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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This is the Final Report for this grant and includes major results along with publications. Some results noted include preparation and study of a low band-gap transparent conducting polymer, poly[1,4-bis(2-heteroaryl)-p-phenylenes], electroactive transition metal containing polymers and conducting polymer composites. In addition, many studies dealing with ion transport upon redox switching of these electroactive polymers have been carried out and new probes to monitor these ion fluxes have been developed. A highly efficient polypyrrole platinum "nano-composite," with useful catalytic properties has also been developed. Accurate theoretical and computational techniques, along with a modified Extended Hückel band structure procedure, have been developed.					
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FINAL REPORT

Electronic and Ionic Transport in Processable Conducting Polymers

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Electronic and Ionic Transport in Processable Conducting Polymers

The following is a summary of some of the important results which we have achieved and studies which have been done over the past three years.

- 1) Poly(2,3-dihexylthieno[3,4-b]pyrazine), with a band-gap of 0.95 eV and a doped conductivity of $3.6 \times 10^{-2} \text{ S cm}^{-1}$, has been prepared and it went from opaque blue-black to transparent light yellow upon doping.
- 2) Bis(2-furanyl) phenylene polymers have been synthesized and shown to exhibit substituent independent conductivities due to low steric interactions along the conjugated chain.
- 3) Dual ion transport has been induced during electrochemical switching using conducting polymer bilayers.
- 4) Water soluble polybenzimidazole (PBI) based polyelectrolytes have been synthesized by PBI derivatization reactions.
- 5) A chain-growth polymerization mode has been discovered for the electropolymerization of pyrrole in aqueous ClO_4^- , BF_4^- and PF_6^- electrolytes.
- 6) Poly(1,3-cyclohexadiene-*alt*-2-fluoroacrylonitrile) has been synthesized, shown to be an alternating copolymer and exhibits improved thermal stability over its chloroacrylonitrile analog.
- 7) Symmetrically substituted poly[1,4-bis(2-thienyl)-2,5-dialkoxyphenylenes] have been shown to be more highly ordered (semi-crystalline) and to exhibit higher conductivities than their amorphous, unsymmetrically substituted analogs.
- 8) EPR studies of poly[1,4-bis(2-thienyl)-2,5-dialkoxyphenylenes] during redox switching has shown a rare stabilization of a polaronic state.
- 9) Composites of electrically conducting metal tetrathiooxalates and poly(vinyl alcohol) with high mechanical durability have been prepared.
- 10) Processable and electroactive nickel bis(dithiolene) containing polycarbonates and polyurethanes have been shown to serve as near-infrared absorbing films.
- 11) Fibers and films of blends of poly(3-decylthiophene) with polyethylene, prepared in collaboration with Hoechst-Celanese Research Center, showed no diminution in electrical conductivity compared with pure poly(3-decylthiophene) but spinning properties were vastly improved.
- 12) New families of in situ probes for monitoring ion fluxes across electrode/electrolyte interphases were developed.
- 13) Highly efficient polypyrrole/platinum "nanocomposites" for electrocatalysis and fuel cell applications were developed. (patent pending)

- 14) A new voltammetric method for characterizing chemically-synthesized conducting polymers was developed. (patent pending)
- 15) The electrochemical quartz crystal microgravimetry technique for the study of conducting polymers was refined.
- 16) A better understanding of ion transport in "self-doped" conducting polymer composites was achieved.
- 17) Accurate theoretical techniques for the evaluation of the relative stability of the quinoid and aromatic forms of conjugated polyheterocycles was developed.
- 18) Efficient and practical computational techniques for performing conformational analyses on conjugated polyheterocycles, including accurate estimates of the backbone twist angles, which are extremely important for the prediction on band gaps, was developed.
- 19) A modified Extended Hückel band structure procedure which yields remarkably accurate band gaps in these systems was developed.

The following is a listing of the journal publications and technical reports which have emanated from the grant.

