shed light on microstructural heterogeneities. The method has the potential to determine how the performance of the Li-ion batteries is affected under high rate conditions.

OPEN ACCESS

Edited by:
Emilia Morallon,
University of Alicante, Spain

Reviewed by:
José Rodríguez-Mirasol,
University of Malaga, Spain

***Correspondence:**
Federico Cesano
federico.cesano@unito.it

Specialty section:
This article was submitted to Carbon-Based Materials, a section of the journal Frontiers in Materials

Received: 23 September 2020
Accepted: 23 October 2020
Published: 18 November 2020

Citation:
Cesano F, Uddin MJ, Mao Y and Huda MN (2020) Editorial: Carbon- and Inorganic-Based Nanostructures for Energy Applications. Front. Mater. 7:609576. doi: 10.3389/fmats.2020.609576

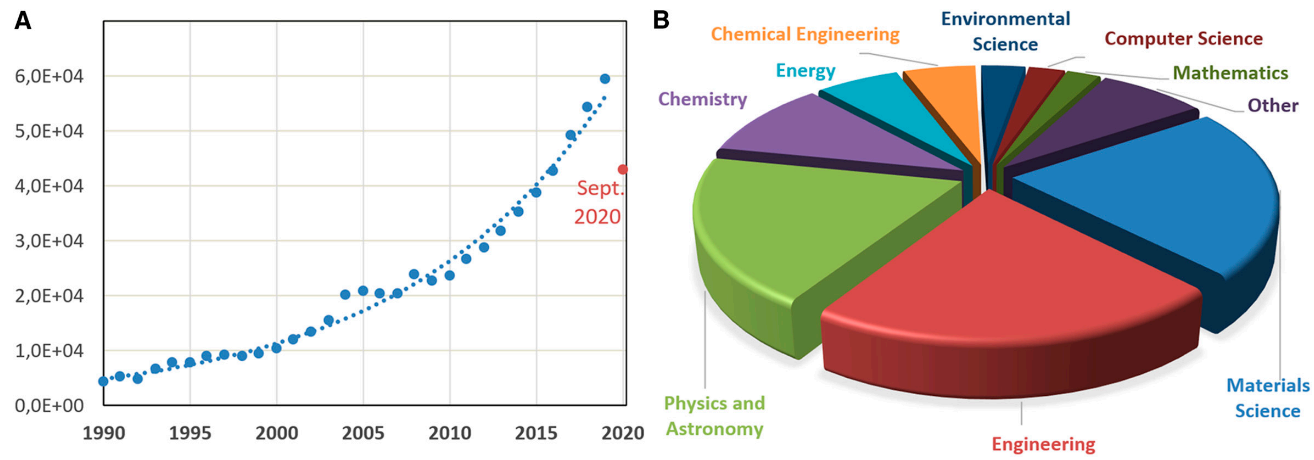

FIGURE 1 | Number of documents (keywords: Energy AND Materials, source: Scopus) published in the last 30 years **(A)**; Subject areas of scientific contributions dedicated to energy materials **(B)**.

The present article collection, composed of six research articles and three reviews, showcases some of the latest achievements and future perspectives in the field of the carbon-based and inorganic materials that are being designed to meet some of our energy challenges. In the present article collection, the attention to the environment is a common perspective, due to preparation methods adopted from natural resources, polymers and the attempt to minimize (or replace) metals for a more sustainable development of technologies. Cesano et al. reviewed the topic of *metal-free* conductors based on macrosized and nanoscale carbons (i.e., carbon fibers, carbon nanotubes, graphene) from the viewpoint of the electrical and thermal conductivity for electronic and electrical wiring applications. Specifically, CNTs and graphene can be assembled into macroscopic fibers, yarns and ropes to be used as conductors (Akia et al., 2017; Jang et al., 2020). From the perspective of replacing metals, which are present in nature with limited amounts, the role played by the chemistry in helping to exceed the electrical conductivity of metals by means of the molecular-level control and doping, is emphasized. The contribution helps to elucidate most recent results in the field, and envisages new directions and potential applications. Jangir et al. designed and fabricated a bio-hybrid electrode, which integrates Li, sulfur, and molybdenum in a nitrogen-doped reduced graphene oxide (NDRGO) matrix of biological origin. The obtained composite material works as an electrode, based on concepts of "*embedded redox couples*" and "*induced electron transfer*," behaving as a supercapacitor. Wu et al. reviewed MnO_2/carbon composites for supercapacitors from the viewpoints of the synthesis and of the electrochemical performance. Along with this broad theme, MnO_2 has emerged as one of the most promising electrode materials for its specific capacitance, wide potential range, high electrochemical activity, and environmental friendliness. In addition, due to their low electrical resistances, significant thermal stabilities, large specific surface areas, and porosities, carbons are ideal materials to be compounded with MnO_2. The authors show the latest findings on MnO_2/carbon supercapacitor electrodes, focusing on the fabrication strategies and the electrochemical performance influencing factors, with an outlook on the possible development directions in future for designing high-performance materials. Kulandaivalu et al. reviewed the subject of the layered double hydroxide (LDH)/carbon nanocomposites containing Ni^{2+} and $Co^{2+/3+}$ for supercapacitor applications. The combination of Ni-Co LDHs with carbon-based materials gives a remarkable improvement in the specific energy, specific capacitance, and specific power performance of supercapacitors. The authors explore important factors influencing the synthesis of LDHs and the correlation among morphology, structure, and electrochemical performances of the Ni-Co LDHs. Improvements needed to increase the performance of these new supercapacitors are also provided. Kumar et al. synthesized hexagonal copper phosphide (Cu_3P) platelets by chemical vapor deposition technique and incorporated it in the highly conducting 3D graphene scaffold, leading to the formation of Cu_3P/graphene hybrid to be used as supercapacitors with high Coulombic efficiency. The fabricated asymmetric supercapacitor using Cu_3P/graphene hybrid on graphite as cathode and activated carbon on graphite as anode showed high specific capacity, energy density, remarkable power density and an excellent cycle life. Li et al. fabricated spinel Li manganese oxide ($LiMn_2O_4$) in Li-ion battery. The authors observed improved stability even at elevated temperature with the addition of 1, 3-propane sultone working as an electrolyte additive compared to the cell without additive. On the other hand, Gouda et al. fabricated membrane electrode assembly in the proton exchange membrane fuel cells using graphene materials obtained from the thermal dissociation of polyethylene terephthalate, working as catalytic electrodes, and a ternary polymer blend (i.e., polyvinyl alcohol, polyethylene oxide, and polyvinyl pyrrolidone). The authors then investigated the effect of gas diffusion layers and the number of catalyst layers in three types of membrane electrode assemblies. Alternatively, semiconductor nanowires have the potential to reduce costs and increase the efficiency of the devices. On this topic, Zayas-Bazán et al. prepared CdS nanowires utilizing the chemical vapor deposition technique and Bi nanoparticles working as a catalyst. The authors proposed a solar cell configuration, in which CdS nanowires operate as windows material (or even as absorber) in hybrid solar cells, like Quantum Dots Dye Sensitized Solar Cell, CdTe, or colloidal CdSeTe. Perovskite oxides are an important and effective class of mixed oxides which play a significant role in the fields of energy conversion, transport, and storage systems. For active electrocatalysts as water electrolysis to meet the demands of the sustainable energy-powered economy, they are fascinating alternatives to noble metals because of their catalytic activity and cost-effectiveness. Along this line, Mao et al. developed a series of Sr^{2+}-doped cobaltite perovskite $LaCoO_3$ particles as efficient catalysts for oxygen evolution reaction (OER).

