pendent measurements of the magnetic susceptibility of doped $(CH)_x$ films, and both believe that their results at low (acceptor) doping concentrations are not in full accord with the conventional semiconductor picture of electron carriers jumping from the valence band to the dopant level. Such a picture implies an increased magnetic susceptibility with doping, due to unpaired spins on the polymer chain.

Solitons. Heeger and theorists J. Robert Schrieffer and Wu-pei Su at Penn, and independently, Michael Rice at Xerox have attempted to explain[5] these anomolous magnetic-susceptibility data in terms of an alternative picture of charge transfer at low doping levels, involving polymer excitations called "solitons." These solitons are kinks moving along the polymer chain, separating two domains, to the left and right of the kink, whose single-double bond alternation patterns are out of phase with one another. The Penn theorists have calculated that at low doping levels it is energetically more economical for the carrier to bind to a soliton kink than to enter the conduction (or valence) band. They believe that charged solitons may be the primary conduction mechanism in lightly doped organic polymers. Heeger's belief in this picture is strengthened by the observation of an enhanced infrared absorption peak in $(CH)_x$ corresponding to a 0.1-eV transition, a value consistent with the soliton calculation.

Bryan Street disagrees. Because of experimental results in his lab and at IBM's Watson Research Center, he does not believe that solitons play a significant role in the conductivity of doped $(CH)_x$. His colleagues John Rabolt and Tom Clarke found that the 0.1 eV infrared enhancement, which Heeger attributes to solitons, shifts when one replaces the hydrogen in $(CH)_x$ by deuterium.[6] Such a shift convinces them that this ir peak represents a molecular vibrational mode in the polymer chain. They believe that the entire ir spectrum in doped $(CH)_x$ can be explained without reference to solitons, in terms of an enhancement of the Raman A_g modes by a vibronic coupling mechanism. The shifts they observe in the carbon–carbon stretching frequencies are consistent with the bond weakening expected when doping removes valence electrons from the polymer.

Street also told us that Yaffa Tomkiewicz and her colleagues at the IBM Watson Research Center will report in the near future that they have found the magnetic-susceptibility effect in doped $(CH)_x$ whose apparent absence had triggered the soliton idea. Tomkiewicz explained that they discovered the effect of doping on magnetic suspectibility in the "cis" isomer of $(CH)_x$. The Penn group had looked in vain for the effect in film in which the "trans" isomer predominates. Tomkiewicz believes that it is more difficult to see the increased magnetic susceptibility in such material because of the higher background in the trans isomer. On the other hand, Heeger regards the observation of paramagnetic resonance by Chin and Karasz, emerging during the isomerization of pure cis-$(CH)_x$, as further evidence for soliton formation.

Street's group has also been active in the search for a stable, moldable conducting polymer. He told us that his colleagues Keiji Kanazawa and Art Diaz had recently synthesized polypyrrole, a highly stable, non-fibrous organic polymer.[7] As prepared at IBM by the electrolytic oxidation of a mix of pyrrole monomers, the polymer is a flexible, shiny blue-black film. The IBM group varies the conductivity of the polymer by altering the mix of different monomers in the electrolyte rather than by doping the end result. By this controlled copolymerization they have been able to produce films varying over five orders of magnitude in conductivity, from insulating to metallic.

The San Jose group has also been developing new doping techniques for $(CH)_x$. By immersing the polyacetylene film in solutions of transition-metal salts they hope to produce film with interesting magnetic properties. Street told us that doping by immersion results in a more uniform doping than does the widely used vapor-phase doping. He fears that nonuniformities at low doping levels produced by vapor-phase doping can confuse the interpretation of the $(CH)_x$ data in the semiconducting region. McDiarmid counters by noting that his group found samples lightly doped by gas-phase doping to exhibit properties identical to electro-chemically doped films. The dopant is not, as some have suggested, confined to the surface of the fibrils, he told us.