Papers Published in Refereed Journals

- 1) Nayak, K. and Marynick, D. S. "The Interplay between the Geometric and Electronic Structures of Polyisothianaphthene Polyisobenzothienophene, Polythieno(3,4-b)pyrazine and Poly(3,4-b)quinoxaline", *Macromolecules* **1990**, *23*, 2237-2245.
- 2) Qiu, Y.-J. and Reynolds, J. R. "Poly[3,6-(carbaz-9-yl)propanesulfonate]: A Self-Doped Polymer with Both Cation and Anion Exchange Properties", *J. Electrochem. Soc.* **1990**, *137*, 900-904.
- 3) Sharma, S. C., Krishnamoorthy, S., Naidu, S. V., Eom, C. I., Krichene, S. and Reynolds, J. R. "Positron Annihilation and Conductivity Correlations in Poly(pyrrole tosylate) and Poly(pyrrole fluoride)", *Phys. Rev. B.* **1990**, *41*, 5258-5265.
- 4) Gieselman, M. G. and Reynolds, J. R. "Poly(*p*-phenyleneterephthalamido propane sulfonate): A New Polyelectrolyte for Application to Conducting Molecular Composites", *Macromolecules* **1990**, *23*, 3118-3124.
- 5) Wang, F. and Reynolds, J. R. "Soluble and Electroactive Nickel Bis(dithiolene) Polymers Prepared Via Metal Complexation Polymerization", *Macromolecules* **1990**, *23*, 3219-3225.
- 6) Reynolds, J. R. and Jolly, C. A. "Mechanically Durable, Semiconducting and Optically Polarizing Poly(nickel tetrathiooxalate)/Poly(vinyl alcohol) Composites", *Chem. Mater.* **1990**, *2*, 479-480.
- 7) Basak, S., Rajeshwar, K. and Kaneko, M. "Ion Binding by Poly{pyrrole-co-[3-(pyrrol-1-yl)propane sulfonate]} Thin Films", *Anal. Chem.* **1990**, *62*, 1407-1413.

- 8) Basak, S., Rajeshwar, K. and Kaneko, M. "In Situ Photogeneration of a Catalyst on a Chemically-Modified Electrode Surface: Application to a Mixed Valent Hexacyanoferrate System," *J. Electroanal. Chem.* **1990**, 295, 403-407.
- 9) Tsai, E. W., Abraham, P. and Rajeshwar, K. "Transient Electrochemical Response of Thermal Ruthenium Oxide Thin Films in Aqueous Electrolytes", *Current Separations*, **1990**, 130-134.
- 10) Reynolds, J. R. and Pomerantz, M. "Processable Electronically Conducting Polymers", in *Electroresponsive Molecular and Polymeric Systems*; Skotheim, T. A., Ed.; Marcel Dekker: New York, 1991; Vol. 2, Chapter 4, pp 187-256.
- 11) Reynolds, J. R., Ruiz, J. P., Child, A. D., Nayak, K. and Marynick, D. S. "Electrically Conducting Polymers Containing Alternating Substituted Phenylenes and Bithiophene Repeat Units", *Macromolecules* **1991**, 24, 678-687.
- 12) Pomerantz, M., Tseng, J. J., Zhu, H., Sproull, S. J., Reynolds, J. R., Uitz, R., Arnott, H. J. and Haider, M. I. "Processable Polymers and Copolymers of 3-Alkylthiophenes and Their Blends", *Synth. Met.* **1991**, 41, 825-830.
- 13) Reynolds, J. R., J. R., Ruiz, J. P., Nayak, K., Child, A. D. and Marynick, D. S. "Electrically Conducting Polymers Containing Alternating Substituted Phenylene and Heterocycle Repeat Units", *Synth. Met.* **1991**, 41, 783-788.
- 14) Prezyna, L. A., Wnek, G. E., Lee, J. J., Qiu, Y.-J., and Reynolds, J. R. "Interaction of Cationic Proteins with Electroactive Polypyrrole/Poly(styrene sulfonate) and Poly(N-methylpyrrole)/Poly(styrene sulfonate) Films", *Synth. Met.* **1991**, 41, 979-981
- 15) Sundaresan, N. S., Reynolds, J. R. and Ruiz, J. P. "Photocurrent Response of Poly(3-ethylmercaptothiophene)", *J. Mat. Sci.* **1991**, 10, 345-347.
- 16) Qiu, Y.-J. and Reynolds, J. R. "Dopant Anion Controlled Ion Transport Behavior of Polypyrrole", *Polym. Eng. and Sci.* **1991**, 31, 417-421.
- 17) Baker, C. K., Qiu, Y.-J. and Reynolds, J. R. "Electrochemically Induced Mass Transport in Poly(pyrrole)/Poly(styrene sulfonate) Molecular Composites", *J. Phys. Chem.* **1991**, 95, 4446-4452.
- 18) Wang, F., Qiu, Y.-J. and Reynolds, J. R. "Electroactive, Near-Infrared Absorbing, Nickel Bis(dithiolene) Complex Polycarbonates and Polyurethanes", *Macromolecules* **1991**, 24, 4567-4574.
- 19) Prezyna, L. A., Wnek, G. E., Qiu, Y.-J. and Reynolds, J. R. "Interaction of Cationic Polypeptides with Electroactive Polypyrrole/Poly(styrene sulfonate) and Poly(N-methylpyrrole)/Poly(styrene sulfonate)", *Macromolecules* **1991**, 24, 5283-5287.
- 20) Stickle, W. F., Reynolds, J. R. and Jolly, C. A. "Surface Characterization of Electrically Conducting Nickel Tetrathiooxalate/Poly(Vinyl Alcohol) Composites", *Langmuir* **1991**, 7, 2460-2463.
- 21) Child, A. D. and Reynolds, J. R. "Separation of Neutral-to-Polaron and Polaron-to-Bipolaron Redox Events in Alkoxy Substituted Di-2-thienylphenylene Polymers", *J. Chem. Soc., Chem. Commun.* **1991**, 1779.

