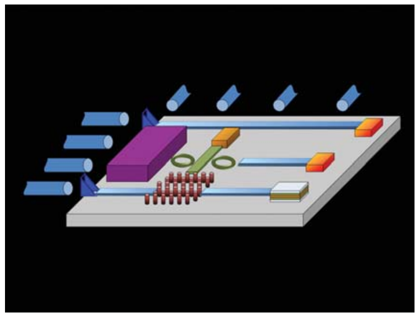
Polymers in Photonics: Controlling Information by Manipulating Light

In electronic devices, the control of information, with the generation, modulation, transmission, collection and storage of data, is achieved by components that respond to and affect electron flow and charge distribution. The electronic revolution of the past few decades has been made possible by the development of ever smaller and more powerful integrated circuits and of extended networks to exchange data between large numbers of electronic devices. In photonics, the control of information is achieved by light (photons) and it has the potential to overcome some of the limitations of the current generation of electronic devices, in terms of speed and bandwidth attainable. Data transmission already relies heavily on passive optical elements like optical fibers, but optical signals are converted to digital electronic information at the transmitting and receiving ends of the communication system. Data storage is also accomplished with passive polymeric materials such as those in compact discs, but again, the optical signals are converted to electronic signals.

It is in principle possible to accomplish all the functions of electronic devices with optical equivalents. In these photonic devices, starting with light from sources like light emitting diodes (LEDs) and lasers, optical information can be encoded and controlled by linear and/or nonlinear optical filters and switches, and routed/transmitted through optical fibers, waveguides, and/or photonic crystals to collection vessels like photodetectors. Optical information can be transferred over long distances or processed locally on optically integrated circuits. In active configurations, filters and modulators controlled by electric or magnetic fields, the local thermal environment, or with light itself can be used to dynamically change the direction, amplitude, phase, or wavelength of optical signals.

Due to the complexity of optically integrated circuits, a combination of materials and fabrication techniques are likely needed to build all the necessary functionalities into a single, small footprint device and to ensure compatibility with existing silicon electronics, where needed. Many practical problems still need to be solved before photonics can fully affect how we process and transmit information, such as miniaturization issues caused by diffraction limitations. Strategies to



circumvent these limitations include, for example, using plasmonics to localize and miniaturize elements. Quantum computing offers an alternate approach to information processing for which light is inherently well-suited. Active research areas include the development of new materials and the optimization of their properties, the design of viable optical circuitry and architectures in 2D or 3D, and the identification of common protocols on which to develop modular building blocks that can be assembled into more complex structures. The final integrated solution will most likely be a combination of organic and inorganic materials, building on the strengths of both types.

In this developing environment, polymers show promise as being instrumental to a variety of the sub-components, both passive and active. One of the advantages of polymers over other materials classes is that their physical and optical properties can be tailored to a large extent by controlling the chemical structure and degree of polymerization. Functionalities can be added by incorporating appropriate molecular moieties into the polymer chain or as side pendants. Polymers can be processed using a variety of methods, including solution and gas-phase deposition, and can be made compatible by suitable surface functionalization with substrate chemistry (including inorganic building blocks). Polymers also have the potential to be produced on a large scale and at low cost.

This special issue focuses on the study and applications of polymers in photonics, as we look towards realizing a future as outlined above. Sun and Wu review the development of polymer network liquid crystals for use in spatial light modulators and the search for optimized operation conditions of such devices by varying monomer and liquid crystal host.

Another type of liquid crystal-polymer composite is discussed in the Perspective by De Sio and Tabyrian. Here the authors describe the fabrication and use of layered structures of liquid crystals and polymers, whose optical properties can be switched by an electric field, which could be of interest as switchable diffractive optical elements with fast response times in photonics devices.

Priimagi and Shevchenko discuss how polymers containing azobenzene derivatives, which undergo photoisomerization under appropriate illumination conditions and thus experience large-amplitude molecular motions, can be used to produce surface relief gratings with micro- and nano-scale features for applications in a variety of optical devices. A different approach to generating periodic polymeric structures is overviewed by Li, Smith and Bunning, in which fabrication techniques, material properties induced by phase separation, and applications of the patterned materials are presented.

Lynn, Blanche and Peyghambarian focus on photorefractive polymers, with emphasis on their use in holography and on models for the materials response. Polymer versatility is evident in tunable distributed feedback lasers, as discussed in the review by Andrews, Crescimanno, Singer, and Baer. Ioppolo and coworkers demonstrate the effect of electric and magnetic fields on optical resonances of polymeric microspheres, which can be exploited as an operating principle for sensors.

Whereas it is not possible to review all the recent work devoted to the material development and understanding of requirements for polymer-based photonics in a single journal issue, the chosen contributors provide a wide sampling of the rich and multidisciplinary research being carried out across the world in polymer optics. As the control of data and information becomes increasingly more reliant on the efficient transport of light, the need for versatile, inexpensive polymeric materials continues to grow.

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