Together with Ari Aviram and Hans Brom, Tomkiewicz has recently found that heating the commercially available polymer Kapton to 600 K in an inert atmosphere results (after cooling) in a 10^{20} increase in conductivity, up to 200 $(\text{ohm-cm})^{-1}$. At higher temperatures many polymers become conducting simply because of graphitization, the pyrolytic formation of elementary graphite. But the Watson Research Center group rules out graphitization as the source of the effect they observed in Kapton. They vary the conconductivity not by doping, but by adjusting the pyrolysis temperatures. Tomkiewicz stresses the ease of producing this stable, highly conducting polymer film, but notes that it does become brittle as a result of the pyrolysis treatment.

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NRC panel examines need for high magnetic fields

Do we need higher magnetic-field facilities? That question is addressed in a recent report by a panel established by the Solid-State Sciences Committee of the National Research Council. The study was initiated at the behest of NSF, which supported the panel's efforts.

The panel, headed by Seymour Keller of IBM Research, produced a 100-page report that identifies the scientific opportunities and applications of higher magnetic fields than are available at present, argues that higher fields are feasible and offers the following recommendations:

"I. A design program should be started to determine appropriate methods for producing steady-state, highly homogeneous magnetic fields up to 75 T (750 kG) . . . Although the attainment of 75-T fields is the eventual goal of this recommendation, fields of 45 T and 60 T, steps along the way to 75 T, will help to provide the technology necessary for higher-field-magnet development . . . The first step should be an in-depth feasibility and cost analysis to determine the status of appropriate methods for producing these 75-T fields, including a study of high-field superconducting magnets, resistive magnets, and hybrid systems." These hybrid systems (which combine superconducting outer coils and water-cooled inserts) "represent the approach most likely to result in the highest steady-state fields, and as such should receive priority attention."

The panel urged increased funding for materials processing and magnet technology so that some of the known higher-field superconductors might be fabricated into practical magnets.

The present record for a static field is 30 T, but that was a *tour de force* by the Bitter National Magnet Laboratory at MIT (PHYSICS TODAY, December 1977, page 20). The highest static fields for relatively routine operation are available now only at the University of Nijmegen in the Netherlands and the Kurchatov Institute in Moscow, each of which have hybrid magnets with 25 T, and at the Bitter Lab, which has 23.5 T. The Bitter Lab is constructing a 30-T hybrid, the Naval Research Laboratory is constructing a 24-T hybrid, and the Laue-Langevin Institute in Grenoble is planning a 30-T hybrid now and a 40-T hybrid in the future.

"II. The design and construction of a quasistatic pulsed magnet with fields up to and beyond 100 T should be undertaken." A facility at the CNRS solid-state laboratory in Toulouse, France is already producing 40 T with a roughly 1-sec fall time.

The panel says fields of 75–100 T with roughly 1-sec duration are feasible and can be economically attained using existing technology and large pulsed power supplies similar to those in the fusion program. Furthermore, the availability of the quasistatic fields would allow preliminary experiments for the eventual high steady field.

"III. The design and construction of short-pulse magnets affording fields greater than 1000 T is feasible and should be undertaken."

Much of the short-pulse generation of high magnetic fields has been done in connection with weapons work or magnetic fusion. Los Alamos and Livermore have had huge transient-field installations that produced 1000–1500 T for times between 0.5 and 1 microsec. The Livermore facility has been disassembled, and the Los Alamos facility is on stand-by. Los Alamos also has an active facility that produces 250 T fields for 3–4 microsec.

"Because we feel that small regional facilities containing [superconducting] magnets with field strengths less than 15 T are not in sufficient demand to justify capitalization and operating costs, we recommend that additional general facilities with less than 15 T should not be established at this time; however, we do recommend the continued support of such magnets for in-house research projects."

The report identified a wide breadth of research that could be done with high-field magnets. However, the panel did not find any experiments that were so compelling as to justify a crash program for high magnetic fields. Accordingly, the panel did not propose a funding program for Federal agencies, instead suggesting that a coordinated plan be produced for funding and for a detailed design and development of hardware and associated facilities.

William Oosterhuis of the NSF Division of Materials Research told us that NSF does not plan to solicit proposals for construction of the magnets recommended by the panel. Although NSF sees no justification for spending the $100 million or so such projects would cost, he went on, it is considering supporting (probably at the Magnet Lab, which has an ongoing pulsed-field project) a facility to produce 50 T for as much as one second. Such a facility would cost one to a few million dollars. The Magnet Lab has already done some experiments with 50 T lasting 100 millisec and 60–70 T lasting 0.7 millisec.