- 22) Krishna, V., Ho, Y-H., Basak, S. and Rajeshwar, K. "Luminescence Probe and Voltammetric Study of Ion Transport During Redox Switching of Poly(pyrrole) Thin Films", *J. Am. Chem. Soc.* **1991**, *113*, 3325-3333.
- 23) Tsai, E. W. and Rajeshwar, K., "Influence of Temperature on the Voltammetric Response of Thermal Ruthenium Oxide Electrodes", *Electrochim. Acta* **1991**, *36*, 27-30.
- 24) Basak, S., Zacharias, P. S. and Rajeshwar, K. "Binding and Surface Coordination Chemistry of Copper (II) Macrocycles at Nafion-Modified Glassy Carbon Electrodes", *J. Electroanal. Chem.*, **1991**, *319*, 111-123.
- 25) Pomerantz, M., Chaloner-Gill, B., Harding, L. O., Tseng, J. J. and Pomerantz, W. J. "Poly(2,3-dihexylthieno[3,4-b]pyrazine). A New Processable Low Band-Gap Polyheterocycle", *J. Chem. Soc., Chem. Commun.* **1992**, 1672-1673.
- 26) Hong, S. Y. and Marynick, D. S. "Modified Extended Hückel Band Calculations on Conjugated Polymers", *J. Chem. Phys.* **1992**, *96*, 5497-5504.
- 27) Hong, S. Y. and Marynick, D. S. "A Theoretical Study of the Conformations and Electronic Structures of Phenylene-pyrrole and Phenylene-furan Copolymers", *Macromolecules* **1992**, *25*, 3591-3595.
- 28) Hong, S. Y. and Marynick, D. S. "Understanding the Conformational Stability and Electronic Structure of Modified Polymers Based on Polythiophene", *Macromolecules* **1992**, *25*, 4652-4657.
- 29) Rajeshwar, K., Lenza, R. O. and de Tacconi, N. R. "Light in an Electrochemical Tunnel? Solving Analytical Problems in Electrochemistry via Spectroscopy", *Anal. Chem.* **1992**, *64*, 429A-441A.
- 30) Ruiz, J. P., Dharia, J. R., Reynolds, J. R. and Buckley, L. J. "Repeat Unit Symmetry Effects on Physical and Electronic Properties of Processable, Electrically Conducting, Substituted Poly(1,4-bis(2-thienyl)phenylenes)", *Macromolecules* **1992**, *25*, 849-860.
- 31) Panchalingam, V. and Reynolds, J. R. "Poly(1,3-cyclohexadiene-*alt*- α -fluoroacrylonitrile): A Thermally Stable, Alternating Copolymer", *J. Polym. Sci., Part A, Polym. Chem.* **1992**, *30*, 967-976.
- 32) Qiu, Y.-J. and Reynolds, J. R. "Electrochemically Initiated Chain Polymerization of Pyrrole in Aqueous Media", *J. Polym. Sci., Part A, Polym. Chem.* **1992**, *30*, 1315-1325.
- 33) Gieselman, M. B. and Reynolds, J. R. "Water Soluble Polybenzimidazole Based Polyelectrolytes", *Macromolecules* **1992**, *25*, 4832-4834.
- 34) Son, Y. and Rajeshwar, K. "Potential-modulated Ultraviolet-Visible and Raman Spectra of Polypyrrole Thin Films in Aqueous Electrolytes: Combination with Voltammetric Scanning and the Influence of Dioxygen on the Stability of Radical Cations and Dications of the Conducting Polymer", *J. Chem. Soc., Faraday Transactions* **1992**, *88*, 605-610.
- 35) Bose, C. S. C., Basak, S. and Rajeshwar, K. "Preparation, Voltammetric Characterization, and Use of a Composite Containing Chemically Synthesized Polypyrrole and a Carrier Polymer", *J. Electrochem. Soc.* **1992**, *139*, L75-L76.

