

Number of Organic Superconductors Grows

New discoveries suggest that the superconductivity of certain organic salts is a general phenomena

Superconductivity—the complete absence of electrical resistance—has long been assumed to have great industrial potential. Power transmission without any loss of energy would increase the efficiency of the national electrical grid and would make possible more efficient electric motors and much more powerful electromagnets. The absence of heat generation would make possible much larger, more powerful computers. And the ability of a superconductor to expel an external magnetic field (the Meissner effect) could make it possible to “float” a vehicle above a superconducting roadway for smooth and efficient transportation.

The problem with all of these potential applications is that superconductivity in metals requires very low temperatures and, thus, expensive cooling equipment. The highest recorded critical temperature (the temperature at which a material passes from conducting to superconducting) is 23.2 K for the alloy Nb_3Ge . Since that critical temperature was discovered in 1973 and no higher one has yet been observed, many investigators have concluded somewhat reluctantly that metallic alloys with significantly higher critical temperatures will probably not be observed soon. Some of these people have turned to organic materials in the hope that a material with a higher critical temperature can be rationally designed.

In 1979, Klaus Bechgaard of the University of Copenhagen and Denis Jérôme of the University of Paris-South at Orsay found a family of selenium-based organic chemicals that are superconducting. Earlier this year, Edward M. Engler, Richard L. Greene, and their colleagues at the IBM San Jose Research Laboratory reported the discovery of a sulfur-containing organic superconductor. This result dispelled fears that the French results might represent an anomaly rather than a general phenomenon.

The first stable conducting organic material was synthesized in 1960 at the Du Pont Company. The new compound was 7,7,8,8-tetracyano-*p*-quinodimethane, usually abbreviated TCNQ. This material is not itself conductive, but in salts such as $\text{Cs}_2(\text{TCNQ})_2$, some of the TCNQ molecules become negatively charged and electrons can move from charged molecules to neutral ones, carrying a current in the process. The best organic conductors have a conductivity of about 1000 to 2000 $\text{ohm}^{-1} \text{cm}^{-1}$ at room temperature, compared to $10^5 \text{ ohm}^{-1} \text{cm}^{-1}$ for copper.

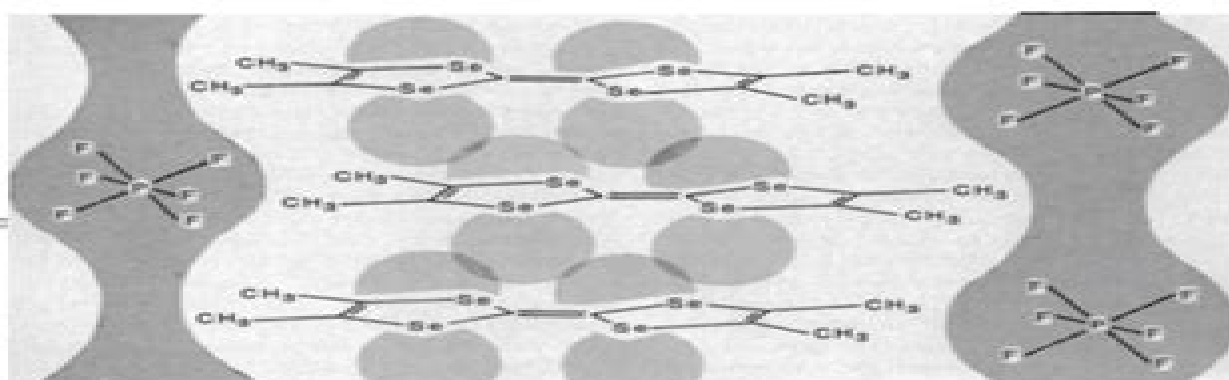
Organic conductors like $\text{Cs}_2(\text{TCNQ})_2$ typically undergo a phase change at low temperatures, where they are converted from conductors to insulators. Nonetheless, they share two key characteristics with the subsequently discovered superconductors. The organic portion of the

conductor is composed of large, planar molecules with extended π -electron systems above and below the planes. The energy cost of partially filling or partially opening the valence bands is small, and the molecules can become stacked one over the other like pancakes so that electrons can propagate from plane to plane along the stack. The counterions occupy the spaces between the stacks. These arrays are highly anisotropic—that is, the electrical conductivity is much greater (often as much as 500 times greater) in the direction parallel to the stacks than in a direction perpendicular to them.