Overall, the papers published in this issue cover materials for energy. The subject is manifold, multifaceted, and sometimes very different, but we can easily conclude that the theme will have significant developments in the coming years. We truly hope that contributions published within this article collection will contribute to help to increase the value of research articles in the field of energy materials, providing inspiration for new relevant publications.

AUTHOR CONTRIBUTIONS

All authors have made a substantial contribution to the work and they approved it for publication.

FUNDING

FC acknowledges support from MIUR (Ministero dell'Istruzione, dell'Università e della Ricerca), INSTM Consorzio and NIS (Nanostructured Interfaces and Surfaces) Inter-Departmental Centre of University of Turin. YM would like to thank the support from the Illinois Institute of Technology start-up funds. MNH was supported by the National Science Foundation Award No. 1609811. MU acknowledges the generous support from US Office of Naval Research.

ACKNOWLEDGMENTS

We thank all authors, reviewers, and editors who assisted in the article collection. We thank Dr. Alexander Stephens, Dr. Emily Young and all the editorial staff who assisted the Topic Editors.

REFERENCES

Akia, M., Cremar, L., Chipara, M., Munoz, E., Cortez, H., De Santiago, H., et al. (2017). *In Situ* production of graphene–fiber hybrid structures. *ACS Appl. Mater. Interf.* 9, 25474–25480. doi:10.1021/acsami.7b07509

Deppe, T., and Munday, J. N. (2020). Nighttime photovoltaic cells: electrical power generation by optically coupling with deep space. *ACS Photon.* 7, 1–9. doi:10.1021/acsphotonics.9b00679

Jang, Y., Kim, S. M., Spinks, G. M., and Kim, S. J. (2020). Carbon nanotube yarn: carbon nanotube yarn for fiber-shaped electrical sensors, actuators, and energy storage for smart systems. *Adv. Mater.* 32, 2070034. doi:10.1002/adma.202070034

Jiang, Z., Li, J., Yang, Y., Mu, L., Wei, C., Yu, X., et al. (2020). Machine-learning-revealed statistics of the particle-carbon/binder detachment in lithium-ion battery cathodes. *Nature Commun.* 11, 2310. doi:10.1038/s41467-020-16233-5

Lu, X., Bertei, A., Finegan, D. P., Tan, C., Daemi, S. R., Weaving, J. S., et al. (2020). 3D microstructure design of lithium-ion battery electrodes assisted by X-ray nano-computed tomography and modelling. *Nature Commun.* 11, 2079. doi:10.1038/s41467-020-15811-x

Raman, A. P., Li, W., and Fan, S. (2019). Generating light from darkness. *Joule* 3, 2679–2686. doi:10.1016/j.joule.2019.08.009

Sarker, P., Prasher, D., Gaillard, N., and Huda, M. N. (2013). Predicting a new photocatalyst and its electronic properties by density functional theory. *J. Appl. Phys.* 114, 133508. doi:10.1063/1.4821429

Uddin, M. J., Daramola, D. E., Velasquez, E., Dickens, T. J., Yan, J., Hammel, E., et al. (2014). A high efficiency 3D photovoltaic microwire with carbon nanotubes (CNT)-quantum dot (QD) hybrid interface. *Phys. Status Solidi RRL.* 8, 898–903. doi:10.1002/pssr.201409392

Zhang, L., Chen, Z., Su, J., and Li, J. (2019). Data mining new energy materials from structure databases. *Ren. Sustain. En. Rev.* 107, 554–567. doi:10.1016/j.rser.2019.03.036

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.