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A review of: "Advances in Synthetic Metals Twenty Years of Progress in Science and Technology" edited by P. Bernier, S. Lefrant, and G. Bidan, Elsevier Science S.A., 1999; ISBN 0 444 72003 0 (hardback); 0 444 72004 9(paperback); xii + 445 pages; $198.00; 390.00 NLG(hardback).

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Book Review

"Advances in Synthetic Metals Twenty Years of Progress in Science and Technology" edited by P. Bernier, S. Lefrant, and G. Bidan, Elsevier Science S.A., 1999; ISBN 0 444 72003 0 (hardback); 0 444 72004 9(paperback); xii + 445 pages; $198.00; 390.00 NLG(hardback).

The motivation for this book is apparently the 20th anniversary of the initial report in 1977 of the rendering of the Shirakawa polyacetylene film conductive by exposure to oxidizing and reducing agents, commonly termed "dopants". The authors of the articles in this book were invited by the organizers of the International Conference on Science and Technology of Synthetic Metals '98(ICSM'98) to "review the progress of research in the past two decades in a unifying and pedagogical manner". Thus, 1998 is the 21st anniversary of polyacetylene doping, the 25th anniversary of the initial reports of the charge-transfer salt TTF-TCNQ the first organic metal, or the 35th anniversary of the report of the rendering of poly-*p*-phenylene conductive by exposure to $SbCl_5$. The book consists of a preface, 8 articles, and a 5 page subject index.

The articles are "20 Years of "Synthetic Metals"-the Role of Synthesis" by D. Marsitzky and K. Müllen, "Twenty Years of Conducting Polymers: From Fundamental Science to Applications" by M.D. McGehee, E.K. Miller, D. Moses, and A.J. Heeger, "The Normal Phase of Quasi-One-Dimensional Organic Superconductors" by C. Bourbonnais and D. Jérome, "Interplay of Structural and Electronic Properties" by S. Kagoshima, R. Kato, H. Fukuyama, H. Seo, and H. Kino, "Organic Lower-Dimensional Crystalline and Monolayer Conductors" by R.M. Metzger, "Electron Transport in Conducting Polymers" by A.J. Epstein, "Inherently Conducting Polymers: Their Role in the Evolution of Intelligent Polymer Systems" by G.G. Wallace and L.A.P. Kane-Maguire, and "Conducting Forms of Carbon: Fullerenes, Onions, Nanotubes" by L. Forró, A. Jánossy, D. Ugarte, and W.A. de Heer.

The editors did not write a preface or introduction. The preface, titled "Synthetic metals-General considerations" was written by J. Friedel. The usage of English in the preface is substandard, and the preface has the feeling of something written "off the top of one's head". Nevertheless, it is clear that Friedel

appreciates that a significant literature of "synthetic metals" existed before 1978 (or 1977).

The first two articles are the longest in the book, 97 and 108 pages, respectively. Collectively they make several key points: 1) since "synthetic metals" are new materials, a new field of science and technolgy was created; 2) the organic materials, especially polymers, offer a unique combination of properties (electronic and processability) not found in known materials; 3) much of the progress in the organic synthetic metals has been driven by synthesis, purification, and characterization of new materials. The article by Marsitzky and Müllen presents a strong overview of synthetic methods for conjugated polymers, charge-transfer donors, especially tetrachalcogenofulvalenes, polycyclic aromatic hydrocarbons, functional dyes, and functionalization of fullerenes. This article also contains a number of philosophically relevant remarks and some perspectives concerning interaction of chemists with physicists and engineers.

