Organic Electronic Materials Conjugated Polymers And Low Molecular Weight Organic Solids Springer Series In Materials Science

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This book constitutes the Proceedings of the NATO Advanced Research Workshop on Conjugated Polymers held at the University of Mons, Belgium, during the first week of September 1989. The Workshop was attended by about fifty scientists representing most of the leading research groups within NATO countries, that have contributed to the development of conjugated polymeric materials. The program was focused on applications related to electrical conductivity and nonlinear optics. The attendance was well balanced with a blend of researchers from academic, industrial, and government labs, and including synthetic chemists, physical chemists, physicists, materials scientists, and theoreticians. The Workshop provided an especially timely opportunity to discuss the important progress that has taken place in the field of Conjugated Polymers in the late eighties as well as the enormous potential that lies in front of us. Among the recent significant developments in the field, we can cite for instance: (i) The discovery of novel synthetic routes affording conjugated polymers -that are much better characterized, especially through control of the molecular weight; - that can be processed from solution or the melt; the early promise that conducting polymcrs would constitute materials combining the electrical conductivities of metals with the mechanical properties of plastics is now being realized; -that can reach remarkably high conductivities.

Organic semiconductors with varying physical and optoelectronic properties are readily obtained by incorporating different functional groups in conjugated polymers. While controlled chain-growth polymerization routes have been developed for a handful of these conjugated polymers, most conjugated polymers are still synthesized through step-growth methods that allow little to no control over the resulting polymers. Robust and versatile synthetic methodologies are needed to access conjugated polymers with unprecedented control and optimized properties. In Chapter 2, I describe a rapid and selective synthetic route to thionated naphthalene diimides (NDIs). Thionated NDIs exhibit improved electron mobilities and ambient stabilities. Thionation procedures, however, are lengthy, unselective, and low yielding. Polymeric analogues had not previously been reported due to incompatibilities between sulfur atoms and prevalent palladium catalysts. I illustrate that the rate and selectivity of thionation is drastically improved using steric control and highly efficient microwave irradiation. This methodology is readily applied to synthesize NDI-based polymers with varying degrees of thionation through post-polymerization modification. In Chapter 3, I investigate the anion-radical polymerization of parent and thionated, thiophene- and selenophene-flanked NDIs. Although NDI-based polymers exhibit among the highest electron mobilities for n-type conjugated polymers, their existing synthetic routes are still largely uncontrolled. Anion-radical polymerization provides a promising alternative, wherein thiophene- flanked NDIs have been shown to exhibit chain-growth polymerization. I show that thiophene- and selenophene-flanked NDIs undergo anion-radical polymerization, albeit through step-growth mechanisms. While thionated NDIs form anion-radical complexes and exhibit signs of catalyst insertion, they do not undergo further polymerization. In Chapter 4, I present the templated oxidative synthesis of conjugated polymers. Templated synthesis is a prevalent route to accessing biological and bioinspired polymers but has only sparingly been applied to the synthesis of conjugated polymers. I illustrate that well-defined macromolecular templates synthesized through ring-opening metathesis polymerization undergo subsequent oxidative coupling to form well-defined conjugated polymers. I apply this methodology to synthesize soluble, poly(3,4-ethylenedioxythiophene)-based polymers with controlled molecular weights and low dispersities. In Chapter 5, I summarize the main conclusions and outlook of this thesis work. Further optimization and expansion of the methodologies described herein could greatly impact the fields of conjugated polymers and organic electronic materials.

A must-have resource to the booming field of sulfur-containing polymers Sulfur-Containing Polymers is a state-of-the-art text that offers a synthesis of the various sulfur-containing polymers from low-cost sulfur resources such as elemental sulfur, carbon disulfide (CS2), carbonyl sulfide (COS) and mercaptan. With contributions from noted experts on the topic, the book presents an in-depth understanding of the mechanisms related to the synthesis of sulfur-containing polymers. The book also includes a review of the various types of sulfur-containing polymers, such as: poly(thioester)s, poly(thioether)s and poly(thiocarbonate)s and poly(thiourethane)s with linear or hyperbranched (dendrimer) architectures. The expert authors provide the fundamentals on the structure-property relationship and applications of sulfur-containing polymers. Designed to be beneficial for both research and application-oriented chemists and engineers, the book contains the most recent research and developments of sulfur-containing polymers. This important book: Offers the first comprehensive handbook on the topic Contains state-of-the-art research on synthesis of sulfur containing polymers from low-cost sulfur-containing compounds Examines the synthesis, mechanism, structure properties, and applications of various types of sulful-containing polymers Includes contributions from well-known experts Written for polymer chemists, materials scientists, chemists in industry, biochemists, and chemical engineers, Sulfur-Containing Polymers offers a groundbreaking text to the field with inforamtion on the most recent research.

Organic Electronics
Conjugated Polymers
Introduction to Organic Electronic and Optoelectronic Materials and Devices, Second Edition
Organic Flexible Electronics
Functionalized Conjugated Polymers Promoted High Performance Materials for Organic Electronic Devices
Organic Radical Polymers

Since conjugated polymers, i.e. polymers with spatially extended pi-bonding system have offered unique physical properties, unobtainable for conventional polymers, significant research efforts directed to better understanding of their chemistry, physics and engineering have been undertaken in the past two and half decades. In this thesis we discuss the synthesis, characterisation and investigation of conjugated semiconducting organic materials for electronic applications. Owing to the versatile properties of metal-organic hybrid materials, there is significant promise that these materials can find use in optical or electronic devices in the future. In addressing this issue, the synthesis of bisthiazol-2-yl-amine (BTA) based polymers is attempted and their metallation is investigated. The focus of this work has been to examine whether the introduction of coordinating metal ions onto the polymer backbone can enhance the conductivity of the material. These studies can provide a basis for understanding the photophysical properties of metal-organic polymers based on BTA. In their neutral (undoped) form conjugated polymers are semiconductors and can be used as active components of plastics electronics such as polymer light-emitting diodes, polymer lasers, photovoltaic cells, field-effect transistors, etc. Toward this goal, it is an objective of the study to synthesize and characterize new classes of luminescent polymeric materials based on anthracene and phenanthrene moieties. A series of materials based on polyphenylenes and poly(phenyleneethynylene)s with 9,10-anthrylene subunits are not only presented but the synthesis and characterization of step-ladder and ladder poly(p-phenylene-alt-anthrylene)s containing 9,10-anthrylene building groups within the main chain are also explored. In a separate work, a series of soluble poly-2,7- and 3,6-phenanthrylenes are synthesized. This can enable us to do a systematic investigation into the optical and electronic properties of PP.

