Special Issue: Plasma Processing of Materials for Energy Conversion and Storage

The ever-increasing need for clean, sustainable energy heavily relies on approaches to convert energy from one form to another and to store it for a wide range of applications, i.e. from stationary to portable, included transportation. Plasma technology and processing are presently addressing the need for functional layers in photovoltaics, i.e. from transparent conductive oxides and anti-reflection coatings to thin film absorbers, as well as attempting to meet the challenge of high throughput, large area processing. Other sustainable technologies, instead, cope presently with the challenges of replacing high cost materials with inexpensive solutions, without hampering the device performance, as in the case of fuel cells, capacitors and Li-ion batteries. For instance, the world-wide commercialization of fuel cells is hampered by the cost of the catalytic materials and the proton-selective membrane. Designing batteries and capacitors with longer cycle life and rapid charge/discharge rates, higher specific energy and power, requires a deeper understanding of the relationship between properties and performance of materials. Advanced batteries such as lithium-ion and nickel-metal hydride offer the potential for improved performance if low-cost materials can be developed. In this framework, we are strongly convinced that plasma technology can play an important role, just as in the field of photovoltaics.

This special issue intends to report on the state-of-the-art research trends in the field of plasma processing of materials for energy conversion and storage. Major breakthroughs in the field are highlighted and discussed, and the factors limiting its exploitation as key enabling technology are identified. The issue presents a series of original papers and reviews on plasma processing of materials for different energy applications including photovoltaics, fuel cells, batteries and photocatalysts for solar fuels.

The review from Baurt reports on recent advances in plasma processing of electro-catalysts for fuel cells. It shows that plasmas allow tuning the composition of the catalyst as well as its structure and topography, leading to improved catalytic properties and fuel cell performance. Reniers et al. propose an atmospheric plasma approach for the deposition of platinum nanoparticles serving as electro-catalyst, which opens up interesting opportunities for cost reduction. Another example focusing on fuel cells and reported in the paper from Jiang et al. is the plasma deposition of membrane electrolytes. The authors show the negative side effect of plasma in the excessive cleavage of the acidic functionality, essential to guarantee good material performances. Nevertheless, the authors demonstrate the use of pulsed plasmas as an effective approach to limit the above-mentioned cleavage while keeping good barrier properties towards fuel crossover, thanks to the intrinsic cross-linked structure of the plasma-deposited films.

The special issue also includes papers on plasma processing of materials involved in Li-ion battery technology. Agarwal et al. report on a single-step plasma synthesis process for growing silicon nitride encapsulated silicon nanocrystals as passivating anode material. The paper from Colombo et al. covers the atmospheric pressure plasma treatment of electrospun Li-ion separators. The treatment improves the fiber morphology and increases the electrolyte uptake up to ten times that that of commercial Celgard® separators.

Two full papers offer an overview on the deposition of highly conductive Al-doped ZnO films by different plasma techniques, of interest in photovoltaics. Specifically, Hori et al. adopt inductively-coupled assisted DC magnetron plasmas and correlate the plasma properties with the electrical and structural properties of the films. Creatore et al. present a review of the expanding thermal plasma – CVD of Al-doped ZnO transparent conducting oxides, providing insights into the influence of the plasma chemistry on the film opto-electrical properties and microstructure. In their paper, Losurdo et al. report on how low pressure plasma processing can be exploited to tailor defects, morphology and composition, and consequently, to develop tailored categories of oxides, which could lead to substantial improvements for applications in energy, such as batteries and photovoltaics.

The special issue includes other three full papers and two reviews on photovoltaics. Ostrikov et al. demonstrate the fabrication of fully functional poly-Si based cells. Massines et al. report on the deposition of hydrogenated silicon nitride by dielectric barrier discharge. Solar cells made with atmospheric pressure plasma deposited SiN, anti-reflective coatings result in the same efficiency as low pressure deposited layers. Wolden et al. present a work on low temperature plasma-enhanced chemical vapour deposition of hybrid nano-laminates consisting of titania and silicone, serving as broadband anti-reflective coating. The approach allows the deposition of optical coatings with the performances of all oxide multilayers while introducing flexibility to
allow for roll-to-roll manufacturing. The work from Mariotti et al. is a comprehensive review on atmospheric pressure plasmas for third-generation photovoltaics. It highlights how the work carried out so far in the field demonstrates the potential and versatility of atmospheric pressure plasmas and confirms their potential in an R&D environment and possibly in industrial PV manufacturing. The review from Dogan and van de Sanden focuses on the synthesis of silicon nanoparticles by plasmas. The review discusses the mechanisms of nanoparticle formation in plasmas and presents recent advancements in solar cell and lithium-ion battery applications of gas-phase plasma synthesized Si-NPs. Further technological applications such as thermo-electrics and water splitting are also illustrated.

The water splitting application is also addressed in the contribution by Barreca et al. where nanocomposite Fe$_2$O$_3$—Co$_3$O$_4$ photo-anodes are prepared by a combined plasma-enhanced chemical vapour deposition and sputtering process. The photo-electrochemical performances in solar water splitting highlight the accurate control on the Co$_3$O$_4$/Fe$_2$O$_3$ heterostructure in order to exploit the catalytic function of Co$_3$O$_4$ when coupled with Fe$_2$O$_3$-based photo-anodes.

The guest editors are confident that the present issue will be a valuable reference and learning material to other researchers and students in the field of plasma processing. Also, we expect it will serve to identify new opportunities and address new challenges in the field.

The guest editors would like to express their sincere gratitude to the contributing authors for their hard work and dedication. Our sincere thanks go to the reviewers for their input and effort in ensuring the high quality of the papers, and to the editorial board of Plasma Processes and Polymers for supporting and enabling our project. A special thanks goes to Dr. Renate Förch, Managing Editor of Plasma Processes and Polymers, who has been enthusiastically supportive during the whole process of this special issue.

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