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THE AUSTRALIAN PHYSICIST

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FRONT COVER
The model depicts the cations in two unit cells of the
structure, plus their surrounding anions. The latter are oxygen
(yellow balls); the former are barium (green balls) and yttrium
(red balls). Copper atoms are not shown, but occupy the blue
co-ordination units: the squares are CuO4 and the half-octahedra/
square pyramids are CuO6. The transparent parts of the model
(polyhedron shapes and balls) have no significance; they are
for constructional purposes only. (But note that the yellow and
clear spheres together form the anion array in the ideal
perovskite structure, i.e. YBa2Cu3O6+y, where y= clear
sphere.) The oxygen content is variable; the formula being
coviniently written as YBa2Cu3O7+y. The structure is
orthorhombic, and the unit cell axes are shown.
The model was built by B.G. Hyde and photographed by
Byam Wight.


The Australian Physicist, Vol. 24, 1987-Page 157
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President's column

The 1988 Bicentenary Congress of Australian Physicists is the Institute's largest single undertaking in its 25 years of existence. The Institute's Executive sees it as a multi-faceted exercise, and a very important development in Australian Physics.

First and foremost, it is the eighth in the ongoing series of AIP biennial congresses, which are the Institute's principal occasions for reporting research in physics in Australia. For the first time in this country, some ten independent physics-related societies and four specialist groups associated in varying degree with the Institute have combined to produce a "mega-congress". Secondly, the coverage of eighteen subject classifications in twelve parallel sessions is something quite new in Australian physics. One immediate advantage, that we hope will help attract a very large attendance, is the capacity of a meeting of this scale to host a galaxy of overseas luminaries across a very wide area of research.

The plenary lecturers include three Nobel Laureates:
- Prof. Klaus von Klitzing (Würzburg; quantum Hall effect)
- Prof. Charles H. Townes (Berkeley; lasers)
- Sir Bernard Katz FRS (London; biophysics)

Other distinguished plenary speakers include:
- Prof. O.V. Lounasmaa (Helsinki; ultra-low temperatures and magnetoencephalography)
- Prof. D.A. Bromley (Yale; President of IUPAP; experimental nuclear physics)
- Prof. L.A. Frank (Iowa; auroral images from spacecraft observations)
- Dr M. Nieto (Los Alamos; theory of quantum gravity)
- Dr. R.S. Pease FRS (UKAEA; plasma fusion)
- Prof. E. Wolf (Rochester; theoretical optics)
- Dr. Martin Green (UNSW; photovoltaic cells)

In addition, individual subject sessions will feature their own invited lectures given by other distinguished Australian and overseas experts.

The scope of this Congress is exciting. The chance for local physicists to meet and listen to some of the world's best during a concentrated week of physics is not to be missed.

Besides being a first-class opportunity to hear invited and contributing speakers, the Bicentenary Congress will be a fitting celebration of the Institute's Silver Jubilee and will, I hope, be looked on with pride and satisfaction by those of our founding fathers who are still active in physics. The signatories to the Memorandum and Articles of Association, who established the AIP in 1963, will be invited to the Congress Dinner as the guests of the Institute as part of our celebration. The Executive also intends to put before the Council Meeting in October a plan for a permanent memento of our 25th anniversary.

The Congress provides an excellent opportunity to put into practice the Institute's policy of fostering much closer relationships between physics-related societies in Australia. On a previous occasion I have written of the need that we see for co-ordinating activity in furtherance and in defence of our discipline, and the Congress is an ideal vehicle with which to set such a movement rolling.

Lastly, but certainly not least, the Congress is the Australian physics community's contribution to the Bicentenary.

The fact that the Congress will be held in Sydney in the Bicentennial Week is both exciting and intimidating.

The Congress Committee faces a major task in organizing a meeting of this size at any time, but this particular week introduces additional difficulties, not the least of which is accommodation. I want to reiterate the message given elsewhere in this issue by Congress Chairman, Dr Brian Window, that it is essential that intending participants reserve their college or motel accommodation by the appointed date. It

The statements made and the opinions expressed in the Australian Physicist do not necessarily reflect the views of the Australian Institute of Physics, its Council or Committee.
is highly desirable that they do so well ahead of that date.

The Institute is holding adequate bookings for the Congress, but the pressure on accommodation in Sydney during the last week in January 1988 means that the Institute has had to underwrite substantial deposits that it must monitor very carefully as the weeks go on. Please help us by booking early and help yourselves by avoiding last-minute worries should accommodation become unavailable.

The organization of the Congress is a most interesting exercise in itself. The Congress and Program Committees have been in existence already for at least two years. The resources of the Institute, as the major physical society in this country, have been necessary to back such a major enterprise. The coalition of participating societies has, like all coalitions (I write on Election Day!), had its strains and diversions of view, but unlike some coalitions it has worked remarkably harmoniously towards a common goal. What has happened so far gives me encouragement for the future success of collaborative meetings between related physics sectors in this country.

I close with a word of praise for the 36 hard-working scientists who make up our two committees and with an exhortation to all our members to come to Sydney for the Congress. Be part of the Bicentennial Week, enjoy the delights of Sydney where this nation has its beginnings, and benefit from the wealth of physics that will be presented to you on this unique occasion!

J.G. Collins.

Editorial

Prof Peierls, now Sir Rudolf, has written a very fine autobiography which I would like to recommend as important reading for senior physicists. It is called "Bird of Passage". In it he describes the relationship that he endeavoured to establish with his graduate students, namely that he took not only to turn them into excellent physicists but by looking after their every-day problems and welfare to turn them into useful, kind and concerned human beings. During my postgraduate period, he was not my Professor in Birmingham, as I was taking my Ph.D. in Crystallography which was attached to the Chemistry Department. Nevertheless I spent a considerable amount of my time in his Department as he was the only person with a new Meccano calculating machine, the best at that time! I had to calculate thousands of structure factors by hand and then turn them into Fourier transforms. (How lucky the present day crystallographers are with their rapid computer calculations, something that we could only dream about!). It was thus very kind of him to let me use the equipment in his Department and no doubt today I would be told under similar circumstances in Australia that the machine is being used full time.

This brings me to my point. I have the impression that the general behaviour in the physics community has deteriorated. Graduates whether as students or as employees are not given the guidance and encouragement that they need. They are not instructed in how to give good talks, how to write readable scientific articles nor given enough opportunities to attend meetings, let alone invited around for a meal by their teachers. Yet we urgently need to train young graduates to stand their ground when they leave the cloistered atmosphere of the University as scientific honesty in employment has not been my experience. One excuse offered by senior staff is their shortage of time but I have found that those in charge tend to hog all committees and decision making processes thus trying to hold on to power and not giving the younger people a chance to learn. Even worse, because they are not delegating authority, they are usually too busy to get things done.

Another example of poor behaviour has been the scramble and complaints that I have received over the superconducting articles. While, of course, a certain amount of egotism is a necessary component of research work, it must be kept under control and the scientific endeavour should always remain the major component. Otherwise all co-operation becomes impossible. One contributor has written "there are only a few gentlemen of physics left", with reference to the fact that I have received contributions that were not presented at the meeting. There is, of course, no need for all this nonsense as it is far more important to work together. Especially as far as the superconductors are concerned, it is imperative that we, physicists, persuade the government that our Australian control lies with refining and producing rare earth metals for future manufacture of both high-power magnets and superconductors and does not lie in jumping into a fast moving scientific market over which we have little control. This should really not be so difficult as eminent people like "Barry O" seem to have an excellent understanding of scientific matters judging by his contributions to Robyn Williams' Science Show. In order to achieve this objective we must prepare a detailed report together with metallurgists, engineers and other disciplines to show the Government that we know what needs to be done. If the Government can create devision among ourselves it will do so. As most senior physicists well know, one of the administrators' most powerful weapons is to tell you that they have no money. Firstly it makes them feel good to have put you in your place, giving them a sense of power and secondly, it absolves them from taking any action that could adversely affect their career.

Because physicists in future will have to take part in a much more public arena it is of great importance that some codes of behaviour be laid down. Jim Graham is drawing attention to this important issue in the Editor. It is a subject that I have been interested in for some time and may take up after retiring from the Editorship. It certainly should be widely discussed as we, physicists, are the only scientific profession without a code of conduct, perhaps believing in our goodness which I have not found to be self evident!

Self criticism is never a pleasant process but it would not hurt all physicists to have a think about these problems.

Trudi Thompson.

Errata: In spite of my great endeavour to produce a copy without errors this has so far eluded me. For the error on page 152, I must apologise to our new Company Subscribers Data Electronics for losing part of their address over the bottom edge. The only explanation that I can offer is that their boots are too heavy and caused the problem as the final laser prinit was fine. So if you wish to buy the boots or the Datatker, consult their advertisement on page 104, previous issue.

AUSTRALIAN INSTITUTE OF PHYSICS

23rd Pawsey Memorial Lecture
in honour of the late Dr J.L. Pawsey
will be delivered by

Professor John M. Cowley
of Arizona State University, USA

on

To be announced (the speaker has indicated that the lecture will cover image processing techniques and related topics)

Date: Monday 10th August 1987.
Time: 8.15pm.
Place: Ross Lecture Theatre,
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Conducting Polymers
R.J. Fleming, Department of Physics, Monash University

Introduction
The class of compounds commonly called plastics are organic polymers, e.g., high density polyethylene film in the form of tear-off bags in the fruit and vegetable sections of supermarkets, polyvinylchloride insulant in domestic power distribution cables, and polymethylacrylate in lighting fittings and aircraft canopies. Their attraction lies in their combination of toughness, plasticity, strength-to-weight ratio, low cost, and ease of fabrication. The vast majority are good insulators.

The search for an organic metal was given initial impetus by a proposal [Little, 1964] that it might be possible to synthesize a room-temperature superconductor by attaching readily-polarizable side-chains to a long chain (polymer) molecule containing alternating single and double carbon-carbon bonds. A room-temperature superconductor has not yet been reported in the open literature, although its realization (in non-polymeric form) can perhaps be expected in the not too distant future given the very recent exciting advances in the field of rare-earth oxides [Chu et al., 1987]. However, the last twenty years or so have seen the synthesis of a large number of new organic molecules, e.g., the TCNQ compounds [Garito and Heeger, 1974; Heeger and Garito, 1973], with much increased electrical conductivities and interesting magnetic properties, and a truly interdisciplinary research effort involving preparative chemists, materials scientists and theoretical and experimental physicists has led to the development of several new and interesting physical concepts, particularly in relation to one-dimensional conductors. Most of this effort is today concentrated on organic polymers because of their expected technological potential. The prospect of tailoring electroactive polymers with unique properties is indeed an exciting one.

In this article I describe the synthesis and some of the electrical properties of trans-polyacetylene and polypyrrole, two conducting polymers which have been thoroughly investigated. I also comment briefly on polymer composites. Readers are referred to a recent two-volume publication for further details [Skothiem, 1986].

