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Advanced Printed Semiconductors for Energy and Electronic Applications

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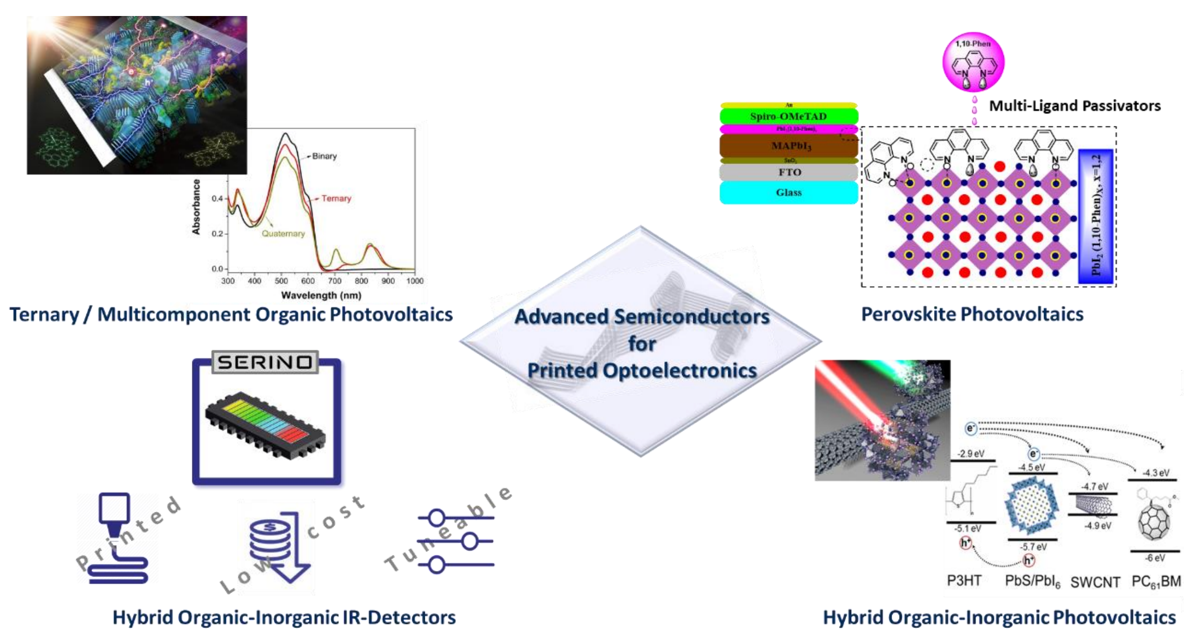
Graphical Abstract



Abstract

We study advanced functional materials for solar power and detection applications. This includes development of emerging printed organic, hybrid, and perovskite photovoltaics and next generation IR-detectors. The aim of our work is to understand the fundamentals and improve the performance, stability and manufacturing processes of these technologies to provide cheaper/more effective solutions for issues of key importance of society: particularly medical equipment and solutions to the climate emergency.

The unique selling points of organic photovoltaics (OPVs), such as excellent light harvesting capability, freedom of form, colour and transparency, environmental friendliness, easy scalability and lower manufacturing costs based on roll-to-roll printing methods, position this technology for the mobile power market, and this most properly reflects the state of the art in commercialization. An important milestone towards OPV commercialization has been surpassed by reaching a power conversion efficiency (PCE) of over 17%. To overcome the absorption and thickness limitations, the concept of ternary near IR sensitization of organic solar cells has been explored in the last decade. As one of the pioneer research groups in development of "Ternary Organic Solar Cells", we demonstrated the potentiality of this concept and comprehensively investigated various prototype organic ternary systems with a central focus on the fundamental complexity of microstructure and charge transport mechanisms. Importantly, we realized the key issues that result in modified recombination mechanisms and consequently improved fill factor and open circuit voltage in high efficiency ternary/ multicomponent solar cells. Ternary Solar Cells are nowadays a leading strategy in organic photovoltaic technology with the potential to further address the challenges of global energy demand and climate emergency.

Additionally, hybrid systems, a combination of the unique properties of both organic and inorganic semiconductors, are of significant interest to develop printed hybrid electronic devices for use in modern applications. We focused particularly on developing a comprehensive understanding, design, and development of printable hybrid ternary solar cell by implementing an appropriate inorganic or hybrid compound in the form of nanoparticles (NPs)/ nanostructures (NSs) into the organic host matrices. Photodetectors, image sensors, and X-ray detectors are a few examples of the optoelectronic devices which would benefit from the outcome of our research immensely.

Importantly, organic- inorganic hybrid perovskite photovoltaics (PPvs) have attracted tremendous attention due to rapid progress in terms of PCE in the last few years, from 3.8% to present record values in excess of 25%. However, fundamental problems, such as the toxicity of hybrid lead halide perovskites, hysteresis and structural instability remain to be solved for perovskite solar cells. Indeed, the low-temperature solution-processing of perovskite films inevitably causes formation of a certain amount of defects on the surface and at the grain boundaries, which lead to serious trapping, charge accumulation, and recombination problems as well as stability issue. We pursue the interface engineering and defects passivation by introducing various types of multifunctional conjugated organic compounds, such small molecules and graphene-based quantum dots. We were successfully able firstly to heal detrimental defects on perovskite film surfaces, which adversely affect the photovoltaic performance and stability of corresponding devices, and secondly to convert excess or unreacted PbI_2, which is also detrimental for long-term stability of solar cell devices, into beneficial complex species for efficient hole transfer at the modified interface.

Finally, within the framework of our recently founded start-up SERINO, we develop the next generation of IR-detectors for medical applications. Our technology is much cheaper and affordable in manufacturing, and more sensitive in performance compared to the standard detector technology available in the market.

In this presentation, we will discuss our achieved results in details for various prototype organic, hybrid and perovskite systems with a central focus on the fundamental complexity of microstructure and charge transport mechanisms and their correlation to the device performance and stability.

Keywords: Printed Optoelectronics, Organic Solar Cells, Perovskite Solar Cells, Near IR Detectors, Ternary Solar Cells.

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Biography of Presenting Author

Tayebeh Ameri is a Senior Lecturer (Associate Professor) in the Institute for Materials and Processes, Chemical Engineering discipline at the University of Edinburgh. She conducted her PhD research in Konarka GmbH Austria and received her PhD degree in Engineering Sciences from the Johannes Kepler University Linz, in 2010. Afterwards, she conducted her postdoctoral and Habilitation research in the institute of Materials for Electronics and Energy Technology (i-MEET), Department of Material Science and Engineering at the University of Erlangen-Nürnberg (FAU). From 2018 till 2020, Dr. Ameri was a team leader and lecturer in the chair of Physical Chemistry, Department of Chemistry at the University of Munich (LMU). Dr. Ameri is also the scientific mentor of the recently founded start-up SERINO on development of the next generation of IR-detectors for medical applications. Her main research interests include investigation and development of printed optoelectronics with a focus on photovoltaic and photodetector technologies. She has authored over 120 peer-reviewed and widely cited publications/book chapters, and has received several prestigious awards including Wolfgang Finkelnburg, Medical Valley and Arnold Sommerfeld Awards.

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