The molecular structure of a conjugated polymer critically impacts its physical and optoelectronic properties, thus determining its ultimate performance in organic electronic devices. In this work, new polymers and derivatives are designed, synthesized, characterized, and tested in photovoltaic devices. Through device engineering and nanoscale characterization, general structure-function relationships are established to aid the design of the next-generation of high performance polymer semiconductors for organic electronic applications. Using a prototypical conjugated polymer, the influence of backbone regioregularity is examined and found to highly impact polymer crystallinity, solid state morphology and device stability. The investigation of alternative aromatic units in the backbone also led to new understandings in polymer processability and the development of promising materials for organic photovoltaics. Besides the backbone structure, the side chain choice of the polymer can significantly affect material properties and device performance as well. In fact, the side chain substitution can influence both the optoelectronic properties and the physical properties of the polymer. A sterically bulky side chain can be used to tune the donor/acceptor separation distance, which in turn determines the charge separation efficiency. The addition of a polar side group increases the dielectric constant of a polymer and improves overall charge separation. Choosing the appropriate solubilizing group can also induce solid state packing of the polymer and considerably enhance device efficiency. Finally, the influence of post-fabrication processing techniques on the crystallinity and charge transport properties of a polymer is highlighted.

Chapter 1 gives an introduction to the structure, operation mechanism, performance parameters, and challenges of organic photovoltaic devices. We also discuss some strategies to improve the performance of photovoltaics, with an emphasis on morphology control in polymer bulk-heterojunction devices. Chapter 2 describes the synthesis of a class of polymer additives for bulk-heterojunction (BHJ) solar cells based on an extended triptycene-containing unit. The incorporation of these additives on BHJ photovoltaic devices based on PTB7 and PC71BM leads to an increase in power conversion efficiencies of 10-20%. We also found that the additives produce more consistent performance in devices, minimizing variation from processing conditions. Chapter 3 presents a modular synthetic route to access functionalized 2,5-di(thiophen-2- y1)- 1-H-arylpyrroles (SNS) from readily available starting materials. We demonstrated the use of this building block in the synthesis of conjugated polymers with high thermal stability and solubility. Characterization of the polymers reveals a correlation between molecular packing and charge carrier mobility. Chapter 4 discusses strategies to enhance conjugation in organic electronic materials, using 2,5-di(thiophenyl)-N-arylpyrrole (SNS) as a model system. The first section describes synthetic routes to access a novel polycyclic heteroaromatic building block via intramolecular cyclization reactions. The second section explores the electrochemical properties of SNS units for the opportunity to enhance conjugation via electrochemical methods.

The Fourth Edition of the Handbook of Conducting Polymers, Two-Volume Set continues to be the definitive resource on the topic of conducting polymers. Completely updated with an extensive list of authors that draws on past and new contributors, the book takes into account the significant developments both in fundamental understanding and applications since publication of the previous edition. One of two volumes comprising the comprehensive Handbook, Conjugated Polymers: Perspective, Theory, and New Materials features new chapters on the fundamental theory and new materials involved in conducting polymers. It discusses the history of physics and chemistry of these materials and the theory behind them. Finally, it details polymer and materials chemistry including such topics as conjugated block copolymers, metal-containing conjugated polymers, and continuous flow processing. Aimed at researchers, advanced students, and industry professionals working in materials science and engineering, this book covers fundamentals, recent progress, and new materials involved in conducting polymers and includes a wide-ranging listing of comprehensive chapters authored by an international team of experts.

Conjugated Polymer Design and Engineering for Organic Electronics
Iontronics
Conjugated Polymers and Small Molecules with Latent Hydrogen-bonding for Organic Electronic Applications
One-Dimensional Metals
Introduction to Organic Electronic and Optoelectronic Materials and Devices

Sustainable Strategies in Organic Electronics reviews green materials and devices, sustainable processes in electronics, and the reuse, recycling and degradation of devices. Topics addressed include large-scale synthesis and fabrication of safe device materials processes that neither use toxic reagents, solvents or produce toxic by-products. Emerging opportunities such as new synthetic approaches for enabling the commercialization of pi-conjugated polymer-based devices are explored, along with new efforts towards incorporating materials from renewable resources for a low carbon footprint. Finally, the book discusses the latest advances towards device biodegradability and recycling. It is suitable for materials scientists and engineers, chemists, physicists in academia and industry. Discusses emerging opportunities for green materials, synthesis and fabrication of organic electronics Reviews the challenges of integration of sustainable strategies in large-scale manufacturing of organic electronics Provides an overview of green materials and solvents that can be used as alternatives to toxic materials for organic electronics applications

Conjugated polymers hold tremendous potential as low-cost, solution processable materials for electronic applications such organic light-emitting diodes and photovoltaics. While the concerted efforts of many research groups have improved the performance of organic electronic devices to near-relevant levels for commercial exploitation over the last decade, the overall performance of organic light-emitting diode and organic photovoltaic devices still lags behind that of their traditional, inorganic counterparts. Realizing the full potential of organic electronics will require a comprehensive, molecular-level understanding of conjugated polymer photophysics. Studying pure, well-defined, and reproducible conjugated polymer materials should enable these efforts; unfortunately, conjugated polymers are typically synthesized by metal-catalyzed step-growth polycondensation reactions that do not allow for rigorous control over polymer molecular weight or molecular weight distribution (i.e., dispersity). Chain-growth syntheses of conjugated polymers would not only allow for precise control over the aforementioned polymer metrics such as molecular weight and dispersity, but could also potentially create new applications by enabling the preparation of more advanced macromolecular structures such as block copolymers and surface grafted polymers. Our efforts toward realizing these goals as well as toward exploiting chain-growth methodologies to better understand fundamental conjugated polymer photophysics and self-assembly will be presented.