Polyacetylene
In 1971 Shirakawa and Ikeda [1971] reported the synthesis of thin films of polyacetylene (PA), and six years later [Chung et al., 1977] showed that its room temperature conductivity could be increased to around $10^3$ S cm$^{-1}$ by chemical doping, (S Siemins is equal to ohm$^{-1}$), cf. polyethylene $\sim 10^{-15}$ S cm$^{-1}$, and copper $\sim 6 \times 10^7$ S cm$^{-1}$. Proposals for its commercial use are numerous, e.g., as electrodes in light-weight high-energy-density batteries and in low-cost solar photovoltaic devices [Heeger, 1981], but several problems, relating in particular to its stability in air, remain to be solved before commercial viability is achieved.

Polymerization of acetylene occurs readily when the surface of a solution of a Ziegler-Natta catalyst is exposed to an atmosphere containing acetylene, a shiny metallic PA film forming at the liquid-gas interface. PA has two isomers, as shown in Figure 1. The cis-isomer is obtained by polymerizing below -78°C, and the trans-isomer above 150°C. The cis-form tends to isomerize to the trans-form, even at low temperature.

Both isomers consist of randomly oriented fibrils with typical diameter 200Å, the -(CH$_2$)$_n$ chains being aligned along the fibril axis to give a percentage crystallinity around 90%, but with low perfection. The films have a very open structure (about two-thirds void) and a low density around 0.4 g cm$^{-3}$. They can be partially oriented by stretching up to three times their original length. I shall concentrate on trans-PA because of its more interesting physics.

According to simple band theory all the carbon-carbon bonds in trans-PA should be the same length, rather than alternating, and a continuous $\pi$-band should run above and below the planar zig-zag $\sigma$-bands. (Essentially, three of the four valence electrons of each carbon atom are involved in coplanar directed $\sigma$-bonds, one with each of the two flanking carbon atoms and one with the attached hydrogen atom; the fourth electron is involved in the other "half" of the double bond with one of the flanking carbons, the $\pi$-orbital being orthogonal to the three $\sigma$-orbitals). Then, since each carbon atom contributes only one electron to the $\pi$-band, that band is only half full. In addition, the inter-chain interaction is relatively weak. Trans-PA should therefore be a quasi-one dimensional metal. However, undoped PA is a semiconductor as a result of the Peierls distortion [Peierls, 1955], shown schematically in Figure 2.

In an idealized one-dimensional conductor, a periodic

---

vibration of the lattice with wavevector $2k_F$, where $k_F$ is the Fermi wavevector, can generate electron-hole pairs with momentum differences of $2k_F$ and energies around $E_F$. The number of such pairs increases with decreasing temperature and they can interact with the phonons which generate them in such a way as to reduce the phonon frequency to zero [Kohn, 1959]. The lattice then distorts to form a new periodic superlattice; in the particular case of a half-filled band with $k_F = \pi n/2a$, where $a$ is the original lattice spacing, the new superlattice has spacing $2a$. An energy gap also opens up around $E_F$. However, a real trans-PA chain is not a purely one-dimensional system, because of its (weak) interaction with neighbouring chains, and so instead of a doubling of the lattice spacing an alternate lengthening and shortening of the carbon-carbon bond occurs. Thus, the longer (single) bonds and shorter (double) bonds differ in length by about 0.1 Å [Fincher et al., 1982], and the gap in the $\pi$-band at the Fermi level is about 1.5 eV wide.

Clearly, the ground state of trans-PA is structurally two-fold degenerate, in the sense that the energy of the chain would be unchanged if the longer and shorter bonds were interchanged. Thus, there exists the possibility of a non-linear excitation generating a domain "wall" separating two sections of the chain with opposite bond alternation, as shown in Figure 3(a).

![Diagram](image)

Figure 3. Defect structures in a trans-PA chain. Hydrogen atoms have been omitted for clarity and the full spatial extent of the defects along the chain is not shown.

(a) neutral soliton. (b) positively-charged soliton with dopant acceptor radical anion. (c) Positively-charged polaron. (d) Soliton-antisoliton pair (biloparion).

This excitation is a particular example of the class of non-linear phenomena known as solitons or solitary waves [Pokrovsky et al., 1986]. In trans-PA the soliton causes, over a distance of about 14 carbon-carbon bonds along the chain, a gradual transition between two different bond alternation patterns, equivalent to moving from one potential minimum to another of the same energy. The spatial extent of the soliton arises from competition between the Peierls distortion forces and the lattice elastic restoring forces. It is expected to be highly mobile along the chain because of its small effective mass $m_{\text{eff}}$, where $m_{\text{eff}}$ is equal to 6 times the rest mass of the electron [Su et al., 1979] and the translational symmetry of the chain. ESR data for undoped trans-PA indicates one soliton for every ~3000 carbon atoms, a much bigger concentration than would be expected from simple thermodynamics. This result, along with the insensitivity of the spin concentration to temperature, suggests that the soliton in trans-PA is an intrinsic defect created during cis-trans isomerization. Associated with it is a localized electronic state with energy at the mid-point of the gap between conduction and valence bands. This state is a solution of the Schrödinger equation in the presence of the domain wall [Su et al., 1980], and can therefore contain 0, 1 or 2 electrons. The neutral soliton (1 electron) has spin 1/2, while the positively-charged and negatively-charged solitons (no electrons and 2 electrons respectively) have zero spin and are non-magnetic, i.e., the opposite of the usual solid-state spin-charge relationship.

As a result of the domain wall, the electron in the mid-gap level of a neutral soliton may be transferred to a dopant acceptor molecule, thereby creating a positively-charged soliton and a dopant radical anion, as shown in Figure 3(b). Correspondingly, negatively-charged solitons and radical cations result from n-type doping. However, since the concentration of neutral solitons is relatively small, so also is that of charged solitons. Furthermore, doping eliminates unpaired spins from the chain and the charged soliton is pinned to the dopant ion by Coulombic attraction.

Isolated charged solitons are certainly found on trans-PA chains at low dopant concentrations following charge transfer to or from neutral solitons. However, photoexcitation generates soliton-antisoliton pairs. (The antisoliton induces the opposite bond alternation pattern to the soliton). Thus, when an electron is photoexcited from the valence band to the conduction band, generating a hole in the valence band, strong electron-phonon coupling causes localized distortion of the "soft" polymeric lattice. A pair of electronic energy levels begins to split off symmetrically from the top of the valence band and the bottom of the conduction band, each level containing one electron. Within a time of order 10^{-12}s the localized lattice distortion evolves to a soliton-antisoliton pair and two closely-spaced mid-gap electronic energy levels (defect levels) are spatially localized at the pair sites, the lower level containing two electrons and the upper level containing one. More precisely, a spinless negatively-charged soliton ($S^-$) and a spinless positively-charged antisoliton ($S^+$) are formed (or $S^-$ and $S^+$). Once again each has a "strange" spin-charge relationship.

Numerical calculations using a discrete lattice model [Su et al., 1980] have shown that the energy required to generate a pair of solitons from the ground-state of a trans-PA chain is around 2 $E_g$, where $E_g$ is the band-gap. Since energy $E_g$ is required to produce an electron-hole pair it is clear that a soliton-pair is the first excited state of the trans-PA chain.

If a single electron is transferred from the valence band to a dopant molecule, or from a dopant molecule to the conduction band, a polaron is formed. (In the case of amorphous semiconductors, a polaron consists of a charge and the polarization of the surrounding medium which it induces). Consider electron transfer from the valence band to a dopant molecule. Again a pair of electronic energy levels splits off from the valence and conduction bands and moves towards the mid-gap. However, the level from the conduction band is empty, and there is one electron in the other, so that although a soliton-antisoliton pair is again formed, in this case one is charged and the other neutral (see Figure 3(c)). After the chain distortion relaxes the split-off levels settle approximately 0.3 eV above the valence band and 0.3 eV below the conduction band. It has been estimated [Bredas et al., 1982] that the polaron energy is least when the alternating bond length pattern undergoes a 360° phase change over a distance of about 14 carbon atoms along the chain. It may also be shown that the polaron is the lowest energy excitation available to a single electron (or hole) added to a trans-PA chain. Since $S^-$ carries spin, but $S_0$ does not, the polaron has the usual spin-charge relationship.

At higher dopant concentrations more than one polaron may be formed on a given chain, and they can interact in pairs. The positive charges on the chain are of course pinned to the
CONDUCTING POLYMERS

The Australian Physicist, Vol. 24, 1987-Page 162

corresponding negatively-charged dopants but the two neutral solitons (radicals) will eventually separate from their "parent" polarons and recombine, thereby annihilating each other and leaving two charged solitons, usually called a bipolaron (Figure 3(d)). The neutral solitons have to overcome an energy barrier to separate from the polarons, the barrier height reducing with increasing dopant concentration and becoming zero at dopant concentrations around 3 x 10^{-2} molecules/carbon atom. The remaining two like-charged solitons repel each other strongly. They carry charge but no spin.

Several models of charge transport in doped trans-PA have been proposed and the question is still keenly debated. Of critical importance is the fact that the charge carriers appear to be spinless, i.e., the spin concentration observed in ESR measurements is much too low to account for the measured conductivities [Chung et al., 1984]. For dopant concentrations \( y \) in the range zero to about 10^{-2} dopant molecule/carbon atom the dc conductivity increases exponentially some ten orders of magnitude to values around 10^4 S cm^{-1} and then begins to saturate. The thermoelectric power assumes high values (\(-10^{-3} \text{ V/K}\)) characteristic of a semiconductor for \( y \) up to about 10^{-2}, and then falls rapidly to about 10^{-4} \text{ V/K} and is independent of \( y \). Its sign but not its magnitude changes on going from p-type to n-type doping. At higher dopant concentrations it is linear in temperature, characteristic of delocalized carriers. For \( y > 0.07 \) the geometrical distortions of the chain due to the dopant ions begin to overlap, the energy gap eventually disappears and "normal" metallic conductivity via carriers with spin replaces semiconductor behaviour with spinless carriers.

The model of bipolaron charge transport in trans-PA proposed by Chance et al., [1984] seems to be consistent with most of the above experimental data. In particular, it allows for easy interchain transport of charge, an essential feature in any model given the high conductivity values and the substantial amount of disorder in trans-PA samples. Thus, consider two adjacent trans-PA chains, one of which carries a single charged soliton and the other is defect free. In order for the charged soliton to hop between the chains a relatively large number of carbon atoms on both chains must take up new equilibrium positions, and although the overall energy cost of the soliton hop is zero (energy lost by one chain equals energy gained by the other) the activation energy may be considerable. On the other hand, if a bipolaron (a pair of charged solitons) hops between two chains the activation energy barrier will be much smaller because only those carbon atoms between the solitons on each chain will have to assume new equilibrium positions. Hence, both models imply spinless charge transport the latter seems likely.

Work on PA is continuing in many laboratories, it having been predicted [Park et al., 1980] that a dc conductivity of at least 3 x 10^4 S cm^{-1} should be attainable. However, the problems of sample brittleness, moisture sensitivity and decay of conductivity after sample synthesis remain to be solved before large-scale commercial exploitation of doped PA is possible.

Polypyrrole

Polypyrrole (PPy) belongs to a family of polymers which have in common a five-membered ring structure containing one heterotenon (Figure 4).

In the last five years they have begun to attract more attention in this field, largely because of their ease of electrochemical synthesis. Potential applications include light-weight batteries, electro-optic devices, radiation detectors, solar cells and molecular-based transistors.