- 36) Bose, C. S. C. and Rajeshwar, K. "Efficient Electrocatalyst Assemblies for Proton and Oxygen Reduction: The Electrosynthesis and Characterization of Polypyrrole Films Containing Nanodispersed Platinum Particles", *J. Electroanal. Chem.* **1992**, *333*, 235-256.
- 37) Basak, K., Bose, C. S. C. and Rajeshwar, K. "Electrochemical Quartz Crystal Microgravimetry of Poly{pyrrole-co-[3-pyrrol-1-yl]propane sulfonate} Films: Electrosynthesis, Ion Transport and Ion Assay, *Anal. Chem.* **1992**, *64*, 1813-1818.

Papers Accepted For Publication in Refereed Journals

- 38) Pomerantz, M., Chaloner-Gill, B., Harding, L. O., Tseng, J. J. and Pomerantz, W. J. "New Processable, Low Band-gap, Conjugated Polyheterocycles", *Synth. Met.* in press.
- 39) Pyo, M. and Reynolds, J. R. "Dual Ion Transport During Electrochemical Switching of Conducting Polymer Bilayers", *J. Chem. Soc., Chem. Commun.* in press.
- 40) Chen, C. C., Bose, C. S. C. and Rajeshwar, K. "The Reduction of Dioxygen and the Oxidation of Hydrogen at Polypyrrole Film Electrodes Containing Nanodispersed Platinum Particles", *J. Electroanal. Chem.* in press.
- 41) Bose, C. S. C., Basak, S. and Rajeshwar, K. "The Electrochemistry of Polypyrrole Chloride Films: A Study of Polymerization Efficiency, Ion Transport During Redox and Doping Level Assay by Electrochemical Quartz Crystal Microgravimetry, pH and Ion Selective Electrode Measurements", *J. Phys. Chem.* in press.

Paper Submitted to Refereed Journals

- 42) Reynolds, J. R., Child, A. D., Ruiz, J. P., Hong, S. Y. and Marynick, D. S. "Substituent Effects on the Electrical Conductivity and Electrochemical Properties of Conjugated Furanyl Phenylene Polymers", *Macromolecules* submitted for publication.

Other Reports

- 43) Reynolds, J. R. and Pomerantz, M. A report on "The International Conference on Science and Technology of Synthetic Metals", *ESN Information Bulletin* (ONR European Office), **1991**, No. 4, 6-9.
- 44) Wynne, K. J., Pomerantz, M. and Reynolds, J. R. A report on "The International Conference on Science and Technology of Synthetic Metals", *ESN Information Bulletin* (ONR European Office), in press.

Papers Acknowledging DARPA Support for Instrumental Purchase

- 45) Pomerantz, M. and Levanon, M. "Bis(dimethyl Malonato)ketazine. Formation and Inversion/Rotation Barrier", *Tetrahedron Lett.* **1990**, *31*, 4265-66.
- 46) Brown, K. L., Brooks, H. B., Zou, X., Victor, M., Ray, A. and Timkovich, R. "Heteronuclear NMR Studies of Cobalamins. 11. ¹⁵N NMR Studies of the Axial Nucleotide

and Amide Side Chains of Cyanocobalamin and Dicyanocobalamin", *Inorg. Chem.* **1990**, *29*, 4841-4844.

- 47) Pomerantz, M. and Levanon, M. "Carbene Addition to the 2,3-Bond of Naphthalene and Thermal Wolff Rearrangement of Bis(methoxycarbonyl)carbene", *Tetrahedron Lett.* **1991**, *32*, 995-998.
- 48) Chou, W.-N. and Pomerantz, M. "*N*-Phenyl-*P,P,P*-triarylphospha- λ^5 -azenes, Triarylphosphines and Triarylphosphine Oxides. Substituent Effects on ^{15}N , ^{31}P and ^{13}C NMR Spectra", *J. Org. Chem.* **1991**, *56*, 2762-2769.