While much research in the field of conducting polymers and organic electronics focuses on development of novel polymers and other related materials, or enhancing the properties of existing materials and understanding the mechanisms behind them, in many cases, clear and reliable future directions or applications of the research are unclear. Developing an understanding of the roles of different physical and chemical mechanisms and establishing simple, cheap and reliable manufacturing and processing technologies for conducting polymers will be crucial to guide future research to uncover modern materials for advanced practical applications. In the present work, several novel manufacturing and processing routes have been established to firstly create organic materials with desired properties and, later, to apply them in functional devices. Several adjustments have been made to the synthesis of conducting polymers, and novel ways for patterning of thin organic films developed, so that high-quality materials can be made cheaply and relatively quickly and then used to create functional devices with improved properties. Conducting polymers such as polyacetylene, polythiophene, polyaniline or poly(3,4-ethylenedioxythiophene) have been studied for several decades now; however, their properties have not been sufficient for widespread commercial application. Only recently have developments in the field and improvements in the properties of these materials, as well as better understanding of mechanisms underlying their functionality, allowed their use in prototype devices. The conductivity of organic materials is still relatively low compared to that of their inorganic counterparts, although some applications do not require such high electrical properties. A critical step was to better understand conductivity mechanisms and improve them using several different methods. Examples of methods to improve properties include blending two or more conducting or non-conducting polymers, co-polymerizing different monomers together or designing polymers and their surfaces on the nano-level. This work presents a study of two conducting polymers: poly(3,4-ethylenedioxythiophene) and poly(thiophene) and some attempts to increase their current properties or develop new properties to meet requirements for specific applications. Most of the effort focuses on the development of properties that are important for application in fields like energy production and storage, photonics and electronics. These critical properties include high electrical performance and high conductivity, good electrochemical properties, high surface area, broad light absorption spectra, biocompatibility, good mechanical properties and long lifetime. Chapter 3 discusses vapor phase co-polymerization of bithiophene and terthiophene as a route to widen absorption spectra of polythiophene materials. Chapter 4 describes processes responsible for formation of polythiophene nano-structures during vapor phase polymerization. It also explains conditions and polymerization parameters responsible for formation of different nano-structures so that those materials can be tuned for desired applications. Chapter 5 shows development of a laser ablation technique as a way to pattern conducting polymers to get the shape and architecture required for a specific device or application. The laser ablation technique is applied to manufacture organic electrochemical transistors and gas sensors. Lastly, Chapter 6 builds on knowledge from previous chapters to develop organic light sensors and opto-logic gates that can be used in an optical-to-electronic interface. This work significantly advances the state of knowledge of conducting polymers within the organic electronics field, and gives insights into how those materials interact with each other and how to tailor their properties. The findings here can serve as a basis for developing new conducting polymers, as well as direct investigations for new applications using the materials presented here.

Conjugated polymers have important technological applications including solar cells and light emitting devices. They are active components in many important biological processes. This book describes and explains the electronic and optical properties of conjugated polymers by developing theoretical models to understand the key electronic states.

Conjugated Polymers and Low Molecular Weight Organic Solids
Polymers for Light-emitting Devices and Displays
Organic Electronics for Electrochromic Materials and Devices
Properties, Processing, and Applications
Organic Optoelectronic Materials
Conjugated Materials for Organic Electronics

Since their discovery, organic electronic materials have been of great interest as an alternative active layer material for active area materials in electronic applications. Initially studied as probes or lasing material the field has progressed to the point where both conjugated polymers and small organics have become fashionable objects of current device oriented solid state research. Organic electronic materia liquid crystalline materials, packing into well-ordered domains when annealed thermally or via solvent annealing. The macromolecular orientation of the molecules in the solid state causes a shift in the electronic properties due to coupling of the dipoles. The amount of interaction between molecules can be correlated to different nanoscale morphologies. Such morphologies can be measured using microscop techniques and compared to the spectroscopic results. This can then be extrapolated out to infer how the charges move within a film. Cyanine dyes represent an interesting form class of dyes as the molecular packing is strongly affected by hydrophilic and hydrophobic pendent groups, which cause the dye to arrange into a tubular bilayer. Spectroelectrochemistry is used to monitor and controllably oxidize t samples. Using singular value decomposition (SVD) it is possible to extract each electronic species formed during electrochemical oxidation and model the proposed species using semi empirical quantum mechanical calculations. Polyfluorene is a blue luminescent polymer of interest for its high quantum yield. The solution and solid-state conformation has shown two distinct phases. The formation of the se phase shows a dependence on the molecular weight. In a poor solvent, as the molecular weight increases, the secondary phase forms easier. In the solid state, the highly efficient blue emission from polyfluorene is degraded by ketone defects. The energy transfer to preexisting ketone defects is increased as the filmed is thermally ordered. Glass transitions of block copolymers are studied using synthetical polymers where an environmentally sensitive fluorescent reporter is placed within various regions of a self-assembled film. Different dynamics are observed within the block of the film then specifically at the interface of two blocks.