Unlike PA, these polyheterocycles do not have degenerate ground states since the configurations shown in Figure 4 do not have exactly the same energies as those in which double bonds form the linkages between repeat units. PPy cannot, therefore, support free solitons and the basic excitation is polaron formation, as shown in Figure 5(a). Bredas et al. [1984] have shown that a polaron in PPy extends over about four pyrrole rings and that bipolaron formation (Figure 5(b)) via a reaction between two polarons results in an energy reduction of 0.45 eV. The bipolaron also extends over about four pyrrole rings.

Figure 4. (a) Polypyrrole. (b) Polythiophene
(c) Polyselenophene.

Figure 5. (a) Polaron in polypyrrole. (b) Bipolaron in polypyrrole.

In PPy, as in trans-PA, there is little correlation between spin concentration and conductivity, especially at higher conductivity levels. Thus, if a neutral polypyrrole film is exposed to increasing oxygen pressures its conductivity increases by roughly 3 orders of magnitude for an oxygen uptake of about 0.5\% by weight, and then saturates; over the same range the ESR intensity increases by a factor of roughly 5 but then falls to zero [Scott et al., 1983]. The initial rise of the ESR intensity was interpreted as resulting from the formation of polarons, which have both charge and spin, and its subsequent disappearance as due to polaron recombination yielding bipolarons, which have charge but no spin. The UV-visible absorption spectra of neutral and oxidised PPy films support this suggestion [Bredas et al., 1984]. The bipolaron introduces two states into the band-gap, one roughly 0.8 eV above the valence band and the other at a similar separation from the conduction band edge. As the bipolaron concentration increases these states broaden into bands. However, the gap between them does not disappear, even at the highest dopant levels achieved to date, so that PPy cannot be considered as a conventional metal.

PPy is usually prepared by electrochemical polymerization of a pyrrole solution [Bidan et al., 1984] using a two-compartment cell made of glass or teflon with the compartments separated by a porous membrane. The main advantages of electrochemical synthesis, as distinct from chemical synthesis, are that (1) with a judicious choice of solvent a continuous film is formed on the anode and can be easily removed without damage, (2) doping of the films to give higher conductivities can be performed simultaneously with the polymerization by incorporating a suitable dopant in the pyrrole solution, and (3) the required film thickness can be obtained by varying the applied voltage (\(-1\) V) and the time for...
Conducting Polymers

which the current is passed. The cathode is usually a platinum foil, the anode being similar or a microsce slide on which a 2000-3000A thick semiconducting indium-tin oxide layer has been sputtered. Current densities of order 1mA/cm² are usually sufficient to initiate the polymerization process, which is believed to proceed via the formation of a pyrrole radical cation, followed by reaction of two such cations to form a dimer by elimination of two protons, and then reaction of the dimer with further cations to build up the polyrrole chain.

The choice of solvent influences the mechanical properties of the PPy film deposited on the anode. Stronger films are obtained using a solvent with high dielectric constant and low viscosity, e.g. aqueous acetonitrile or tetrahydrofuran. The dopant added to the solvent is usually a quaternary ammonium salt such as (C₅H₅)NBF₄ or a metal salt such as LiBF₄ or AgClO₄. The dopant molecule offers one of its ions to couple with the monomer and also renders the electrolyte in the electrochemical cell more conductive. The film formed on the anode is then not neutral PPy, but say PPy-tetrafluoroborate, in which each BF₄⁻ ion is associated with three to four pyrrole monomer units.

Electrical conductivities up to 100 Scm⁻¹ have been measured for doped PPy films. The temperature dependence of the conductivity usually takes the approximate form \[ \sigma(T) = \sigma_0 \exp\left(-\frac{E_a}{kT}\right) \] over several orders of magnitude between 10 K and room temperature. \( \sigma_0 \) and \( E_a \) being constants. Similar characteristics have been found in spin-coated films of silicon and germanium, and like these materials doped PPy has a low p-type thermoelectric power (-10 µV/K) but an n-type Hall coefficient with a weak temperature dependence. The variable range hopping model [Mott and Davis, 1979] proposed for amorphous silicon and germanium may therefore also be appropriate to doped PPy, but with bipolarons as the charge carriers rather than electrons or holes. The microscopic host such a mechanism is not clear, e.g. a bipolaron might hop as a whole or it might dissociate into a pair of polarons which hop separately before recombining.

Polymer Composites

The addition of carbon black or metal flakes to an insulating polymer to increase its conductivity is well-known. In the present context we are interested in the use of conducting polymers as the "filler". Galvin and Wnek [1982] have reported the successful polymerization of acetylene within a low-density polyethylene matrix impregnated with a Ziegler-Natta catalyst. With the addition of 3% by weight of PA to the matrix, conductivities of order 10 Scm⁻¹ were measured when the polyacetylene was oxidized by exposure to iodine. Other insulating matrices such as polyvinylmethacrylate and polystyrene have been found suitable, in the sense that the composite retains the mechanical properties of the matrix. Lindsey and Street [1985] have reported that a PPy-sulphate/polyvinylalcohol composite film with conductivity of order 10 Scm⁻¹ could be folded and creased without cracking.

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Australian Journal of Physics

Contents Volume 40 Number 4 1987

Editorial: Publication of author-prepared compuscripts

General Physics


Elementary Particles and Fields

A bosonisation of QCD and realisation of chiral symmetry. C.D. Roberts and R.T. Cahill 499

Atomic and Molecular Physics

Non-hydrodynamic contributions to the end effects in time of flight swarm experiments. R.K. Standish 519

Fluids, Plasmas and Electric Discharges

Observation and analysis of nanosecond time-resolved, r.f. corona in air and comparison with N₂. N. Sato and S.C. Haydon 527

Condensed Matter: Electronic Structure, etc.

Microstructure of high temperature superconductors of the perovskite type. A.F. Moodie and H.J. Whiffin 547

Geophysics, Astronomy and Astrophysics

Spectral behaviour of pulse width in pulsars. O.B. Snee, A.D. Bobra and S.K. Alurkar 557

The Australian Physicist, Vol. 24, 1987-Page 163
No Reverse A.C. Josephson Effect in Y$_{1.2}$Ba$_{0.8}$CuO$_x$

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Since the discovery of superconductivity at a temperature of over 90K in a multiphase oxide of composition Y$_{1.2}$Ba$_{0.8}$CuO$_x$, where x was undetermined, [Wu et al. 1987] there have been a number of reports of phenomena associated with superconductivity occurring at much higher temperatures. The only one that is at present documented in detail is the reported observations of the reverse A.C. Josephson effect in a sample of composition Y$_{1.2}$Ba$_{0.8}$CuO$_x$ [Chen et al.]. Their experiment consisted of passing an A.C. current of around 0.5µA at 5 MHz frequency through a sample in a four terminal resistance measurement configuration. Chen et al. observed that a D.C. voltage of a few mV arose at the voltage terminals. The voltage had peaks at the superconducting transition temperature of their sample (≈60K) and at around 120K, the voltage reduced to zero at 240K. Chen et al. proposed that the D.C. voltage was due to the reverse A.C. Josephson effect in a granular superconductor and suggested that it indicated the presence of some form of superconductivity in their sample at temperatures of up to 240K.

I have repeated the experiment of Chen et al. on a sample of composition Y$_{1.2}$Ba$_{0.8}$CuO$_x$ (the composition of the sample in which superconductivity above 90K was originally observed by Wu et al.). The D.C. voltage across the sample as a function of temperature is shown in Figure 1. It is independent of frequency for frequencies of between 1 and 10 MHz and independent of A.C. current for currents of three orders of magnitude greater and smaller than those used by Chen et al. The D.C. signal of a few tenths of a mV that I observed can be attributed to thermal voltages. This is suggested by the fact that the voltage tends to zero as room temperature is approached. The discontinuity at ≈100K occurred when the sample holder was removed from the cryostat in order to warm it more quickly. I have therefore found no trace of a reverse A.C. Josephson effect in the sample of composition Y$_{1.2}$Ba$_{0.8}$CuO$_x$, and therefore no signs of high temperature superconductivity in this material.

It should be noted that the sample examined by Chen et al. [2] lies in a region of the phase diagram in which no superconducting material should exist if the sample is in phase equilibrium. The sample of Chen et al. could have contained quantities of the insulating phase Y$_2$CuBaO$_4$. If this latter material is ferroelectric, as has been reported, the consequent piezoelectric voltages due to thermal strains could have resulted in D.C. voltages that vanished at the Curie point.

References

EPR and NMR Measurements on High-Temperature Superconductors
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Sir Neville Mott has recently suggested that there are perhaps as many explanations of the physical mechanism involved in high-temperature superconduction, as there are theoretical physicists (Nat., May 1987, 327 p185). On the hypothesis that the copper oxide layers in the 1:2:3 superconductors are indispensable for superconductivity, we have undertaken both NMR (Nuclear Magnetic Resonance) and EPR (Electron Paramagnetic Resonance) studies of the copper sites. The compounds studied were the mixed phase compounds Ba$_x$Y$_{1-x}$Cu$_2$O$_y$ (black) and Ba$_x$Y$_{0.5}$Cu$_2$O$_y$ (green), and the pure phase compounds YBa$_2$Cu$_3$O$_y$ (1:2:3), Bi$Cu_2$O$_2$ (0:1:1), Y$_2$Cu$_2$O$_3$ (2:0:2), Y$_2$BaCu$_2$O$_6$ (2:1:1), YBa$_2$Cu$_3$O$_y$ (1:3:2), and CuO. For the 1:2:1 and 1:3:2 compounds we find strong EPR signals with $g_{yy} \approx 2.23$ and $g_{zz} \approx 2.09$ with a linewidth of $0.025T$, whereas for the 2:0:2 compound $g=2.12(2)$ with a linewidth of 0.047T. No NMR ($^{63}$Cu) or EPR ($^{63}$Cu, $^{65}$Cu) signals could be detected in the pure 1:2:3 superconductor. Any EPR signals in nominally pure 1:2:3 material are almost certainly due to the presence of either 1:2:1 or 1:3:2 impurities.

The absence of both NMR and EPR signals in the 1:2:3

![Figure 1. EPR spectra of YBa$_2$Cu$_3$O$_y$, at 295K and on a different ordinate scale Y$_2$BaCuO$_3$.](image-url)
high temperature superconductor is surprising. Simple valence calculations indicate the presence of both Cu$^{2+}$ and Cu$^{3+}$ ions. These results are discussed [Bowden] in terms of (i) Anderson's resonating bond model and (ii) the recent FLAPW band structure calculations of Freeman and co-workers. In particular, it is argued that the absence of both the NMR and EPR signals is probably due to exceptional spin-spin dipolar broadening, brought about by the de-localised nature of the Cu 3d electrons near the Fermi surface.


Zero Field Effects in the EPR Spectrum of YBa$_2$Cu$_3$O$_{7-\delta}$

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To observe electron paramagnetic resonance (EPR) a non-conducting solid or powder of 1mm dimensions is placed in a resonant microwave cavity in a region where the microwave magnetic field is most intense. The spectrum is slowly swept with a magnetic field $H_{em}$ which is also modulated with an amplitude rather less than the spectral line-widths to enable phase-sensitive detection.