Among scientific opportunities, the report mentions:

▶ Semiconductor research. With higher magnetic fields, one could observe the transition to lower dimensionality at reasonable temperatures and concentrations through the "freezing out" of the kinetic energy inherent in the occupation of low Landau levels, study magnetic semiconductor electronic structure, sweep through the electron–phonon "clothing" of electronic motion, test the effective mass approximation, study shallow impurities and Zeeman splitting of deep impurity states.

▶ Metals research. Here the most unusual opportunities are in electronically driven phase transitions, charge density waves in potassium, electronic structure of exotic metals, and concentrated binary alloys.

▶ Low-temperature physics. Two phase transitions otherwise unobservable become feasible: the Bose condensation of spin-aligned hydrogen and the ferromagnetic moment for the A phase of liquid He^3.

▶ Materials research. The report discusses possible studies in high-field superconductivity, metallurgical phase transitions, field-induced changes in pressure and temperature with geophysical applications, and nmr studies of various nucleation phenomena related to mechanical strength of materials.

▶ Chemistry. High fields will help to understand: complex reactions in condensed phases; factors determining the dynamics of atoms in molecules and of atoms during molecule formation; electronic structures of highly excited states.

▶ Biology. Higher magnetic fields (75 T) will enable higher resolution nmr, which will allow studies of such things as the solution structure of transfer RNA, thermal folding and unfolding of RNA, antigen–antibody interaction of protein and lipid interaction in cell membranes, interaction of histones with nucleic acids, enzyme complex assembly, and identification and mapping of receptor binding sites.

▶ Magneto-quantum electrodynamics. The availability of high magnetic fields and high-energy electrons will allow more precise tests of quantum electrodynamics without the need to calculate many other, nonelectrodynamic effects.

▶ Molecular and atomic spectroscopy. The topics discussed are: high Rydberg states in which the Zeeman energy and Coulomb energy are comparable, motional Stark effect lineshape, anticrossing observations, and collision dynamics.

The panel also considered applications but concluded that presently available fields are sufficient to satisfy application needs at this time. —GBL □

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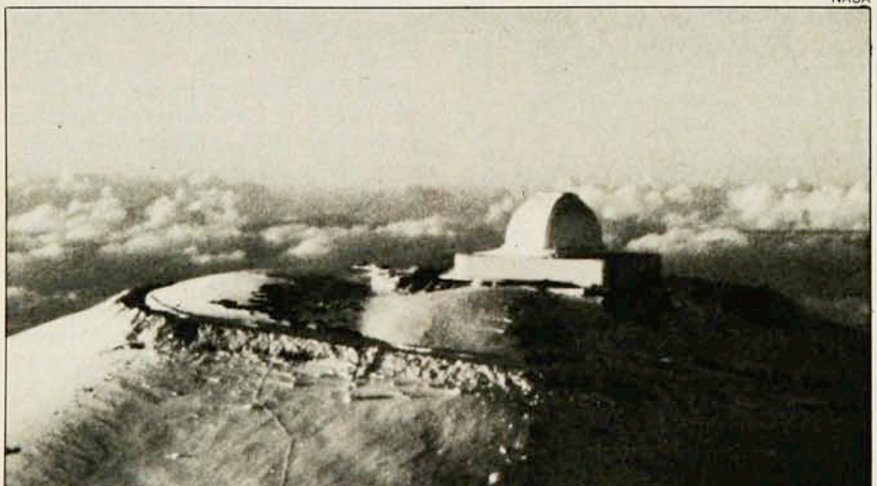

The NASA 3-meter infrared telescope on 14 000-ft Mauna Kea in Hawaii achieved first light in May and is now being operated as a national facility. Proposals for observing time during the first half of 1980 are being solicited; deadline is 15 October. Visiting observers will be given 75% of the observing time; 50% of the time will be allotted to solar-system studies.

A visitor may either use the facility instrumentation or his own equipment. Limited support services will be available, including all local transportation and cryogenics. Send inquiries about instrumentation and proposals to: E. E. Becklin, Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, Hawaii 96822. Phone: (808) 948-6666.