Polymer Materials for Energy and Electronic Applications is among the first books to systematically describe the recent developments in polymer materials and their electronic applications. It covers the synthesis, structures, and properties of polymers, along with their composites. In addition, the book introduces, and describes, four main kinds of electronic devices based on polymers, including energy harvesting devices, energy storage devices, light-emitting devices, and electrically driving sensors. Stretchable and wearable electronics based on polymers are a particular focus and main achievement of the book that concludes with the future developments and challenges of electronic polymers and devices. Provides a basic understanding on the structure and morphology of polymers and their electronic properties and applications Highlights the current applications of conducting polymers on energy harvesting and storage Introduces the emerging flexible and stretchable electronic devices Adds a new family of fiber-shaped electronic devices

This book provides a detailed introduction to organic radical polymers and open-shell macromolecules. Functional macromolecules have led to marked increases in a wide range of technologies, and one of the fastest growing of these fields is that of organic electronic materials and devices. To date, synthetic and organic electronic device efforts have focused almost exclusively on closed-shell polymers de promise of open-shell macromolecules in myriad applications. This text represents the first comprehensive review of the design, synthesis, characterization, and device applications of open-shell polymers. In particular, it will summarize the impressive synthetic and device performance efforts that have been achieved with respect to energy storage, energy conversion, magnetic, and spintronic applications. B combining comprehensive reviews with a wealth of informative figures, the text provides the reader with a complete "molecules-to-modules" understanding of the state of the art in open-shell macromolecules. Moreover, the monograph highlights future directions for open-shell polymers in order to allow the reader to be part of the community that continues to build the field. In this way, the reader will gain a rapid understanding of the field and will have a clear pathway to utilize these materials in next-generation applications.

The field of organic electronics promises exciting new technologies based on inexpensive and mechanically flexible electronic devices, and is now seeing the beginning of commercial success. On the sidelines of this increasingly well-established field are several emerging technologies with innovative mechanisms and functions that utilize the mixed ionic/electronic conducting character of conjugated organi materials. Iontronics: Ionic Carriers in Organic Electronic Materials and Devices explores the potential of these materials, which can endow electronic devices with unique functionalities. Fundamental science and applications With contributions from a community of experts, the book focuses on the use of ionic functions to define the principle of operation in polymer devices. It begins by reviewing the scientifi understanding and important scientific discoveries in the electrochemistry of conjugated polymers. It examines the known effects of ion incorporation, including the theory and modulation of electrochemistry in polymer films, and it explores the coupling of electronic and ionic transport in polymer films. The authors also describe applications that use this technology, including polymer electrochromic devices, artificial muscles, light-emitting electrochemical cells, and biosensors, and they discuss the fundamental technological hurdles in these areas. The changes in materials properties and device characteristics due to ionic conductivity and electrochemical doping in electrically conductive organic materials, as well as the importance of these processes in a number of different and exciting technologies, point to a untapped potential in the development of new applications and novel device architecture. This volume captures the state of the science in this burgeoning field.

Synthesis of Conjugated Polymers and Block Copolymers Via Catalyst Transfer Polycondensation
Sulfur-Containing Polymers
Design, Synthesis and Characterization of Self-assembling Conjugated Polymers for Use in Organic Electronic Applications
Properties and Applications
Synthetic Methods for Conjugated Polymer and Carbon Materials
Analyzing Photochemical and Physical Processes for Organic Materials

Conjugated polymers and small molecules are gaining a growing attention as the active materials for flexible and printed electronics. The present work discusses the exploration of novel conjugated polymers and small molecules with latent hydrogen-bonding on the conjugated backbone for electronic applications. In the first study, we synthesized a class of conjugated polymers with latent hydrogen-bonding utilizing Suzuki coupling reactions. The resulting polymers can be converted into actual hydrogen-bonded polymers upon thermal or UV removal of the t-butoxyl carbonyl (t-Boc) protection groups on the main chains. Large bathochromic absorption shift and dramatically decreased material solubility of the polymer were shown after the formation of hydrogen-bonding, indicating their enhanced interchain interactions. Photolithographic patterned electrochromic devices was fabricated and tested with the latent hydrogen-bonded conjugated polymers. The second study extends in assessing the field-effect transistor performance of two diketopyrrolopyrrole-based conjugated small molecules with latent hydrogen-bonding. Effects of the activation of latent hydrogen-bonding networks on the small molecule film properties, including UV/Vis absorption, band gap, solvent resistance, film morphology, molecular packing mode, and charge mobility are investigated. Highly crystalline films and improved field-effect mobility of the device was observed for both small molecules after the hydrogen-bonding activation, suggesting an efficient control of molecular organization and device performance of the latent hydrogen-bonding strategy. Based on similar principles, a series of conjugated statistical copolymers with varied latent hydrogen-bonding content on the main chain were studied in the third part of this work. Increased hole mobility was observed for the organic field-effect transistor devices of polymers in which higher percentage of hydrogen-bonded repeating units were comprised, which suggested the potential of latent hydrogen-bonding strategy in constructing solution-processed conjugated polymers with improved semiconducting performance.

Small molecules and conjugated polymers, the two main types of organic materials used for optoelectronic and photonic devices, can be used in a number of applications including organic light-emitting diodes, photovoltaic devices, photorefractive devices and waveguides. Organic materials are attractive due to their low cost, the possibility of their deposition from solution onto large-area substrates, and the ability to tailor their properties. The Handbook of organic materials for optical and (opto)electronic devices provides an overview of the properties of organic optoelectronic and nonlinear optical materials, and explains how these materials can be used across a range of applications. Parts one and two explore the materials used for organic optoelectronics and nonlinear optics, their properties, and methods of their characterization illustrated by physical studies. Part three moves on to discuss the applications of optoelectronic and nonlinear optical organic materials in devices and includes chapters on organic solar cells, electronic memory devices, and electronic chemical sensors, electro-optic devices. The Handbook of organic materials for optical and (opto)electronic devices is a technical resource for physicists, chemists, electrical engineers and materials scientists involved in research and development of organic semiconductor and nonlinear optical materials and devices. Comprehensively examines the properties of organic optoelectronic and nonlinear optical materials Discusses their applications in different devices including solar cells, LEDs and electronic memory devices An essential technical resource for physicists, chemists, electrical engineers and materials scientists

This book covers the combined subjects of organic electronic and optoelectronic materials/devices. It is designed for classroom instruction at the senior college level. Highlighting emerging organic and polymeric optoelectronic materials and devices, it presents the fundamentals, principle mechanisms, representative examples, and key data.

