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Introduction

MRS Communications, Polymers and Soft Matter special issue, Part A

The functionality of polymers: fundamentals to technology

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The continued development of innovative chemical synthetic routes to synthesize polymers that possess a diverse range of functional chemical moieties has enabled interdisciplinary research groups to use polymers for a range of fascinating applications, many of which were not envisioned even a few years ago. Applications include solid state electrolytes for batteries and capacitors, resists for nanolithography, semiconductors for organic solar cells and organic light emitting diodes, thermoelectric devices and electromechanical applications, and biomedical devices where living tissue is connected to inorganic and polymeric components. Advantages of using polymers include the ease of processing and fabrication: low temperature processing, cost, and the potential to make mechanically flexible devices and sensors that may be integrated into clothing, for example. This special issue on the functionality of polymers, presented here as Part A with additional contributions to come in the following issue, is of particular interest to MRS because a large cross section of materials researchers needs to better understand how to exploit the behavior of polymers for new functional applications where they have been impactful.

The properties and performance of polymers in these applications depend not only on the chemical functional groups, but also on the morphological structure of the polymer: phase separation, assembly, and organization of chemical moieties at varying length scales. The transport of charge carriers and the optical properties are highly anisotropic, and, therefore, strongly influenced by the spatial orientation and alignment of chains, disruptions in the alignment of the chains, and the degree of crystallinity. Optimizing the performance of polymer-based materials requires a combination of multi-scale simulations to guide the morphological design, and complementary experimental tools to probe details of the morphology, interfacial behavior, and transport properties. To reach the marketplace in new application areas, polymers must be studied and understood as solid-state materials with their defects and microstructure existing in a range of length-scales. The full promise of polymeric materials would be realized when important intellectual/scientific challenges are met.

In this special issue of *MRS Communications*, current and future challenges associated with the use of polymer-based devices, from biomedical devices and stimuli responsive materials to solar cells and batteries, are described. Contributing authors present molecular design strategies for polymeric materials that include the synthesis of linear chain polymers and copolymers of various chemical structures and architectures to enhance optical and carrier transport properties. Also reported are break-through innovations describing the chemical synthesis of new polymers that are more reliably processed to achieve new and specific nano-scale morphologies of varying symmetries. New materials and new processing strategies (patterning, electrospray, etc.) to enhance the device performance are described, along with the synthesis of new functional polymers, including a new class of conducting polymers, and strategies that enable the development of different morphologies, and fabrication strategies, to create high efficiency polymer-based devices. The state-of the art and future challenges associated polymer-based device development are also discussed.

In summary, the state-of-the-art advances and the challenges that are posed in this highly interdisciplinary area of soft matter, clearly demonstrate the importance of polymeric materials to current technologies and the potential of polymers in emerging areas. Indeed, polymeric materials have been an important component of materials science in the past and will continue to be of importance as materials science expands into applications relevant to energy, water, food and biology, the most important problems facing mankind.