The high-temperature superconductor is suitable for EPR because those Cu$^{2+}$ ions with a 3D valence configuration should be observable in the ceramic lattice. If these ions participate in the superconducting regions their spectrum should become totally screened by the Meissner effect and their reappearance on warming would indicate the onset of the critical temperature $T_c$. The onset of superconductivity in a microwave resonant cavity will change the effective cavity dimensions and may also be accompanied by the generation of unspecified Josephson emfs and a strong diamagnetic response from the sample material.

The EPR spectra below and above $T_c$ are shown in the accompanying figure. Both spectra show a typical concentrated Cu$^{2+}$ line with a DPPH marker just above 300mT while a broad line from the quartz dewar appears above 150mT. The copper spectrum intensity increases with the gradual oxidation and degradation of the superconducting lattice. It is not observed in freshly prepared samples of YBa$_2$Cu$_3$O$_{7-\delta}$. The Cu$^{2+}$ line can be seen above and below $T_c$, and the rate of its appearance in powders and solids suggests that the copper centres are forming near the surfaces of the material.

The presence of superconducting regions in the lattice is indicated by the strong microwave absorption at zero field.

Another absorption is observed at all fields whenever the applied field sweep is on, this does not otherwise alter the spectrum. The zero field absorption has been attributed to motion of the sample particles or the superconducting regions. It is observed in the spectra of the powder and from pressed solids and is present for modulation frequencies over the range of 40Hz to 100kHz.

This study was made using samples and spectrometer provided by the CSIRO Division of Applied Physics.

TEM and SEM Microanalysis of a Crystal in Superconducting YBa$_2$Cu$_3$O$_x$

S.X. Dou, S. Ringer, A.J. Bourdillon, C.C. Sorrell and K.E. Easterling, School of Materials Science and Engineering, The University of NSW.

We have shown [Dou et al.], how properties of superconducting depend on microstructures imaged and analysed by the SEM (Scanning Electron Microscope) and TEM (Transmission Electron Microscope), and we have identified them by X-ray diffraction.

A calibrated [Bourdillon 1985] fully quantitative Link Systems energy dispersive X-ray spectrometer was used with a JEOL 2000 FX transmission electron microscope, to analyse crystals on a specimen known to contain the YBa$_2$Cu$_3$O$_x$ phase, which we have shown to be the dominant phase in good superconductors.

Figure 1. TEM image of a Y$_2$Ba$_2$Cu$_3$O$_x$ microcrystal showing line scans used in Figure 2.

Figure 2. Line scans of (a) Cu/Y and (b) Cu/Ba in the horizontal direction about the crystal centre (see Figure 1) and of corresponding ratios in the vertical direction (c) and (d). Lower graphs go off-scale at +170nm.

The Australian Physicist, Vol. 24, 1987-Page 165
NEW SUPERCONDUCTORS II

An electron transparent thin foil was ion milled. A typical crystal of approximately 0.2mm area was systematically probed in the horizontal and vertical directions shown in Figure 1, to observe possible change in Cu/Y, and Cu/Ba elemental ratios. A probe size of order 10um was used. The central area was found to consist of the elements in ratios reasonably consistent with the formula YBa2Cu3Ox as expected, though oxygen was not analysed. However away from the centre changes in stoichiometry appeared.

Figure 2 shows that the crystal is rich in copper about the edges which are apparently influenced by adjacent phases.

References

Influence of Composition on Properties in the Pseudobinary System BaCuO2 - 1/2Y2Cu2O5
S.X. Dou, C.C. Sorrell, A.J. Bourdillon and K.E. Easterling, School of Materials Science and Engineering, The University of NSW.

Abstract
The influence of composition on the electrical and magnetic properties of materials in the Y-Ba-Cu-O system along the BaCuO2 - 1/2Y2Cu2O5 pseudobinary join was investigated at temperatures from 900°C to 1100°C. X-ray diffraction, scanning electron microscopy (SEM), differential thermal analysis, and image analysis were used to characterise multicomponent materials with compositions contained within phase fields associated with the YBa2Cu3Ox superconducting phase. Cold stage X-ray diffraction and SEM data indicate that the superconducting transition is not phase transition dependent. Dissociation of Y2BaCuOx above ~1050°C results in alternate phase relations in the low-BaO region of the phase diagram. Electrical resistivity and magnetic susceptibility measurements confirmed the strong effect that composition, phase assemblage, and microstructure have on the existence and degree of the superconducting transition in materials in the Y-Ba-Cu-O system.

Structure of "123" (Y1Ba2Cu3 Oxide)
B. Hyde, J. Thompson, Research School of Chemistry, Australian National University, and L. Davies, Lucas Heights.

At least four groups, [Beno et al., Capponi et al., David et al., and the present authors], in the U.S.A., France, U.K. and Australia, respectively, have reported analyses of high resolution neutron powder diffraction patterns of YBa2Cu3O7x+δ over the past few months. There is a general agreement between these groups that the structure of this new high temperature (95K) superconductor is orthorhombic, space group Pmm2, the basic building block of which is shown schematically in Figure 1. Apart from a reduction in thermal vibration and uniform shrinkage, no significant structural changes have been detected as a result of cooling through the superconducting transition temperature.

One extremely important piece of information, upon which there is no agreement as yet, is the location of the oxygen site deficiency. Although everyone agrees that the O3 and O4 sites are full, Beno et al. found only 92% of the O1 sites and 94.5% of the O2 sites occupied giving a total of 6.81(4) oxygens per formula unit. David et al. found only the O2 sites deficient with an occupation of 92.5(3)% giving 6.85(9) oxygens, and we found only the O1 sites deficient with an occupation of 85(2)% and 88(1)% for two separate samples giving 6.82(4) and 6.87(3) oxygens, respectively. Capponi et al. presumed a total of 7 oxygens in their analysis.

This problem and others should be solved using neutron scattering techniques over the next few months and we hope this brief comment is not too outdated as you read it.

Figure 1. YBa2Cu3O6.87 Unit Cell

Figure 1. DC electrical resistivity of sample E (Y1.4 Ba0.6) CuOx as a function of temperature.

The Australian Physicist, Vol. 24, 1987-Page 166
NEW SUPERCONDUCTORS II

References
Hyde (29th May 1987), NML Meeting.

TEM Observation of Defects in Superconducting Y$_1$Ba$_2$Cu$_3$O$_7$-$\delta$


Changes to the defect structure of Y$_1$Ba$_2$Cu$_3$O$_7$-$\delta$ have been observed under exposure to the electron beam in a 300keV electron microscope. Elsewhere we have described the microstructures, phases and superconducting properties of oxide compounds containing Y, Ba and Cu in varying compositions, and we have shown that the most desirable superconducting properties are obtained from a homogeneous Y$_1$Ba$_2$Cu$_3$O$_7$-$\delta$ phase.

Specimens of this phase were either ion milled, or ground and picked from a water suspension onto a holey carbon film, and then viewed in a Philips EM430 electron microscope. High resolution images taken along the [001] and [100] axes show large crystalline areas without obvious planar or line defects. However many crystals contain both planar defects and dislocations.

A common arrangement of twins is shown in Figure 1. The plane of the twin boundaries has been determined as (110) and (110), from tilting experiments and from the presence of twin reflections in the diffraction pattern (Figure 1, insert). During electron beam exposure, the twins within one crystal frequently disappear instantaneously, together with the twin spots in the diffraction pattern. With further heavy electron beam exposure, both the 100 and 010 lattice parameter double.

The transformation referred to above may be due to heating, or it may be induced by radiation damage. So far have we not observed obvious changes to the microstructure in specimens cooled near to liquid nitrogen temperatures. Dislocations are commonly observed, lying in the (001) plane. Under the influence of the electron beam they can be induced to move (glide?) in this plane.

Electric and Magnetic measurements in YBa$_2$Cu$_3$O$_7$-$\delta$

C. Edwards, M. J. Buckingham and L. D. Mann, Physics Department, The University of WA.

Samples of YBa$_2$Cu$_3$O$_7$-$\delta$, hereafter referred to as 123-Y, were prepared by F. J. Lincoln and P. G. McCormick (Departments Physical & Inorganic Chemistry and Mechanical Engineering respectively). After the initial firing stages, the raw samples were reground and pressed into a variety of shapes and subsequently annealed in flowing oxygen, cooling slowly from 900°C over 24 hours. Sample shapes included discs about 12mm diameter and 2mm thick, tori 2.5mm high with outside diameter 6mm and inside diameter 3mm; cylinders about 25mm long, 6mm diameter. Bar samples were cut from the latter. Typically the rectangular sections were 3.2 x 1.4 mm and the length was 10 to 20 mm.

Four terminal measurements were made with a lock-in amplifier using differential mode with a measuring current up to a few mA rms at 10Hz. We tested for a frequency dependence in the apparent resistance, but found none between 1Hz and 10kHz. Early measurements showed significant deterioration on thermal cycling. We attributed this to the uptake of atmospheric moisture, rather than to specifically thermal effects. One sample - which had been left on the bench for a whole day - lost its superconductivity altogether, in fact showing a resistance which increased with decreasing temperature. After heating the sample with a hot air gun for a few seconds, the normal decreasing resistance and the sudden drop at the superconducting transition temperature were restored.

For more careful measurements, a sample was mounted inside a dewar probe. The sample temperature was measured with a platinum resistance thermometer. Figure 1 shows a typical resistance versus temperature profile. Just above zero resistance is the "foot" region of the RvsT characteristic - a region of some interest, showing magnetoresistive and nonlinear effects.

Figure 1. Resistance versus temperature for a 123-Y sample.

For example, the sample clearly remembers the magnetic flux conditions prevailing as it is cooled through the transition. Figure 2 shows a number of isotherms of resistance versus magnetic field. The latter was scanned with a linear ramp of amplitude corresponding to 12 x 10$^{-4}$T at a frequency of 100kHz. At temperatures below the foot -i.e. well into the superconducting region the resistance remains essentially zero during the whole sweep, but for slightly higher temperatures the resistance becomes finite at modest fields. At still higher temperatures, the zero resistance state vanishes entirely, yet the resistance still depends markedly on the field. Evidently there are still circulating currents at this stage and presumably not only does the applied field play the role of driving the flux in these loops, but their flux also remembers the cooling field. We looked at this effect after cooling the sample in the Earth's field (H_0), finding isotherms which were approximately symmetric about zero. But cooling

The Australian Physicist, Vol. 24, 1987-Page 167
NEW SUPERCONDUCTORS II

Figure 2. Magnetoresistive isotherms. The resistance of a
canoe cooled in the earth's field H0 would be nearly symmetric
with respect to the swept magnetic field. However, the data
shown here originates from a sample cooled in a field of 25 H0
and reveals evidence characteristic of persistent trapped flux.

through Tc in non-zero field (subsequently switched off) gives
rise to a shift in the isotherms. For example the data shown
here was obtained after cooling the sample in a field of about
25H0. The Figure shows that the magnetoresistive isotherms
are no longer symmetric about zero field, presumably because
the ensemble of flux trapping loops now has quite different
initial boundary conditions.