The great tunability of structure and electronic properties of ?-conjugated organic molecules/polymers combined with other advantages such as light weight and flexibility etc., have made organic-based electronics the focus of an exciting still-growing field of physics and chemistry for more than half a century. The application of organic electronics has led to the appearance of wide range of organic electronic devices mainly including organic light emitting diodes (OLED), organic field effect transistors (OFET) and organic solar cells (OSC). The application of the organic electronic devices mainly is limited by two dominant parameters, i.e., their performance and stability. Up to date, OLED has been successfully commercialized in the market while the OSC are still on the way to commercialization hindered by low efficiency and inferior stability. Understanding the energy levels of organic materials and energy level alignment of the devices is crucial to control the efficiency and stability of the OSC. In this thesis, energy levels measured by different methods are studied to explore their relationship with device properties, and the strategies on how to design efficient and stable OSC based on energy level diagrams are provided. Cyclic Voltammetry (CV) is a traditional and widely used method to probe the energy levels of organic materials, although there is little consensus on how to relate the oxidation/reduction potential ((Eox/Ered) to the vacuum level. Ultraviolet Photoelectron Spectroscopy (UPS) can be used to directly detect vertical ionization potential (IP) of organic materials. In this thesis, a linear relationship of IP and Eox was found, with a slope equal to unity. The relationship provides for easy conversion of values obtained by the two techniques, enabling complementarily use in designing and fabricating efficient and stable OSC. A popular rule of thumb is that the offset between the LUMO levels of donor and acceptor should be 0.3 eV, according to which a binary solar cell with the minimum voltage losses around 0.49 V was designed here. Introduction of the ternary blend as active layer is an efficient way to improve both efficiency and stability of the OSC. Based on our studied energy-level diagram within the integer charge transfer (ICT) model, we designed ternary solar cells with enhanced open circuit voltage for the first time and improved thermal stability compared to reference binary ones. The ternary solar cell with minimum voltage losses was developed by combining two donor materials with same ionization potential and positive ICT energy while featuring complementary optical absorption. Furthermore, the fullerene acceptor was chosen so that the energy of the positive ICT state of the two donor polymers is equal to the energy of negative ICT state of the fullerene, which can enhance dissociation of all polymer donor and fullerene acceptor excitons and suppress bimolecular and trap-assistant recombination. Rapid development of non-fullerene acceptors in the last two years affords more recipes of designing both efficient and stabile OSC. We show in this thesis how non-fullerene acceptors successfully can be used to design ternary solar cells with both enhanced efficiency and thermal stability. Besides improving the efficiency of the devices, understanding of the stability and degradation mechanism is another key issue. The degradation of conjugated molecules/polymers often follow many complicated pathways and at the same time many factors for degradation are coupled with each other. Therefore, the degradation of non-fullerene acceptors was investigated in darkness by photoelectron spectroscopy in this thesis with the in-situ method of controlling exposure of O2 and water vapor separately.

Ionic Carriers in Organic Electronic Materials and Devices
Solution-Processable Components for Organic Electronic Devices
A Practical Guide
Towards Advanced Functional Materials
Organic Electronic Materials
Conjugated Semiconducting Organic Materials for Electronic Applications

Organic Electronics is a novel field of electronics that has gained an incredible attention over the past few decades. New materials, device architectures and applications have been continuously introduced by the academic and also industrial communities, and novel topics have raised strong interest in such communities, as molecular doping, thermoelectrics, bioelectronics and many others. Organic Flexible Electronics is mainly divided into three sections. The first part is focused on the fundamentals of organic electronics, such as charge transport models in these systems and new approaches for the design and synthesis of novel molecules. The first section addresses the main challenges that are still open in this field, including the important role of interfaces for achieving high-performing devices or the novel approaches employed for improving reliability issues. The second part discusses the most innovative devices which have been developed in recent years, such as devices for energy harvesting, flexible batteries, high frequency circuits, and flexible devices for tattoo electronics and bioelectronics. Finally the book reviews the most important applications moving from more standard flexible back panels to wearable and textile electronics and more futuristic applications like ingestible systems. Reviews the fundamental properties and methods for optimizing organic electronic materials including chemical doping and techniques to address stability issues; Discusses the most promising organic electronic devices for energy, electronics, and biomedical applications; Addresses key applications of organic electronic devices in imagers, wearable electronics, bioelectronics.

Understanding structure-property relationships of [pi]-conjugated polymers is key to the development of functional materials for organic electronics. Molecular structure and polymer chain order strongly influence the electrical and mechanical performance of materials. First described is the theoretical and experimental quantification of polaron sizes in polythiophene polymers. Intramolecular and intermolecular charge delocalization length were studied to elucidate prior research relating polymer structure and packing morphology to electrical performance. Polythiophenes were also studied through the analysis of previously reported molecular dynamic simulations. Comparison of these models to experimental neutron scattering experiments revealed the requirement for updated parameters to accurately simulate polymer behavior. Polythiophenes are further described for the development of stretchable electronic materials. Improved compatibility in an elastomer/[pi]-conjugated polymer composite was achieved by the introduction of bromide functional groups. Functionalization led to altered intermolecular interactions and reactive covalent bonding which enhanced mechanical performance.