The article by McGehee, Miller, Moses, and Heeger is an impressive overview of the science and technological potential associated with conjugated polymers and devices derived from them. It includes discussion of electronic structure, doping processes, the elementary excitations of conducting polymers, metal-to-insulator transition, photoconductivity, third order nonlinear optics(NLO), light emitting diodes and electrochemical cells, and laser action. A discussion of the possibility of superconductivity in metallic polymers emphasizes that materials with significantly improved structural order are required before superconductivity might be observed. The article notes that its subject is at the intersection of physics, chemistry, and materials science; it offers Table VA-1 that includes both physics terms and the corresponding chemistry terms(e.g. doping and redox chemistry) for a variety of relevant phenomena. Nevertheless the article is not without problems. It asserts that areas involving electronic and optical properties were previously considered outside the domain of polymer science. This will come as news to the numerous scientists who worked on photoconducting polymers, for example, in the research laboratories of Xerox, IBM, and Eastman Kodak, not to mention other companies, before 1977. The caption for Figure VB-1 is deficient. Studies of NLO in polydiacetylenes are usually traced to the Sauteret, et al. article in *Phys. Rev. Lett.* in 1976 and not the article cited in reference 219.

The article by Bourbonnais and Jérome is a detailed discussion of the experimental physics and associated theory of the organic metal charge transfer salts at temperatures above 3 dimensional ordering transitions. The article by Kagoshima, *et al.*, also deals with metallic charge transfer salts and consists of 3 parts with different authors responsible for each part. The article is a study of the relationship between crystal structure and electronic structure. Hence one

finds detailed discussions of experimental and theoretical aspects of topics such as band structure, diffuse scattering, and the various ground states observed.

The article by Metzger also recognizes that there were "serious researchers of the organic solid state" before the mid 1960s and gives his list of 12 such individuals. If one examines the author index of "Organic Semiconductors" by F. Gutmann and L.E. Lyons(both omitted from Metzger's list) the number of serious researchers is much longer. Indeed, if in the study of the optical properties of conjugated polymers, for example, we must be concerned with excitons and excimers, etc., the list of serious researchers really begins to grow. The article has a series of relatively short paragraphs on topics such as 1D band theory and instabilities, conductivity and superconductivity, C-T complexes and crystals, TTF-TCNQ, Bechgaard and ET salts, and "unimolecular rectification". In my opinion, Metzger's claim that his 1997 paper is a confirmation of the Aviram-Ratner proposal is seriously flawed. The Al electrodes used in the devices are the most serious problem. If Al reacts with polythiophene, then thermodynamics dictates that it will be even more reactive toward the substrate that Metzger and his coworkers use. Hence there is an additional interfacial layer in these devices, as there is in earlier work, and this is not what Aviram-Ratner discussed. The asymmetric current-voltage characteristics reported by N.J. Geddes, *et al., Appl. Phys. Lett.*, 56, 1916(1990), precede those cited by Metzger. Tables II and III have useful, if incomplete, summaries of the properties of organic metals and superconductors.

The article by Epstein is the shortest in the book(18 pages); it is a good summary of the models used to explain the temperature dependence of the conductivity in several conducting polymer systems. Structural disorder is noted as the prime source of carrier localization.

The article by Wallace and Kane-Maguire is a brief review of the use of conducting polymers as sensors, processors, actuators, and energy conversion systems. Wallace has earlier written a book around the theme of conducting polymers as intelligent materials sysstems, and that theme is continued here. The article discusses topics such as enzyme and antibody immobilization by conducting polymers, the introduction of specific substituents into conducting polymers or the dopant anion to give specific sensing functions, battery and other storage applications, and a variety of processing techniques to make these materials more appropriate for various device fabrications.

The article by Forró, Jánossy, Ugarte, and de Heer is a subjective review of properties of these recently discovered forms of carbon. Topics presented include fullerene superconductivity, electronic structure and phase transitions of fullerides and polymers, carbon nanotube production, structure, electronic structure, electrical properties, and carbon onion formation.

This book was sent in soft cover to registrants of ICSM'98 and is also on the CD-ROM containing the proceedings of ICSM'98. In spite of shortcomings noted above, the book will be useful to both people seeking an introduction to various topics as well as experienced researchers in this area.

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