Some investigators reasoned that conductivity could be improved by incorporating atoms with more *d*-electrons into the planar arrays. In the early 1970's, Fred Wudl, now at the University of California, Santa Barbara, synthesized tetrathiafulvalene (TTF), which contains four sulfur atoms and which readily gives up an electron to form a stable, positively charged structure. Wudl found that TTF could be combined with chlorine atoms to produce a highly conductive material. Subsequently, Dwaine O. Cowan and his colleagues at Johns Hopkins University and Alan J. Heeger and his associates at the University of Pennsylvania independently combined TTF and TCNQ to form the first “organic metal.” Neither material, however, gave any hint of superconductivity.

To modify the electron-donating properties of TTF, some investigators tried to make selenium analogs. Bechgaard, then a postdoctoral fellow with Cowan at Johns Hopkins, synthesized tetramethyltetraselenafulvalene or TMTSF. Crystals of TMTSF and TCNQ can be either conductors or insulators at room temperature, depending on how the crystals are prepared, but the conductor becomes an insulator below 60 K. Bechgaard and Jérôme next prepared the analogous salt of TMTSF and 2,5-dimethyl-TCNQ (DMTCNQ). Following up on a suggestion by Meir Weger of the Hebrew University of Jerusalem, they subjected the TMTSF-DMTCNQ to a pressure of 10,000 atmospheres (10 kbar) before cooling it. This produced a stabilization of the conductivity at low temperatures but not the hoped-for superconductivity.

Encouraged by the stabilization of



"Zig-zag" stacks
In Bechgaard salts such as $(\text{TMTSF})_2\text{PF}_6$, the planar organic molecules are stacked like pancakes with every other molecule slightly offset. This provides niches in which the inorganic salts sit. The shaded areas represent regions of charge density.

Organic Superconductors

H. Meier



Organic Superconductors:

Organic Superconductors Takehiko Ishiguro, Kunihiro Yamaji, Gunzi Saito, 2012-12-06 Organic Superconductors is an introduction to organic conductors and superconductors and a review of the current status of the field First organic conductors are described then the structures and electronic properties of organic superconductors are discussed illustrated with examples of typical compounds The book deals in detail with theories of the mechanism of superconductivity and more briefly with spin density waves The design principle and synthesis of organic superconductors are also described This second edition covers the research activities of the last few years *Organic Superconductors* Takehiko Ishiguro, Kunihiro

Yamaji, 2012-12-06 The initial impetus for the search for an organic superconductor was the proposal of the existence of a polymer superconductor with a high critical temperature T_c This spurred on activities having the aim of synthesizing and characterizing organic conductors which had already been going on for two decades These efforts have resulted in the thriving field of low dimensional conductors and superconductors This monograph is intended to be an introduction to and review of the study of organic conductors and superconductors The investigations are to warrant a treatise of some length At the same time sufficiently rich they have produced a few active subfields each containing exciting topics This situation seems to necessitate a monograph describing the current status of the field for both researchers and newcomers to the field Such a need may also be felt by scientists engaged in the study of the high T_c oxide superconductors for comparison of the two kinds of new superconductors which share some important aspects for example the low dimensionality and the competition or coexistence of superconductivity and magnetism However available experimental and theoretical results are sometimes conflicting and have not yet been arranged into a coherent standard picture of the whole field Further developments are continually being reported and therefore it is still premature to write a textbook about some of the topics However we have tried to include discussions of recent topics in this volume *The Physics of Organic Superconductors and Conductors*

Andrei Lebed, 2008-03-26 This bang up to date volume contains the distilled wisdom of some of the world's leading minds on the subject Inside there is a treasure trove of general tutorial and topical reviews written by leading researchers in the area of organic superconductors and conductors The papers hail from all over the world as far afield as the USA and Australia They cover contemporary topics such as unconventional superconductivity non Fermi liquid properties and the quantum Hall effect