Conjugated polymers, representing a new generation of semiconductors, have attracted tremendous attention in the past few decades attributed to their conspicuous properties, such as flexibility, light weight, stretchability and solution processability, which is promising for manufacturing low-cost, large-area, and flexible electronic devices. Moreover, performance of semiconducting behaviors could be readily modulated via manipulating chemical structure and morphology. Organic field-effect transistors (OFETs) are the elemental components in electrical circuits. Although considerable materials were synthesized and investigated, there are still numerous approaches either in novel materials or morphological control which have not been explored. Therefore, in this research, five different strategies were proposed to attain conjugated polymer-based higher performance materials for OFETs, including novel pigment monomers, polymerization method and morphological manipulation by hydrogen bonding and conjugated cross-linking. In Part I, a blue/violet pigment, benzimidazolone-dioxazine-based molecule, was employed into donor?acceptor based conjugated polymers. Through the molecular modulation, the donors with matched size for donor-acceptor packing in the conjugated polymer thin films were uncovered, revealing refined charge carrier mobilities owing to the extended conjugated length of benzimidazolone-dioxazine structure. Part II discloses the diketopyrrolopyrrole(DPP)-quaterthiophene-based donor-acceptor copolymers with latent hydrogen bonding isoindigo-bithiophene to amend the charge transport in amorphous phase via hydrogen bonding-induced aggregation after thermal treatment. Part III applied the robust hydrogen bonding interaction to directly patterning conjugated polymer thin films and their OFETs with exceptional balance of mobilities and resolution of patterns, which is compatible with conventional photolithography in integrated circuit. Part IV introduces a newfangled method to obtain conjugated polymers with controlled molecular weight in the solid state, consisting of conventional anionic-polymerization and topochemical reaction. Moreover, this strategy could be further utilized to prepare the high-performance semiconducting material, graphene nanoribbons. Part V coalesced the concepts of Part II and IV to construct conjugated cross-linking between polymer backbones through topochemical reactions on diketopyrrolopyrrole(DPP)-quaterthiophene-based copolymers with latent cross-linkable diacetylene-bithiophene moieties, ameliorating the charge transport without demolishing the favorable packing of donor-acceptor conjugated polymers.

This first systematic compilation of synthesis methods for different classes of polymers describes well-tested and reproducible procedures, thus saving time, money and chemicals. Each chapter presents the latest method for a specific class of conjugated polymers with a particular emphasis on the design aspects for organo-electronic applications. In this concise and practically oriented manner, readers are introduced to the strategies of influencing and controlling the polymer properties with respect to their use in the desired device.
This style of presentation quickly helps researchers in their daily lab work and prevents them from reinventing the wheel over and over again.

The Key to a New Electronics Technology
Development of Novel Conjugated Polymer Materials and Structures for Organic Electronics and Energy Applications
Handbook of Organic Materials for Optical and (Opto)Electronic Devices
Conjugated Polymeric Materials: Opportunities in Electronics, Optoelectronics, and Molecular Electronics
Molecular Design for Controlling Morphology in Organic Electronics
Interfacial Charge Transport in Organic Electronic Materials

A concise and practical overview of the most important modern synthetic aspects of conjugated polymers and carbon materials, including their properties and applications. Well structured, this book summarizes recent achievements, outlines the current state and reviews research trends. As such, a wide variety of polymerization techniques are included on both a strategic as well as a practical level, including Stille, Suzuki , and direct (hetero)arylation polymerizations. Furthermore, it covers various carbon-rich materials, such as graphene and carbon nanotubes, followed by a look at how the different synthetic pathways and strategies influence their final properties, for example, for use in organic electronic devices. The whole is rounded off with a discussion of future technology advances. An essential reference for newcomers as well as experienced researchers in the field.

Provides first-hand insights into advanced fabrication techniques for solution processable organic electronics materials and devices The field of printable organic electronics has emerged as a technology which plays a major role in materials science research and development. Printable organic electronics soon compete with, and for specific applications can even outpace, conventional semiconductor devices in terms of performance, cost, and versatility. Printing techniques allow for large-scale fabrication of organic electronic components and functional devices for use as wearable electronics, health-care sensors, Internet of Things, monitoring of environment pollution and many others, yet-to-be-conceived applications. The first part of Solution-Processable Components for Organic Electronic Devices covers the synthesis of: soluble conjugated polymers; solution-processable nanoparticles of inorganic semiconductors; high-k nanoparticles by means of controlled radical polymerization; advanced blending techniques yielding novel materials with extraordinary properties. The book also discusses photogeneration of charge carriers in nanostructured bulk heterojunctions and charge carrier transport in multicomponent materials such as composites and nanocomposites as well as photovoltaic devices modelling. The second part of the book is devoted to organic electronic devices, such as field effect transistors, light emitting diodes, photovoltaics, photodiodes and electronic memory devices which can be produced by solution-based methods, including printing and roll-to-roll manufacturing. The book provides in-depth knowledge for experienced researchers and for those entering the field. It comprises 12 chapters focused on: ? novel organic electronics components synthesis and solution-based processing techniques ? advanced analysis of mechanisms governing charge carrier generation and transport in organic semiconductors and devices ? fabrication techniques and characterization methods of organic electronic devices Providing coverage of the state of the art of organic electronics, Solution-Processable Components for Organic Electronic Devices is an excellent book for materials scientists, applied physicists, engineering scientists, and those working in the electronics industry.

Low-dimensional solids are of fundamental interest in materials science due to their anisotropic properties. Written not only for experts in the field, this book explains the important concepts behind their physics and surveys the most interesting one-dimensional systems and discusses their present and emerging applications in molecular scale electronics. Chemists, polymer and materials scientists as well as students will find this book a very readable introduction to the solid-state physics of electronic materials. In this completely revised and expanded third edition the authors also cover graphene as one of the most important research topics in the field of low dimensional materials for electronic applications. In addition, the topics of nanotubes and nanoribbons are widely enlarged to reflect the research advances of the last years.