Technical Reports

- 1) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 18, Grant No. N00014-90-J-1320 DARPA/ONR, January 10, 1990.
- 2) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 19, Grant No. N00014-90-J-1320 DARPA/ONR, April 10, 1990.
- 3) Gieselmann, M. B. and Reynolds, J. R. "Poly(*p*-phenyleneterephthalamide propanesulfonate): A New Polyelectrolyte for Application to Conducting Molecular Composites", Technical Report No. 20, Grant No. N00014-90-J-1320 DARPA/ONR, April 17, 1990.
- 4) Wang, F. and Reynolds, J. R. "Soluble and Electroactive Nickel bis(dithiolene) Polymers Prepared via Metal Complexation Polymerization", Technical Report No. 21, Grant No. N00014-90-J-1320 DARPA/ONR, April 17, 1990.
- 5) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", End-of-the-Year/Technical Report No. 22, Grant No. N00014-90-J-1320 DARPA/ONR, May 25, 1990.
- 6) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 23, Grant No. N00014-90-J-1320 DARPA/ONR, October 5, 1990.
- 7) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 24, Grant No. N00014-90-J-1320 DARPA/ONR, January 16, 1991.
- 8) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 25, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.
- 9) Stickle, W. F., Reynolds, J. R. and Jolly, C. A. "Surface Characterization of Electrically Conducting Nickel Tetrathiooxalate/Poly(vinyl alcohol) Composites", Technical Report No. 26, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.

- 10) Baker, C. K., Qiu, Y.-J. and Reynolds, J. R. "Electrochemically Induced Charge and Mass Transport in Polypyrrole/Poly(styrene sulfonate) Molecular Composites", Technical Report No. 27, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.
- 11) Wang, F., Qiu, Y.-J. and Reynolds, J. R. "Electroactive, Near Infrared Absorbing Nickel Bis(dithiolene) Complex Polycarbonates and Polyurethanes", Technical Report No. 28, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.
- 12) Reynolds, J. R. and Pomerantz, M. "Processable Electronically Conducting Polymers", Technical Report No. 29, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.
- 13) Pomerantz, M., Tseng, J. J., Zhu, H., Sproull, S. J., Reynolds, J. R., Uitz, R., Arnott, H. J. and Haider, M. I. "Processable Polymers and Copolymers of 3-Alkylthiophenes and Their Blends", Technical Report No. 30, Grant No. N00014-90-J-1320 DARPA/ONR, April 12, 1991.
- 14) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", End-of-the-Year/Technical Report No. 31, Grant No. N00014-90-J-1320 DARPA/ONR, May 28, 1991.
- 15) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Quarterly-Technical Report No. 32, Grant No. N00014-90-J-1320 DARPA/ONR, October 21, 1991.
- 16) Qiu, Y.-J. and Reynolds, J. R. "Electrochemically Initiated Chain Polymerization of Pyrrole in Aqueous Media", Technical Report No. 33, Grant No. N00014-90-J-1320 DARPA/ONR, October 21, 1991.
- 17) Panchalingam, V. and Reynolds, J. R. "Poly(1,3-cyclohexadiene-*alt*- α -fluoroacrylonitrile): Synthesis and Structural Analysis of a New Alternating Copolymer", Technical Report No. 34, Grant No. N00014-90-J-1320 DARPA/ONR, October 21, 1991.
- 18) Ruiz, J. P., Dharia, J. R., Reynolds, J. R. and Buckley, L. J. "Symmetry Effects on the Physical and Electronic Properties of Processable, Electrically Conducting, Substituted Poly(di-2-thienylphenylenes)", Technical Report No. 35, Grant No. N00014-90-J-1320 DARPA/ONR, October 21, 1991.
- 19) Child, A. D. and Reynolds "Separation of Neutral-to-Polaron and Polaron-to-Bipolaron Redox Events in Alkoxy Substituted Di-2-thienylphenylene Polymers", Technical Report No. 36, Grant No. N00014-90-J-1320 DARPA/ONR, October 21, 1991.
- 20) Pomerantz, M., Reynolds, J. R., Rajeshwar, K. and Marynick, D. S. "Electronic and Ionic Transport in Processable Conducting Polymers", Technical Report No. 37, Grant No. N00014-90-J-1320 DARPA/ONR, May 21, 1992.
- 21) Hong, S. Y. and Marynick, D. S. "Understanding the Conformational Stability and Electronic Structures of Modified Polymers Based on Polythiophene", Technical Report No. 38, Grant No. N00014-90-J-1320 DARPA/ONR, July 30, 1992.
- 22) Pomerantz, M., Chaloner-Gill, B., Harding, L. O., Tseng, J. J. and Pomerantz, W. J. "Poly(2,3-dihexylthieno[3,4-b]pyrazine). A New Processable Low Band-Gap Polyheterocycle", Technical Report No. 39, Grant No. N00014-90-J-1320 DARPA/ONR, October 5, 1992.

The following are the personnel who were paid with funds from this grant.

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