These measurements prompted questions about the
behaviour of the magnetic susceptibility in the transition
region. To compare this with the behaviour of a classical
superconductor we wound two nominally identical coils of
about 1mH each, one of which contained the sample, the
other a Nb slug of the same size. These two were tested in a
"quick-dip" helium probe so that the magnitude of the
inductance change could be determined near 90K and near 9K
where niobium becomes superconducting. They were
subsequently mounted coaxially in the same environment as
the sample configured for four terminal current resistance
measurement. Both 'susceptibility' and 'resistance' samples
were cut from the same original cylinder and should both be
the same. Apart from possible differences due to their shelf life
periods (samples were packaged with silica gel except when in
use in a low pressure helium atmosphere).

Figure 3 shows the inductance results for both measurements,
and also the resistance near 90K. If we interpret the inductance
cchange as a Meissner effect at
159Hz, we see that the total diamagnetic effect is the same
for both, but the decay of the magnetisation in the ceramic
case extends over a very wide temperature range. The point
here though is that it is the topological features of the sample
that are important for the effects under consideration. Clearly
the magnetic behaviour is much more complex than the
resistivity alone would indicate: the latter is superimposed in
Figure 3 for comparison.

During these measurements, we felt a growing unease that
the sample resistance was not quite as well defined as at first
thought, so we decided to look closely at the dependence on
the magnitude of the measuring current. We rearranged the
measurement system so that a D.C. current could be
superimposed on the 105Hz A.C. measuring current. The
results are shown in Figure 4(a) for a family of dc biases, and
again in 4(b), plotted so as to show that in this example the
resistance is proportional to the effective mean square of the
instantaneous current, i.e., I^2_{dc} + I^2_{rms}.

Preliminary work at higher frequencies has revealed quite
dramatic variations between samples from the same batch. For
example, in one experiment toroidal samples were used as
formers on which copper coils could be wound and resonated
in the 1-60MHz regime. Filling factors close to unity were
achieved, and the largest shift in resonant frequency (from
normal to superconducting state) was 50% - the smallest 3%.
RF losses (deduced from the circuit Qs) showed no systematic
variation but in all samples the losses were greater in both
normal and superconducting states than would have been
found in corresponding air-cored inductors. Once again sample
degradation was observed, presumably due to water, but this
was at least partially reversible.

Measurements were also conducted in the frequency range
200MHz - 1.4GHz, this time using an air-cored transformer
with tuned secondary. The 123-Y samples were placed inside
the air core to influence the mutual inductance of the circuit.
Those samples tested earlier at 1-60MHz exhibited similar
levels of susceptibility shift at the higher frequencies - but
samples from a second batch of material (in slab form)
showed much higher susceptibility shifts and, unfortunately,
were much more prone to water damage. In the latter case, it

Figure 3. A comparison of the magnetic susceptibilities of
niobium and 123-Y. Note that the total change of inductance
is the same for both superconductors and that near Tc the
susceptibility of the 123-Y sample shows considerably more
structure than does its resistance, shown by the curve with
triangular points.

The Australian Physicist, Vol. 24, 1987-Page 168

Figure 4 (a). Non-linear resistance of the sample is indicated
by its dependence on the D.C. current superimposed on the
105Hz measuring current. (b). The resistance appears to be
quadratic in the instantaneous current.
NEW SUPERCONDUCTORS II

is not yet known whether this is reversible.
Finally we have found no apparent susceptibility effect at X-band frequencies. A sample of 123-Y was placed in a copper cavity and we looked for shifts in the eigenmode frequencies as $T_C$ was traversed. Allowing for thermal expansion effects we concluded that the effect was zero to within 1 part in $10^5$.
Although we were surprised at the absence of X-band superconductivity it is too early to make this claim with any confidence. The null effect may be caused entirely by surface damage, and until we have a reliable means of protecting samples from the influence of atmospheric oxygen and moisture, we reserve judgement.

The Effect of Oxygen Temperature and Pressure on the Oxygen Content of $YBa_2Cu_3O_x$

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Many reports, e.g., Hor et al. [1987], Engler et al. [1987], state that the electrical properties of the new, high temperature superconductors, especially $YBa_2Cu_3O_6$, depend on the conditions of preparation especially during the final anneal ("sintering"). The pertinent variables are oxygen pressure and cooling ("quenching") rate. Clearly the phase is non-stoichiometric, i.e. $x$, the oxygen content is variable within a range, so that its equilibrium value of $x$ depends on the oxygen pressure $p(O_2)$ and temperature $T$. During cooling or quenching the kinetics of oxidation will also be important.

Various reports give $x$ = 6.5 to 7; although Engler [1987] gives $x = 7.40 \pm 0.3$ (by electron microprobe analysis).

For the ideal (orthorhombic) structure of the superconducting phase (e.g. 3) $x = 7$, but it is usually oxygen-deficient ($x \approx 6.9$). The common method of investigating $x$ is by thermogravimetry, using $x = 3.5$ for the hydrogen-reduced material ($=Y_2O_3 + BaO + Cu$ metal) as a reference composition. No details of such experiments have been provided (although, in this work, some thermogravimetry has been described, Strobel [1987]). We have done some thermogravimetry. Apart from a $H_2$-reduction, our experiments were isobaric; heating a sample of $YBa_2Cu_3O_x$ in a constant oxygen pressure at $T = 750$°C and at $=750$°C pressure (corresponding roughly to 1 atm of $O_2$ and 1 atm pressure of air).

Data have not yet been corrected for buoyancy and thermomolecular flow effects, and so their accuracy is limited to $d\approx 0.025$ (although their precision is about ±0.001 in $x$). Nevertheless, the results are useful and relevant to understanding the phase preparation process. They are not entirely as might have been expected.

Results
The data of oxygen content $x$ vs. temperature $T$, with $p(O_2)$ constant, are shown in Figure 1. They are obtained from charts on which sample weight (from an automatic recording microbalance) and temperature were simultaneously recorded or a function of time $t$. The sample furnace temperature was programmed to rise to $1400°C \pm 1°C$ min$^{-1}$, to hold at a maximum $T = 840°C$ for 1 hour (750°C) or 2 hours (150°C), and then to fall at the same rate.

Relative to the assumed $x = 3.50$ for a $H_2$-reduced sample at 790°C, the original sample (prepared by slow-cooling in 1 atm of $O_2$) has $x = 7.14$. As soon as the reduced sample was cooled if gained weight (in a $H_2$ atmosphere), which we presume to be a consequence of the very hygroscopic BaO picking up water. (Interestingly, if this later weight were used as a reference $x = 3.50$, the initial value is then (erroneously) calculated to be $x \approx 6.94$).

The following points are noted:
(1) A considerable range in $x$ from $7.15 at \approx 300°C$ to $6.6 at 840°C$.
(2) Very little "hysteresis" (at $dT/dt = 1.4°C \text{ min}^{-1}$): above $500°C, \approx 15°C$ for $p(O_2) = 750$ torr and $\approx 10°C$ for $p(O_2) = 150$ torr; increasing to $= 30°C$ for the latter at $400°C$. This means that the solid equilibrates very rapidly with its $O_2$ gas ambience at or above $400°C$ (but not below). Separate isobars with rapid stepwise temperature changes confirm this: above $= 350°C$ the weight trace mimicked the temperature trace on the chart (weight increasing as $T$ decreased), with no detectable time lag - i.e. (near) quenching occurred in <1 min. Quenching in a given $x$ value from $T \geq 350°C$ is therefore impossible: the sample will pick up oxygen as it cools, unless the quench time is of the order of 1 sec.

![Figure 1. Oxygen content, $x$ as a function of temperature, $T$ for two isobars with $p(O_2) = 750$ torr and 150 torr. Heating and cooling paths are shown with open and filled circles respectively.](image)

However, it should be noted that our sample was a lightly sintered powder. A compressed sample of high density would have a slower equilibration rate. (Experiments on such samples are in progress.)

The $H_2$-reduction experiment is being investigated further to check the assumption that $x = 3.50$ when the sample is hot but $x \gg 3.5$ as it cools.

Similar experiments on $HoBa_2Cu_3O_6$ give $x = 7.00$ for a sample also prepared by slow cooling in 1 atm. pressure of $O_2$, with $x = 6.36$ at $800°C$ in 750 torr. This is to be compared with $x = 6.72$ for $YBa_2Cu_3O_6$ under the same conditions: for the Ho compound $x$ is lower at a given $T$, and more sensitive to $T$ at $p(O_2) = 750$ torr.

References

The Australian Physicist, Vol. 24, 1987-Page 169
LETTERS TO THE EDITOR

Professional Conduct

Because of its role in creating standards for chartered physicists, the (British) Institute of Physics has become interested in standards of professional conduct, and at its July Annual Meeting will be considering an amendment to the By-laws as follows:

PROFESSIONAL CONDUCT

(a) Every member shall, so long as he is a member, act in a manner worthy of the honour and interests of the profession of Physicist and of the Institute, and he shall do nothing that shall bring the profession of Physicist or the Institute into disrepute. He shall at all times safeguard the public interest in matters of safety, health and otherwise. He shall exercise his professional skill and judgement to the best of his ability, and discharge his professional responsibilities with integrity.

(b) In order to ensure the fulfilment of paragraph (a) of this Bylaw, the Council may from time to time issue rules of conduct to which members shall conform.

One assumes that the masculine pronoun includes the feminine, but apart from this, the idea of a code of conduct has some merit for us in Australia. The AIP can only be strong if its public image is strong, and there are many situations in which a professional person is faced with conflicting interests. Even a general statement such as (a) above may give some guidance in individual circumstances, but I believe that the strength of the Bylaw lies in the possibility of formulating more detailed statements which would represent the considered opinions of a group of experienced physicists in response to various needs.

At one time there appeared to be a sharp distinction between right and wrong, but as more options become available, choices are more often between two courses of action, or even conceivably between two evils. We should have a general statement to the effect that physicists are expected to show goodwill to the rest of mankind. We should also be able to give some assistance in making these moral choices, and some way of expressing disapproval when the wrong choices are made.

Jim Graham.

FASTS Reply to Dr. C. Foley

In the June issue of TAP, Dr. Catherine Foley takes FASTS to task over its report 'Industry - Education for Science and Technology', which was prepared as background information for a meeting that was held in October last year between members of the FASTS executive and Senators Button and Ryan and Mr Barry Jones. One purpose of this meeting was to express FASTS's concern over the shortage of suitably qualified personnel in certain disciplines.

Predictions of future workforce requirements are fraught with uncertainty and bedevilled by a lack of appropriate statistics. FASTS, as an organization representing some 60 societies with a total of over 60 000 members has received a wealth of anecdotal information on the supply and demand for qualified personnel, but little hard data. Government statistics are generally aggregated to the point where it is impossible to identify between areas of demand and oversupply at a discipline level.

The AIP, through its Employment Committee and the activities of interested members has maintained comprehensive statistics on advertised positions for physicists and the production of graduates. These statistics were employed in the Institute's submission to the ASTEC Review of Higher Education Research Funding (published in Vol. 23, no.5, issue of TAP) and an unpublished report from the AIP Science Policy Committee, 'The Demand for Physics Graduates'. It is the interpretation of these statistics, given in the latter report and adopted by FASTS, that Dr Foley takes exception to.

It is Dr Foley's assertion, that with the "recycling" of PhD graduates into the job market from fixed term appointments, the employment situation is not as open as the annual figures of approximately 150 advertised positions and 50 PhD graduates might imply.