Organic Superconductivity Vladimir Z. Kresin, William A. Little, 2013-11-11 This book contains papers presented at the International Conference on Organic Superconductivity which was held May 20-24 1990 at the Stanford Sierra Conference Center South Lake Tahoe California In the twenty years since the First Conference on Organic Superconductivity was held Hawaii 1969 there has been remarkable progress in the field At present development is accelerating with contributions from many groups in many countries worldwide The discovery of high T_c superconductivity by G Bednorz and K Muller in 1986 and subsequent developments in the ceramic superconductors have had an enormous impact on the field of

superconductivity as a whole This discovery occurred in an area entirely different from that of conventional superconductivity underscoring the importance of the search for and study of novel materials of all kinds We believe that the organics with their wide range of structural chemical and physical properties belong in this category of novel materials This book reflects the efforts of researchers from various disciplines physicists chemists and materials scientists It addresses the normal and superconducting properties of organic materials as well as the search for new compounds and new syntheses We are pleased to note that one of these papers reports on the discovery of a new organic superconductor with a record high T_c in this class One chapter is devoted to a comparison of organic superconductors and the cuprates another to the prospects of discovering other novel conducting or superconducting compounds

The Physics of Superconductors Karl-Heinz

Bennemann, John B. Ketterson, 2011-06-27 This is the second volume of a comprehensive two volume treatise on superconductivity that represents the first such publication since the earlier widely acclaimed books by R Parks It systematically reviews the basic physics and recent advances in the field Leading researchers describe the state of the art in conventional phonon induced superconductivity high T_c superconductivity and in novel superconductivity including triplet pairing in the ruthenates The second volume is largely concerned with novel superconductors such as heavy fermion metals and organic materials and also includes granular superconductors Important new results on current problems are presented in a manner designed to stimulate further research Numerous illustrations diagrams and tables make this book especially useful as a reference work for students teachers and researchers Volume 1 treats Conventional and High T_c Superconductors

3 540 43883 1 **Organic Conductors** Farges, 1994-08-22 This work examines all aspects of organic conductors detailing recent theoretical concepts and current laboratory methods of synthesis measurement control and analysis It describes advances in molecular scale engineering including switching and memory systems Schottky and electroluminescent diodes field effect transistors and photovoltaic devices and solar cells

The Physics and Chemistry of Organic

Superconductors Gunzi Saito, 1990 **Introduction to Organic Electronic and Optoelectronic Materials and**

Devices Sam-Shajing Sun, Larry R. Dalton, 2008-05-29 Reflecting rapid growth in research and development on organic polymeric electronic and photonic materials and devices Introduction to Organic Electronic and Optoelectronic Materials and Devices provides comprehensive coverage of the state of the art in an accessible format The book presents fundamentals principles and mechanisms complem

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Lebed, 2009-09-02 This bang up to date volume contains the distilled wisdom of some of the world's leading minds on the subject Inside there is a treasure trove of general tutorial and topical reviews written by leading researchers in the area of organic superconductors and conductors The papers hail from all over the world as far afield as the USA and Australia They cover contemporary topics such as unconventional superconductivity non Fermi liquid properties and the quantum Hall effect

Quasi-one-dimensional Organic Superconductors Wei Zhang, Carlos A R Sa De Melo, 2018-06-22 The book includes a

thorough description of a wide range of physical properties of organic superconductors of reduced dimensionality The authors start with an overview of the field followed by a background discussion and selected experimental topics A critical discussion of theoretical proposals is presented under the constraints of experimental observations and exciting possibilities for the symmetry of the order parameter are presented including the cases of inhomogeneous superconducting states and triplet superconductivity The possible origins of Cooper pairing are explored and tests to detect experimentally the pairing symmetry are described in detail The book ends with a discussion of important open questions where the search for their answers will keep the field alive for the next decade

Organic Superconductors (including Fullerenes) Jack Marvin Williams, 1992 A comprehensive coverage of organic superconductors this guide details the synthesis structure conductivity superconductivity and theoretical concepts of the subject The book is intended for chemists physicists and material scientists

