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Editorial

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Electrically Conducting Polymers

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This year marks the 40th anniversary of Shirakawa, MacDiarmid, and Heeger's first ground-breaking publication [1] on electrically conducting polymers. Their original studies were based on polyacetylene, but work quickly progressed to other classes of polymers, including poly phenylenes, poly (phenylenevinylenes), polyanilines, and the poly heterocycles. While "electrically conducting polymers" is, of course, an apt description for these materials, that description fails to capture the most important feature of these polymers: changes in oxidation state result in changes in many properties, including not just conductivity but also color, volume, reactivity, permeability, and solubility. For this reason, describing these materials as "electroactive polymers" might be more appropriate. It is in fact the electro activity of these polymers that has led to many of the potential applications, which include energy storage/conversion, corrosion inhibition, static dissipation, light emitting devices, electrochromics, field effect transistors, sensors, gas separation, water purification, electromagnetic shielding, actuators, artificial nerves/muscles, flexible transparent electrodes, and drug delivery.

The potential biomedical applications of conductive polymers continue to grow. Sensor applications that began with glucose monitoring systems have progressed to rapid detection of genetic markers for disease. Changes in volume as a function of oxidation potential lead to applications in actuators; minute power fluctuations can be used to control conducting polymer-driven movement in microelectro mechanical systems and artificial muscles. Conducting polymers are also being explored for use as artificial neurons, connecting enzyme-based biosensors to organic bioelectronics. Conducting polymers continue to be extensively investigated for use in electrochemically-controlled drug delivery. Finally, some conductive polymers have been shown to be effective at photo thermal therapy, absorbing near infrared light and emitting it as heat, effectively destroying cancerous tumors. While not an issue for external sensors, one area of concern for these otherwise promising materials is their biocompatibility and biodegradability.

The chemical structure of conducting polymers can be modified to tailor properties for a specific application; significant changes can also be accomplished simply by changing the morphology of the polymer. Determination of the correct processing parameters can be time consuming, but processing of conducting polymers remains a major factor in their performance. Many applications require thin films, others require bulk materials, and for some applications, nanoparticles are needed. Controlling crystallinity can be a key to performance in thin film device applications, while surfactant selection in nanoparticles preparation can have significant implications for biocompatibility. Laboratory studies of novel materials generally involve small amounts of polymers that can be prepared via electrochemical deposition, but large-scale implementation of these polymers into commercial applications will likely require alternative deposition methods such as solution- or suspension-based film casting. This leads to a need for soluble polymers or nanoparticle suspensions, and the behavior of these cast films often differs significantly from those of electrochemically-deposited films.

While there are already some commercial uses of electrically conductive polymers, it is clear that there is still significant work to be done to bring these promising materials to market in other applications. Further studies of the fundamental chemistry and physics of these polymers will significantly advance our understanding and lead to improved device performance across a wide range of applications. The coming years promise to be an exciting time for the field!

References

1. Shirakawa H, Louis EJ, MacDiarmid AG, Chiang CK, Heeger AJ (1977) "Synthesis of Electrically Conducting Organic Polymers: Halogen Derivatives of Polyacetylene, (CH)x,". J Chem Soc Chem Commun 578-580.

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