Central to Dr Foley's argument is the statement that... only about 10 out of 150 jobs are permanent. If she can substantiate this it would be a valuable input. However, on the basis of John Prescott's statistics published in TAP 23, 230 (1986) this appears to me to be unduly pessimistic and that a figure closer to one half would be more realistic.

It is implicit in Dr Foley's analysis that it is a fixed set of positions that are being competed for. Australian Bureau of Statistics figures derived from the 1981 census give the number of physicists at the levels of PhD and MSc as 1662 (a figure that is probably low due to the narrowness of the classification). ABS figures also show an annual growth rate for R & D personnel of approximately 2%. While significant variations can be expected between different areas of research, the annual introduction of 20-30 new positions for physicists would not appear unreasonable. Furthermore, with an average working life-time of approximately 35 years for a higher degree graduate, retirements should provide a further 40-50 positions per year.

These figures suggest that the number of "new" positions, i.e., positions which have not been previously held on a fixed term appointment, could be of the order of 60-80 a year even without taking into consideration other reasons for the vacating of research positions.

The annual production of physics PhD graduates is between 50-60, approximately one quarter of whom are overseas students who are required by Australian immigration policy to return to their own countries. On the basis of this analysis, I believe that it is not unreasonable to conclude that there is a significant unmet demand for PhD graduates in physics.

Dr Foley comments on the unfavourable level of post doctoral salaries, specifically compared with those available in CSIRO. I do not dispute this as FAUSA has documented the decline in the salary levels of university scientists relative to those employed by the Government. Indeed, this exacerbates the very situation that FASTS has been drawing to the attention of government officials who are reluctant to accept certain areas of employment.

FASTS relies heavily upon the information provided by its member societies. Should Dr Foley, or any other AIP member, wish to contribute to FASTS activities, either directly or through the AIP, they are welcome to do so. FASTS currently has working groups concerned with the proposed establishment of an Australia Research Council and educational issues. Details may be obtained from the Executive Director, Dr David Widdup on (062) 475334.

T.F. Smith

Teaching Physics in Schools

This letter is triggered by two articles in the June TAP, "Where have all the physics teachers gone!?" by Clifton L. Smith, and "And Who Shall Teach Them What?" by L.G. Little and I.J. Cooper, and what I take as an insulting reference to science teachers in the President's column.

I am a physics teacher at an A.C.T. public secondary college (senior high school). As well as physics I teach
LETTERS TO THE EDITOR

chemistry and general science to Years 11 and 12 students. I have a Ph.D. in physics (Tasmania, 1981) and a Dip.Ed. (N.S.W., 1983). I have been an "M.A.I.P." since 1981, and before that a "G.A.I.P."

I went into teaching because I thought I'd enjoy it (I do), because I wanted a job with security and a decent salary scale (before this I was a Tutor on contract at U.N.S.W. and U. of Wollongong), and because I thought I could make a positive contribution to physics education in Australia (I am). At the time, it was interesting that some of my colleagues believed that I was taking a "step down" and urged me to find some other, somehow "better", employment. They were wrong in their judgements about teaching then, they are still wrong now, and it is a sad reflection on anyone's value system if they do not rank the education of the young as one of the most critically important professional occupations in this country. I have found secondary teaching to be rewarding and challenging. My teacher colleagues are very professional people indeed, with a keen interest in the welfare of their students. They are constantly searching for ways of achieving greater understanding and enthusiasm in their classes, better curricula and better resources.

Certainly, we should recognise the world-wide crisis in physics education. But there are well qualified, professional physics teachers in Australia. I believe that the A.I.P. should be drawing on the experience of such teachers to formulate and implement policies to arrest the decline.

Physics graduates will not take on a year's full-time study for a Dip.Ed. when they can't afford it, or if they perceive that they cannot earn as much or move ahead as quickly as they could in other occupations. As teachers, they would find themselves working harder than their colleagues in non-science or non-technical subjects for the same pay and conditions.

I was interested to see that no Physics Education session has been listed for the next A.I.P. Congress.

The Academy of Science has sponsored publication of senior textbooks in biology, chemistry and geology, yet not in physics.

There has been no national physics competition to parallel those in chemistry and mathematics.

There is a lack of resources for physics teaching in Australian schools. We lack videocassettes, slide sets, guides to new and better equipment.

I strongly support Clifton Smith's contention that "the time is now appropriate for the A.I.P. to ... address this problem of the decline in physics." I would contend that efforts in this direction need national coordination and that at all stages practising teachers of secondary-level physics should be involved. Hopefully there will be teachers in the ranks of the A.I.P. who will take part.

Certainly, we would want to avoid any acrimonious debate between academics and secondary science teachers. We would, I hope, not want to allow unsupported and inflammatory suggestions about "a decline in the quality of people becoming science teachers" or "scientifically illiterate persons" being "churned back in an unstable, positive feedback loop to deter even more students", as appeared in that issue of T.A.P., to get in the way of a constructive dialogue between physicists on what can be done to (a) convince physicists to go into teaching, and (b) convince students to include physics in their studies. A dialogue between physicists across all levels and from all sectors of education.

Terry Beven.

NMR CONFERENCE

NMR - 88

Thredbo, 14th-18th February 1988

The "NMR-88" meeting is to be held from Sunday, 14th to Thursday, 18th February at the Alpine Hotel at Thredbo. There will be invited and contributed papers and posters in the following conference sessions: (1) Structure and dynamics of biological macromolecules; (2) Solid State NMR; (3) In-Vivo NMR Spectroscopy; (4) New physics; (5) Organic and polymer; and (6) Inorganic.


For details and registration forms contact:
L. Harland,
Research School of Chemistry,
The Australian National University,
G.P.O. Box 4, Canberra, ACT 2601.
Phone (062) 49-2863.

The Australian Bicentennial Congress of Physicists

Important Announcement

Our advice from those associated with the tourist industry in NSW is that bookings of both travel to Sydney and accommodation in Sydney for the BICENTENNIAL WEEK (Jan 24-30) are already heavy, and expected to saturate the supply late in 1987. This could have an impact on those wishing to attend the Congress.

You are urged to book your travel requirements and your accommodation as soon as possible. Ample college accommodation has been reserved, but we cannot guarantee accommodation after the registration deadline of 13th November 1987. There are a few double rooms which will be allotted as requested. The situation for those who prefer motel accommodation is more urgent.

Motel accommodation can be booked either through the Congress organisers at selected motels, or directly at these or any other motel of your choice.

We list below motels in the vicinity of the University of New South Wales, indicating those at which we have reserved rooms.

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(*) BARKER LODGE 02 662 8444
(*) ESROW MOTEL 02 398 7022
THOROUGHBRED MOTEL 02 662 6044

We urge that you register and arrange accommodation and travel as early as possible to avoid disappointment.
Research Funding in the Tertiary Sector

I.M. Barrett, for the AIP Science Policy Committee

The ASTEC Report

The following comments are made in the light of the February 1987 ASTEC report entitled "Improving the research performance of Australia's Universities and other tertiary education institutions". On most aspects of policy, the report is probably representative of opinion at the highest levels of Government. In recent comments on the ASTEC report by CTIEC, their main disagreement with it concerned the ministerial location of the proposed Australian Research Council, a point that may have now been determined. The main concern of the ASTEC report, and no doubt of the Government, is that University research should better serve the national interest, without needing too much more public money to be spent on it.

The main recommended method is the inclusion of national need in the criteria for research support (sections 2.10 and 2.11). By contrast, the Australian Research Grants Committee (ARGC) has made intrinsic scientific merit, augmented, for peers review, the sole criterion. ASTEC recommends that a new body, the Australian Research Council (ARC) should replace the ARGC (recommendation 6a, section 5.18). Besides individual or project grants, resembling those typically made by the ARGC, the ARC would offer increased support in the form of programme grants - usually larger, longer term, and more interdisciplinary, and able to target areas of research for which there is a national need not being otherwise met; overall, the flavour would be more applied.

While researchers commonly recognise the ARGC as the main source of research funds, there is another method of reckoning research funding, widely used in government circles, which gives a very different picture: on the grounds that on average 30% of academic staff time is spent on research, 30% of the total public funding of Universities is ascribed to research. Research support calculated in this way amounts to about 600 million dollars per annum (item 53, p.1), an order of magnitude larger than ARGC funding. Public funds for the tertiary sector now come almost entirely through the Commonwealth Tertiary Education Commission (CTEC). ASTEC recommends that CTIEC funding should be based in some substantial degree on research policies and performance of the supported institutions, and not, as at present, largely on effective student numbers or EFTS (Recommendation R3, section 4.9, Recommendation 5, section 4.21, and items S17-S21, pp 4-5).

Comments

First, it must be acknowledged that the present comments are made from the viewpoint of the physical sciences and engineering. While this seems also to be the viewpoint of the ASTEC report, the report recommends, as it were an afterthought, that the humanities and social sciences be included in the scope of ARC. We feel that the value of this inclusion is debatable, and that separate funding arrangements might be better.

There is much in the ASTEC report that will be widely welcomed in the scientific and engineering research community. Few will dispute the value of a national body such as the proposed ARC, with sufficient funds and discretion to initiate research programmes and centres in broad fields where present Australian activity needs to be augmented. For example, it might well be in the national interest to set up a research and training institute in the field of optical science and engineering, resembling that at the University of Rochester in the USA, or the new Canadian institute. It would presumably be part of the task of the proposed ARC to assess the need for, and co-ordinate support for, such a large and multidisciplinary enterprise. The composition of the ARC would lend itself to such a coordinating role: the proposed Board would comprise the Secretaries of the Department of Science and of DITAC, the chairs of CTIEC and CSIRO, and three representatives of higher education and three of industry (Recommendations 6c and 6d, sections 5.27 and 5.30).

There are a number of minor specific suggestions of some value. For example providing for Australian access to overseas facilities (section 5.42), encouraging scientific networking within Australia (section 5.40), and permitting ANU Research School staff to participate in ARC funding (section 5.5).

Indeed, most of what the ASTEC report says will be welcomed. However, there will be some concerns, especially about the things the report does not say.

Nothing is said about peer review. Peer review is an essential part of the present ARGC system, which most researchers regard as successful, if underfunded. ARGC money is the life-giving fresh water in a generally muddy stream. It is under this system that Australian academic research has achieved its high international standing, one of the few areas of Australian endeavour whose quality is internationally competitive. Peer review is a means by which some essential qualitative judgements can be made. The principal of peer review is not indissolubly linked to the "pure" merit system of the present ARGC; it could be used in conjunction with a modified merit system, such as proposed for the ARC, in which account is taken of national need. It would also play a useful role in the assessment of institutional research performance which ASTEC recommends as a partial substitute for EFTS. The rule of EFTS has had a distorting effect on tertiary education practices. Any purely mechanical formula for assessing research performances (number of papers etc.) is likely to distort research practice. Further qualitative judgements are essential, and peer review is well established as an effective method of obtaining such qualitative judgements.

Nothing in the ASTEC report is inconsistent with the use of peer review in this way; however, it is a matter of some concern that it makes no mention of this important mechanism.