Chemical Equilibria Bases for Oxide and Organic Superconductors R. J. Thorn, 1996-03-21 A new perspective on superconductivity This book offers a perspective on superconductivity that focuses on chemical equilibria as the basis for the conceptual difference between chemistry and physics It shows how chemical equilibria involving changes in valence states with small separations in energies render oxides nonstoichiometric similarly in organic conductors the energies of valence states give mixed valencies equilibria The author proposes that mixed valency holds the key to similarities between organic compounds and oxides Chemical Equilibria Bases for Oxide and Organic Superconductors Covers introductory topics relating to superconductivity and superconducting materials Puts crystal structures in context and shows that the structure of a nonstoichiometric phase requires going beyond the conventional methods of X ray and neutron diffraction Identifies the fundamental role that mixed valence states play in chemical equilibria Provides mathematical analyses and interpretation of the pertinent data Shows that the normal state is characterized by small Fermi and small gap energies Sheds new light on the normal state in terms of small polarons and the transition to bipolarons in the superconducting diamagnetic state Explores the interrelations among the three signatures of superconductivity resistance diamagnetic susceptibility and specific heat Includes a disk containing programs that allow the user to calculate and graphically present various properties of superconducting materials This volume presents an excellent selection of topics rather than a review of articles providing an intriguing and insightful treatment of oxide and organic superconductors for professionals teaching faculty and graduate students in solid state chemistry materials science and physics

Fermi Surfaces of Low-Dimensional Organic Metals and Superconductors Joachim Wosnitza, 2006-04-11 Fermi Surfaces of Low Dimensional Organic Metals and Superconductors is an introduction to quasi one and quasi two dimensional organic metals and a review of the current knowledge on the electronic structure of these materials The principal structural electronic and superconducting properties are described and illustrated with many examples The book introduces the basic theoretical concepts necessary for the understanding of the experimental techniques and reviews in detail recent results in the investigation of the Fermi surface

topology The book is intended both as an introduction and as a reference book for active researchers

Organic Superconductivity M. Hérítier, 2000 Organic Semiconductors H. Meier, 1974 *The Physics of Superconductors: Superconductivity in nanostructures, high-Tc and novel superconductors, organic superconductors* K. H. Bennemann, John Boyd Ketterson, Organic Superconductors, 2009

Intense magnetic fields are an essential tool for understanding layered superconductors Fundamental electronic properties of organic superconductors are revealed in intense 60 tesla magnetic fields Properties such as the topology of the Fermi surface and the nature of the superconducting order parameter are revealed With modest maximum critical temperatures 13K the charge transfer salt organic superconductors prove to be incredibly valuable materials as their electronically clean nature and layered highly anisotropic structures yield insights to the high temperature superconductors Observation of de Haas van Alphen and Shubnikov de Haas quantum oscillatory phenomena magnetic field induced superconductivity and re entrant superconductivity are some of the physical phenomena observed in the charge transfer organic superconductors In this talk I will discuss the nature of organic superconductors and give an overview of the generation of intense magnetic fields from the 60 tesla millisecond duration to the extreme 1000 tesla microsecond pulsed magnetic fields *The Physics and Chemistry of Organic Superconductors* Gunzi Saito, Seiichi Kagoshima, 1990 This volume contains the proceedings of the first ISSP International Symposium on the Physics and Chemistry of Organic Superconductors which was held at the Komaba Eminence Hotel in Tokyo August 28 30 1989 This symposium was attended by 205 scientists from 12 countries In total 106 papers were presented 61 as posters and 39 original papers and 6 review papers in oral sessions Of these 102 papers are included in these proceedings These contributions cover the interdisciplinary field of physics and chemistry of organic superconductors with particular emphasis on the following subjects and materials superconducting properties spin density waves electronic and structural properties TMTSF salts and their derivatives BEDT TTF salts and their derivatives metal coordinated organic conductors The contributions to this volume are arranged in 11 categories The Organizing Committee would like to acknowledge all participants who contributed to the great success of this symposium on a growing field in both physics and chemistry The editors express their gratitude to the members of the Organizing and Executive Committees for their cooperation We also wish to thank Dr H Lotsch of Springer Verlag for his management of the publication and Miss S Shibata for her assistance in editing this volume Organic Synthesis in Japan Ryoji Noyori, 1992 **Organic Conductors, Superconductors and Magnets: From Synthesis to Molecular Electronics** Lahcène Ouahab, Eduard Yagubskii, 2012-12-06 The book covers different aspects of the chemistry and physics of molecular materials including organic synthesis of specific organic donors and ligands organic metals and superconductors molecule based magnets multiproperty materials and organic inorganic hybrids The 17 chapters are written by some of the most authoritative authors in their field The two last chapters are devoted to molecular electronics and devices in particular the achievements and potential for applications An excellent work for all

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