Conjugated organic polymers and small molecules could potentially be employed as active material for high-throughput, low-cost and large-area device fabrication through solution processing. Electronic devices employing organic systems, such as organic light emitting diodes (OLEDs), organic photovoltaic cells (OPVCs) and organic thin-film transistors (OTFTs) for sensors and displays, have seen improved performances and commercialization in the recent decade. Continuous material innovation is the key towards the achievement of higher and better performances. Among various high-performing materials, large fused ring linear acenes, such as pentacene (Pn) and anthradithiophene (ADT) have maintained the benchmark for charge transport. Okamoto et al have since employed these structures into polymer backbones for solution-processable functional materials. This thesis explores in details the utility of Pn and ADT as building blocks in conjugated polymers. A variety of material and device characterization was carried out for the new materials developed. These include: (A) regio-regular Pn-containing copolymers. The direction of conjugation-extension (from 2,9- or 2,10-positions) was found to impact molecular order and charge-transport properties. (B) 2,8-conjugation-extended ADT-cyclopentadithiophene copolymers. Adjusting the bulkiness of the central substituents on the acene was found to impact molecular packing and charge-transport properties. Triisobutylethynyl-functionalized ADT achieved a photovoltaic power conversion efficiency of 2.7% in a polymer:fullerene bulk heterojunction device. (C) 5,11-conjugation-extended ADT copolymers. To explore impact on polymer electronic and packing behavior, ADT was incorporated with its long molecular axis orthogonal to the polymer backbone via in situ desilylation and Horner Emmons condensation. Using the first methodology, copolymerization with diketopyrrolopyrrole resulted in a low-bandgap polymer due to extended electron delocalization in the direction orthogonal to backbone. This polymer showed out-of-plane layered packing structure, and a high transistor hole mobility of 0.11 cm2 V-1 s-1. The second methodology enabled the development of an ADT monomer precursor exhibiting high ambient stability. Both 5,11-conjugation extended polymers yielded photovoltaic power conversion efficiencies of around 0.8 %. Through the development of these novel monomers and polymer, this thesis demonstrates the synthetic versatility that could be applied to pentacene and ADT in polymers, and the resulting ability to engineer the materials' energy levels and packing behavior. It shows that acene-containing polymers are promising materials for organic electronic devices.

Design and Synthesis of Conjugated Polymers
From Synthesis to Functional Materials
Towards the Controlled Synthesis of Conjugated Polymers
Elucidating Structural Effects of Conjugated Polymers on Charge Transport and Durability for Organic Electronics and Development of Stretchable Semiconducting Materials
Sustainable Strategies in Organic Electronics
Synthetic Methods in Organic Electronic and Photonic Materials

Conjugated polymers comprise some of the most promising materials for new technologies such as organic field effect transistors, solar light harvesting technology and sensing devices. In spite of tremendous research initiatives in materials chemistry, the potential to optimize device performance and develop new technologies is remarkable. Understanding relationships between the structure of conjugated polymers and their electronic properties is critical to improving device performance. The design and synthesis of new materials which self-organize into ordered nanostructures creates opportunities to establish relationships between electronic properties and morphology or molecular packing. This thesis details our progress in the development of synthetic routes which provide access to new classes of conjugated polymers that contain dissimilar side chains that segregate or dissimilar conjugated blocks which phase separate, and summarizes our initial attempts to characterize these materials. Poly(1,4-phenylene ethynylene)s (PPEs) have been used in a variety of organic electronic applications, most notably as fluorescent sensors. Using traditional synthetic methods, asymmetrically disubstituted PPEs have irregular placement of side chains on the conjugated backbone. Herein, we establish the first synthetic route to an asymmetrically substituted regioregular PPEs. The initial PPEs in this study have different lengths of alkoxy side chains, and both regioregular and regiorandom analogs are synthesized and characterized for comparison. The design of amphiphilic structures provides additional opportunities for side chains to influence the molecular packing and electronic properties of conjugated polymers. A new class of regioregular, amphiphilic PPEs has been prepared bearing alkoxy and semifluoroalkoxy side chains, which have a tendency to phase separate. Fully conjugated block copolymers can provide access to interesting new morphologies as a result of phase separation of the conjugated blocks. In particular, donor-acceptor block copolymers that phase separate into electron rich and electron poor domains may be advantageous in organic electronic devices such as bulk heterojunction solar cells, of which the performance relies on precise control of the interface between electron donating and accepting materials. The availability of donor-acceptor block copolymers is limited, largely due to the challenges associated with synthesizing these materials. In this thesis, two new synthetic routes to donor-acceptor block copolymers are established. These methods both utilize the catalyst transfer condensation polymerization, which proceeds by a chain growth mechanism. The first example entails the synthesis of a monofunctionalized, telechelic poly(3-alkylthiophene) which can be coupled to electron accepting polymers in a subsequent reaction. The other method describes the first example of a one-pot synthesis of a donor-acceptor diblock copolymer. The methods of synthesis are described, and characterization of the block copolymers is reported.

Hybrid organic-inorganic materials and the rational design of their interfaces open up the access to a wide spectrum of functionalities not achievable with traditional concepts of materials science. This innovative class of materials has a major impact in many application domains such as optics, electronics, mechanics, energy storage, and conversion, protective coatings, catalysis, sensing, and nanomedicine. The properties of these materials do not only depend on the chemical structure, and the mutual interaction between their nano-scale building blocks, but are also strongly influenced by the interfaces they share. This handbook focuses on the most recent investigations concerning the design, control, and dynamics of hybrid organic-inorganic interfaces, covering: (i) characterization methods of interfaces, (ii) innovative computational approaches and simulation of interaction processes, (iii) in-situ studies of dynamic aspects controlling the formation of these interfaces, and (iv) the role of the interface for process optimization, devices, and applications in such areas as optics, electronics, energy, and medicine.