There is a more serious omission. The report nowhere mentions the importance of the quality of the key research personnel. Yet the effectiveness of research is determined almost entirely by the quality of the key researchers. Such people are employable anywhere in the world, so in order to retain them, or to dissuade them from leaving the country, it is necessary to provide conditions of work which, taken as a whole, are world competitive. Salary flexibility would be helpful. The level and discrimination of research support is still more important.

The ASTEC report in its introductory chapter offers some sketchy but astounding information about the numbers of scientists and engineers in Australia, in relation to the numbers in Europe, Japan and the USA. These countries have, per capita, roughly eight times more than we do (section 1.7).

These broad figures suggest that we are not turning out nearly enough science and engineering graduates, of all kinds, and at all levels, including the doctorate level. But the ASTEC report makes no quantitative estimates of the rate of production of PhDs which Australia should aim at in the various branches of science and engineering. Nor does it remark upon the absence of the more detailed statistical information which would be needed to make such estimates. Yet the large increase in output which we should probably be aiming at can scarcely be attained without a significant (though not necessarily proportional) increase in research expenditure in the tertiary sector.

Thus the AIP while generally endorsing the ASTEC report, would like to add some caveats and further recommendations. These recommendations fall under three headings - quality, quantity and linkage.
POLICY AND POLITICS

Recommendations

1. Quality
Under quality, we recommend that peer review should continue to be employed as an element in the assessment of research projects and also in the assessment of research performances of groups, departments and institutions. We consider that taking into account national needs does not preclude the use of peer review. Also under the heading of quality, we recommend that national research planning should recognize the over-riding importance of recruiting and holding outstanding researchers.

2. Quantity
Under the heading of quantity we recommend that the numbers of Australians with various types of skills should be ascertained, the comparison with typical developed countries be made, and from these figures a (very rough) estimate made of the required rate of production. The skills must be sufficiently broken down by kind and level. Thus, PhD, Master's or Bachelor's degree, in the several kinds of engineering, in the several kinds of physics and chemistry etc. (Trade skills and language skills should be added to the scope of such a survey.) The Australian Bureau of Statistics should give a high priority to the collection of this information, with the advice and help of the relevant government departments (Science, DITAC, Education, Employment and Industrial Relations). The AIP would help obtain this information in its own field, and there is no doubt that the other professional societies, and FASTS, would also help.

In an increasingly competitive world, it will not be possible to import a substantial proportion of the skilled people we need. Even if it were possible, it would be undesirable. Not only for economic reasons, but also for ethical and political reasons, we should develop the skills of those who are born here.

3. Linkage
The AIP’s last and most important recommendation concerns the linkage between research resources in the tertiary sector and Australian industry.

Basic research, carried out in Australia, is widely regarded as a "cultural" activity which can contribute, at best, only very indirectly to the Australian economy. This view, which is a very natural one, is held at the highest levels of government, and seems to underlie much of the argument of the ASTEC report (see, for example, section 2.10). Though understandable, this view is mistaken and unless corrected, is likely to lead to the degradation of Australian Universities and a degradation of their capacity to help the economy.

Outstanding research work in the experimental sciences nearly always involves the development of new techniques and the critical use of the most up to date knowledge. Where such research work is being done there is apt to be a rich assemblage of knowledge and special equipment and of gifted enthusiastic and hard-driving individuals. A University, with many such groups, can provide a uniquely nourishing environment for commercially oriented research. In the physical sciences and engineering. Typically, this consists of the development of product prototypes. The University environment can make available a wealth of informal free expert advice on a wide range of topics, and the possibility of borrowing equipment, major and minor.

What the University cannot provide much of is person time ("man hours"). University researchers worth their salt are flat out already. Most of them cannot replace their research by prototype development without diminishing the very thing that makes the University a potentially good host to commercial research. So, if commercial research is to proceed on a quantitatively significant scale on campus, it requires additional funds, especially salaries for temporary staff dedicated to the commercial projects in question. The commercial projects can then enrich, and not displace, the research and teaching activities which are the Universities' primary responsibility.

Apparently, in the United States, only 5% of on-campus research funding comes from private sources (ASTEC, section 6.2). Perhaps we in Australia can exceed this percentage. The 150% tax deduction should help. In any case, successful University hosted commercial developments will encourage the funding of more, whether the funds come from private industry or from government.

The AIP recommends that Australian tertiary education institutions, and the science and engineering departments within them, should be willing to act as hosts in this sort of way to commercial research, to product prototype development, and that they should say so loudly and publicly.

We believe that, provided effective measures are taken to maintain and increase the quality of tertiary sector research, the hosting of commercial projects, with independent funding, is an effective way to establish the linkage with industry which Australia so desperately needs. There is no doubt also that the existence of such links will tend to influence the direction of basic research, and the undergraduate syllabus, in such a way as to increase the relevance of both to the needs of Australian industry.

Progress in Organising the Australian Bicentenary Congress of Physicists in 1988

By now you will have all received your registration form for the Congress, but perhaps you have not yet bothered to read it. Let me point out a few features of the Congress. First, it is truly the largest gathering of Physicists ever in this country, our most conservative estimate has 600 attendees, achieved by co-ordinating many specialist Physics meetings. We have the wholehearted support of all these groups, listed on the brochure. Second, the meeting is intended to be a working scientific meeting, with contributed papers the most important aspect. We require you to submit papers to make the meeting a success. The basic streams we have identified are listed as the interests on the brochure. The contributed papers will make up four days with twelve parallel streams. It is anticipated that these streams will join together where a topic bridges a number of interest groups.

The last item which I stress is that we are holding the meeting at an exciting time in an exciting place. We have reasonably priced accommodation, a balmy climate and lively colleagues. IN addition our friends in the Bureau of Meteorology assure us that it won't rain that week!! See you in Sydney, January 24-29, 1988.

B. Window, Chairman, Organising Committee.

Study of Research and Development in Advanced Electronic Materials

A study of research and development of advanced electronic materials has been initiated with the support of the Department of Science, and input is sought from interested groups and individuals for the final report. The aim is to survey what work is going on in Australia (providing a directory of projects), to suggest areas which appear promising in the future for Australian technology, and to propose means of co-ordinating research to make the most effective use of resources. A questionnaire will be sent out to interested groups.

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Mr J. Whitehouse (062) 64 4235,
Sectional Policy and Programs Branch, Department of Science,
PO Box 65, Belconnen, ACT 2616.
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This new generation Electro-Optic Waveform Analyzer was designed specifically to measure the electrical characteristics of ultra-fast electronic and opto-electronic devices. Applications include temporal and frequency response measurements of microwave and millimeter wave devices, GaAs devices, photodetectors, transistors, and waveguides.

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Acton Research Corporation

Model 747 Monochromator Scan Controller

A new, microprocessor-based stepping motor controller is now available from Acton Research Corporation of Acton, MA. The new system, called the Model 747, is an RS-232C compatible stepping motor drive system specifically designed for the control of monochromator scan functions. The Model 747 is a low cost system featuring high performance, multistep scanning (12800 steps/rev), easy programming and operation, multiple scanning speeds, and RS-232C compatibility for computer control. The Model 747 is a complete system, available with all ARC monochromators, spectrometers and accessories to provide a versatile, computer controlled operation.

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For further information contact:
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Five Dock, NSW 2046.
Ph: (02) 712 3111.

ETP OXFORD

Simple Radon Measuring Device

Anyone who owns a PC type computer using PC-DOS/MS-DOS operating system may now, very simply, take radiation readings on residential properties.

In many parts of the USA a "radon level certificate" is required when selling a home. Several cases have arisen in Australia in recent years where appropriate monitoring would have revealed the presence, or otherwise, of radioactive gas. The levels are very low, but now there is an economical method of measuring them, to assure buyers, sellers and agents that the property is not affected by radiation.

Radon is a radioactive gas which emits alpha radiation causing "daughter products" (or progeny) to be produced. Alpha radiation, whilst it cannot penetrate very far into material, is highly ionising (damaging) and being a gas, can be inhaled causing subsequent internal damage.

A company which specialises in the measurement of Radon progeny has produced a Computer Remote Integrating Radon Progeny Area Sampler (CIRAS for short). CIRAS is an integrating area sampler and is completely automatic. It is intended for regional mass surveys, providing time-integrated "Working Level" measurements in 2 to 4 days.

Fastest Waveform Digitizer now has highest Solid-State Digitizer Bandwidth

The world's fastest solid-state waveform digitizer now has the world's highest solid-state bandwidth. It's called the Model 6880A Waveform Digitizer, new from LeCroy Corporation. It samples a 400 MHz bandwidth, single-shot waveform at 1.35 gigasamples/sec (guaranteed, not typical) and will find wide use in such demanding applications as EMC/EMP testing, laser experimentation, lighting studies, ECL circuit design, IC testing and high energy physics experiments.

The earlier LeCroy Model 6880 captured up to 250 MHz signals. The new LeCroy 6880A provides a combination of increased 400 MHz bandwidth, high 8-bit resolution, fast sample rate and 7 μsec long waveform capture memory. These specifications define guaranteed, not typical performance, that is unmatched by any other product. Competitive scan converters and single-channel CCD scope cameras on analogue scopes provide the only other means of capturing a 400 MHz single-shot signal. But scan technology does not offer the solid state 6880A's full automation and low maintenance costs. Moreover, the 10,000 sample point waveform memory is 20 times longer than the memory contained in either scan tube digitizers or the CCD cameras.

For further information contact:
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The Australian Physicist, Vol. 24, 1987-Page 175
NSW

The monthly lecture to the New South Wales Branch was delivered by Dr Joe Unsworth of Macquarie University on the subject of Molecular Electronics. His vision of future electronic devices on the nm scale rather than the current µm scale, with the ability to self-fabricate and self-assemble, leading to the super molecular information processor, was fascinating. He also described many of the current spin-offs from this type of research. It is worth noting that the Department of Science has recently produced a sectorial review of the area of Molecular Electronics, prepared by Norman Gomm and John Whiteleaf, with Dr Unsworth as a member of an ad hoc advisory expert committee.

The June meeting was addressed by Dr David Cockayne of Sydney University on Perfection and Imperfection in Semiconductors studied by High Resolution Electron Microscopy. Dr Cockayne covered three topics in looking at crystalline and amorphous semiconductors, explaining the techniques clearly and simply. He described the observation of dissociated dislocations using the weak beam technique which he pioneered, the use of high resolution images to assess the quality of interfaces in superlattices made by Telecom, and the derivation of radial distribution functions of amorphous semiconductors using elastic electron scattering. He couldn’t resist showing some atom resolution pictures of the new high Tc superconductors. Dr Cockayne has added substantially to the high stature of Australians in electron microscopy through his own work, and has contributed much to materials science in New South Wales through his building up of a facility which is top class and easily accessed.

B. Window

VIC

At the June meeting of the Victorian branch we were fortunate to hear Dr Alex Moodie, of CSIRO Materials Science and Technology, tell us about the exciting new “high temperature” superconductors.

Superconductivity occurs in some materials when they are cooled below a critical temperature, Tc, which is near the boiling point of liquid Helium at 4.2K. Because of the technological importance of superconductivity there have been efforts to find materials with much higher critical temperatures. Since the discovery of superconductivity in mercury by Kamerlingh Onnes in 1911, the highest known critical temperature has increased at a rate of 3K/decade, until 1986 when a ceramic was found to have a critical temperature of about 30K. Now there are materials with critical temperatures above the boiling point of liquid nitrogen, around 90K. This is a major advance because liquid nitrogen is relatively easy to produce.