This volume reviews the latest trends in organic optoelectronic materials. Each comprehensive chapter allows graduate students and newcomers to the field to grasp the basics, whilst also ensuring that they have the most up-to-date overview of the latest research. Topics include: organic conductors and semiconductors; conducting polymers and conjugated polymer semiconductors, as well as their applications in organic field-effect-transistors; organic light-emitting diodes; and organic photovoltaics and transparent conducting electrodes. The molecular structures, synthesis methods, physicochemical and optoelectronic properties of the organic optoelectronic materials are also introduced and described in detail. The authors also elucidate the structures and working mechanisms of organic optoelectronic devices and outline fundamental scientific problems and future research directions. This volume is invaluable to all those interested in organic optoelectronic materials.

This is the final report of a three-year, Laboratory Directed Research and Development (LDRD) project at Los Alamos National Laboratory (LANL). The primary aim of this project is to obtain a basic scientific understanding of electrical transport processes at interfaces that contain an organic electronic material. Because of their processing advantages and the tunability of their electronic properties, organic electronic materials are revolutionizing major technological areas such as information display. We completed an investigation of the fundamental electronic excitation energies in the prototype conjugated polymer MEH-PPV. We completed a combined theoretical/experimental study of the energy relation between charged excitations in a conjugated polymer and the metal at a polymer/metal interface. We developed a theoretical model that explains injection currents at polymer/metal interfaces. We have made electrical measurements on devices fabricated using the conjugated polymer MEH-PPV a nd a series of metals.

New Avenues in Organic Electronics

Electronic Structure of ?-Conjugated Materials and Their Effect on Organic Photovoltaics

Advanced Chemistry and Understanding of Acene-containing Conjugated Polymers for Functional Electronics

Polymer Materials for Energy and Electronic Applications

Fundamentals, Devices, and Applications

Hybrid Organic-Inorganic Interfaces

This book brings together selected contributions both on the fundamental information on the physics and chemistry of these materials, new physical ideas and decisive experiments. It constitutes both an insightful treatise and a handy reference for specialists and graduate students working in solid state physics and chemistry, material science and related fields.

This book covers properties, processing, and applications of conducting polymers. It discusses properties and characterization, including photophysics and transport. It then moves to processing and morphology of conducting polymers, covering such topics as printing, thermal processing, morphology evolution, conducting polymer composites, thin films

Explore this comprehensive overview of organic electrochromic materials and devices from a leading voice in the industry Organic Electronics for Electrochromic Materials and Devices delivers a complete discussion of the major and key topics related to the phenomenon of electrochromism. The text covers the history of organic electrochromism, its fundamental principles, different types of electrochromic materials, the development of device structures and multi-function devices, characterizations of device performance, modern applications of electrochromic devices, and prospects for future electrochromic devices. The distinguished author places a strong focus on recent research results from universities and private firms from around the world and addresses the issues and challenges faced by those who apply organic electrochromic technology in the real world. With these devices quickly becoming the go-to display technology in the field of electronic information, this resource will quickly become indispensable to all who work or study in the field of optics. Readers will also benefit from the inclusion of: A thorough introduction to organic electrochromism, including its history and the mechanisms of electrochromic devices An exploration of polymer electrolytes for electrochromic applications, including their requirements and types A discussion of electrochromic small molecules, including the development of technology in conjugated polymer and violene-cyanine hybrids A treatment of Prussian blue and metallohexacyanates, including their backgrounds, technology development, crystal structures, synthesis, nanocomposites, and assembled electrochromic devices Perfect for materials scientists, polymer chemists, organic chemists, physical chemists, and inorganic chemists, Organic Electronics for Electrochromic Materials and Devices will also earn a place in the libraries of physicists and those who work in the optical industry who seek a one-stop reference that covers all aspects of organic electrochromic materials.

An overview of the tremendous potential of organic electronics, concentrating on those emerging topics and technologies that will form the focus of research over the next five to ten years. The young and energetic team of editors with an excellent research track record has brought together internationally renowned authors to review up-and-coming topics, some for the first time, such as organic spintronics, iontronics, light emitting transistors, organic sensors and advanced structural analysis. As a result, this book serves the needs of experienced researchers in organic electronics, graduate students and post-doctoral researchers, as well as scientists active in closely related fields, including organic chemical synthesis, thin film growth and biomaterials. Cover Figure: With kind permission of Matitaccia.

Perspective, Theory, and New Materials

Emerging Concepts and Technologies

Electronic and Optical Properties of Conjugated Polymers

Conjugated Polymers, Organic Crystals, Carbon Nanotubes and Graphene

Polymers for Light-Emitting Devices and Displays provides an in-depth overview of fabrication methods and unique properties of polymeric semiconductors, and their potential applications for LEDs including organic electronics, displays, and optoelectronics. Some of the chapter subjects include: • The newest polymeric materials and processes beyond the classical structure of PLED • Conjugated polymers and their application in the light-emitting diodes (OLEDs & PLEDs) as optoelectronic devices. • The novel work carried out on electrospun nanofibers used for LEDs. • The roles of diversified architectures, layers, components, and their structural modifications in determining efficiencies and parameters of PLEDs as high-performance devices. • Polymer liquid crystal devices (PLCs), their synthesis, and applications in various liquid crystal devices (LCs) and displays. • Reviews the state-of-art of materials and technologies to manufacture hybrid white light-emitting diodes based on inorganic light sources and organic wavelength converters.

With the development of courses on materials synthesis and the need to carry out specific chemical transformations in the laboratory, good practical advice will be needed for those requiring more detail on conjugated materials synthesis. The purpose of this book is to give researchers and students an introduction and reference that efficiently provides general information for each important synthetic method category and a number of examples from the literature to convey practically important variations. It is useful as an outline for advanced organic and materials science courses as well as a good introduction and desk reference for new and experienced researchers in the field.