Of these high temperature superconductors is a black ceramic YBa2Cu3O7, known as a 1 2 3 compound, with an orthorhombic structure. Dr Moodie explained that the ceramic can be made by mixing CuO, Y2O3 and BaCO3 together and heating to 900°C for about 12 hours. Afterwards the mixture is crushed and then reheated in the presence of O2. Under these conditions it is conceivable that a superconducting compound will be made. It appears as a hard, brittle black sinter with a grain size of about 0.1mm. When in the form of a dense sinter it can be cut with a diamond saw, machined and polished. However, the substance is a quaternary oxide with a complex phase diagram and one is likely to produce Y2BaCu3O7, the infamous “green stuff”, which Dr Moodie describes as decorative but “super resistive!” The problem with these superconducting compounds is that they can be forgiving on some materials but not on others. Virtually any rare earth can be substituted for the Yttrium, but one must begin with very pure compounds.

Having made the material, one way to test for superconductivity is to observe the Meissner effect. When a material becomes superconducting it expels magnetic fields from its interior. This occurs due to the formation of persistent eddy currents which create an opposing field. A consequence of this is that a superconductor is repelled by a magnet. To our delight, this effect was demonstrated to us by Dr Moodie with a sample of the high temperature superconductor suspended from a cotton thread. After cooling it in liquid nitrogen, we all observed the superconducting ceramic repelled by a magnet, which had no effect when the ceramic warmed above its critical temperature.

Superconductivity in most materials has been explained by the BCS theory in which the conduction electrons are coupled by lattice phonons. As an electron passes through the lattice, it attracts the ions towards it and creates a deformation. Another electron can take advantage of this deformation to lower its energy and it therefore interacts with the first electron via the lattice. At low temperature this results in a pairing of equal energy electrons, and a large number of these paired electrons form a “crust” on the Fermi surface. A magnetic field causes the entire crust to move, including the ions, producing no resistance. Physicists need to determine whether the electron-electron interactions in high temperature superconductors are mediated by phonons, as in the BCS theory. It has been demonstrated that the charges carrying the super current are a Cooper pair, that is, coupled spin up and spin down electrons. This was done by observing the quantized magnetic flux from a superconducting ring, which takes a range of values which are multiples of h/cq, where q is the charge of the current carrier. The flux observations show that q=2e where e is the electronic charge, which tells us that two coupled electrons are involved in the conduction process. Some experiments have showed anomalies in other properties of the ceramic superconductors which require further investigation.

Dr Moodie said that we have only just begun to make the superconducting ceramic materials in pure form. Single crystals are small and difficult to come by. Physicists need to push for materials which can carry large supercurrents because that is what technology requires. When commenting on the famous American Physical Society meeting on high Tc oxides which he attended, Dr Moodie said that the people there showed an extraordinary amount of good will, disclosing information which had been difficult to discover. He felt that it will be the hard work of these physicists that will reap the benefits for their countries.

T. Davis

WA.

WASTAC Satellite Centre Opened

The receiving station of the Western Australian Satellite Technology and Applications Centre (WASTAC) was officially opened on July 3rd by the Minister for Science, Barry Jones.

WASTAC comprises Curtin University of Technology’s Division of Engineering and Science; CSIRO Division of Ground Water Research’s Remote Sensing Section; Department of Land Administration’s Remote Sensing Application Centre; and the Bureau of Meteorology. The satellite receiving station is located at Curtin University (formerly the WA Institute of Technology). In 1967 a group was formed in WAIT’s Department of Electrical Engineering to establish a ground station to receive data from polar-orbit weather satellites. In the 1970s this was expanded
to include the geostationary GMS satellite, and NOAA High Resolution Picture Transmission data. By obtaining satellite antennas at disposal sales, the cost of the receiving station has been limited to $300,000.


Branch Meeting June 1987

Murdoch University was the venue for the June meeting of the WA branch where Professor M. Scriven, Professor of Education (UWA) addressed members on the somewhat controversial topic of 'The absolute difference between Science and Technology'. Prof Scriven is well known in Western Australia for his promotion of the use of microcomputers and for his sometimes radical views on a number of subjects. He is currently a member of the WA Government’s Science and Industry Technology Council (SITCO) and has a special interest in technology studies, in their own right, in secondary education.

Science, claimed Prof Scriven, can be thought of as the establishment of a set of descriptions, explanations and predictions leading to systems of classification. The outcomes are linguistic entities which tend to have an abstract nature. In contrast, technology is purely involved with the production and maintenance of artefacts usually involving some material objects. A significant difference between the two pursuits also arises from their methodology. Science tends to the creative-inductive-verification, while technology is based around the needs-design-evaluation cycle. However, despite the strong ‘design’ orientation of engineering, it too could not claim to be the driving force behind much technological progress since the upper echelons of this discipline were closer to science than technology.

At this point Prof Scriven launched an obvious but smart missile at the audience. Technology is older than science by many thousands of years!

After a very well timed pause, Prof Scriven went on to claim that despite this age difference the educated community has been insensitive in getting its priorities right, not only on the semantic issue but in more concrete terms such as funding guidelines. Apparently we scientists have treated technology as a younger stupid brother and toss it off as nothing more than the result of ‘inspired tinkering’ while in essence technology stands proud on its own feet and has in fact created new science. According to Prof Scriven, science has taken too much credit for technological progress. Engineers apparently get very annoyed at the use of terms such as ‘scientific advances’ when applied to successful ventures into outer space (failures are called ‘engineering disasters’). A lively debate ensued which raised a number of issues including the definitions and assertions given by Prof Scriven and the introduction of a technology subject into WA secondary schools.

This subject is currently being trialed in several WA schools (using teachers with scientific training and non-scientific training) on the basis that no science whatsoever is needed to raise technology to its own entity. The principal aim of this school subject is to reduce technophobia through the discussion of appropriate technologies. Emphasis is also being placed on systematic assessment of technology. Asked where science fitted into the proposed programme of study, Prof Scriven suggested that the more investigative students would soon realize that certain issues and technologies would require some scientific understanding to be usefully evaluated.

The most contentious points raised by members were related to the definitions used by Prof Scriven in certain situations. Comments by the members on the validity of the differences asserted by the speaker’s definitions were covered by using the somewhat thin argument of ‘scientists merely defending their own interests’ on this issue. According to Prof Scriven the motive of the person undertaking the activity decided whether science or technology is happening. Thus, if a person is measuring some quantity to develop a better ‘widget’ this is technology but, if it is purely to measure the quantity itself then it is science!! This left me a little bewildered as I knew very few scientists (and even technologists) operate in total isolation. Having just completed a Ph.D. on a study of the OKLO fossil reactors, I made no conscious decision during my study as to the scientific merits versus the application of my results to nuclear waste disposal.

Much (probably 99%) of the work undertaken by scientists is inspired (hopefully organized) tinkering, akin to the so called berated technologist. Neither technologists nor scientists have sole claim to the human activities of inspired tinkering or organized description-explanations-predictions, it’s just something common to human existence. If technologists are solely concerned with the production and maintenance of artefacts how many close technologists must we have amongst Australian scientists frantically trying to maintain much of our ageing or even obsolete scientific research equipment or produce technological masterpieces from scrap materials and the ever tightening budgets.

Similarly, if scientists are solely concerned with description-explanation-prediction then why are most technologists compelled to produce yet another description-explanation of their artefacts to enable them to improve their product?

To quote a recent view from John Maddox (‘Should technology be scorned?’ Nature, Vol 326, April 1987) ‘Science and technology are parts of a seamless spectrum’. While the main thrust of Maddox’s article is to point out the lack of vitality in the engineering literature he also comments at length on the large number of similarities between science and technology.

It was well after the hour, with many unanswered questions left hanging in the air, before the meeting was closed. On leaving the lecture theatre it was obvious that most members were still engaged in discussing many of the finer points raised by the speaker. It has been some time since a WA AIP branch seminar provoked such an enthusiastic response from the audience and the WA branch wishes to thank Prof Scriven for his presentation.

The Perth Observatory

The Perth Observatory was founded in 1896 with the strong support of Sir John Forrest, the first Premier of Western Australia. Although originally near Kings Park, the Observatory was relocated to a dark site in the State Forest near Bickley in 1965. From the beginning the Observatory contributed to international programmes, the first one being the Astographic survey to cover the whole sky with photographic plates down to fourteenth magnitude. The standard Astographic 33cm refractor having recently finished the second epoch plates for the Astographic survey, is now used mostly on Solar System objects. Positions of Comets and Minor Planets down to twelfth magnitude are obtained regularly - this Perth Observatory obtained more positions of Comet Halley than any other observatory in the world and made a major contribution to the success of the GIOTTO approach to Comet Halley.

The PERTH 70 star position catalogue produced with the Meridian Transit telescope is used wherever accurate positions are needed, at other observatories and space agencies. Another meridian catalogue is being prepared.

The Observatory’s largest instrument is a 61cm reflector on loan from the Lowell Observatory. This telescope was first used for a photographic Planetary Patrol on Jupiter and Mars, but the importance of this programme diminished with advanced space vehicle exploration. The main emphasis was then changed to photometry of variable stars, comets, minor planets and planetary occultations. The discovery of Uranus’ rings was jointly made at Perth in 1977. Comet Halley was
intensively observed using narrow band filter photometry with a CCD camera on loan from the University of Maryland. Many unique observations were made in correspondence with specific cometary molecules, the results still being refined and prepared for publication. Nature magazine featured a Comet Halley image taken at Perth as its cover page in December 1986. Currently the CCD camera is being used for the eclipse/occultation phenomena of the Pluto/Charon system. Pluto is magnitude fourteen and it is no mean achievement to obtain reliable results with a telescope of such a modest size.

The unique position of the Perth Observatory in longitude and latitude (we recently recovered a magnitude 20 comet inaccessible to much larger telescopes in the northern hemisphere) naturally gives rise to thoughts of scientific development. A simple spectograph is budgetted for this year to broaden the scope of the Observatory’s work. It is hoped that a CCD camera of our own will be obtained in the next year or so, to allow the 61cm to achieve its maximum potential. A larger telescope is, of course, what is really needed and co-operation is being sought from northern observatories to set up a joint facility in Perth. Possibly, as has occurred in the past, one or more of them can be persuaded to provide a large telescope while the local contribution would be the building and support facilities. Another possibility is that one radio dish of the Australia Telescope could be located at the Perth Observatory -- a logical site -- as currently work is in hand to correlate optical and radio astrometric reference frames.

The Perth Observatory has an illustrious past and it is clear the potential exists for an illustrious future.

M.P. Candy, AiDirector.

La Trobe University

Radiation Protection Officer

The University requires a suitably qualified person for the position of Radiation Protection Officer to provide professional advice and expertise in the area of radiation protection for the research and undergraduate programmes. Although a 100% appointment with La Trobe University, the position will be 40% at Royal Melbourne Institute of Technology.

The person will be responsible to the University Safety Officer for the implementation of the Radiation Safety Programme, including administration of the Health (Radiation Safety) Act 1983 and the Health (Radiation Safety) Regulations 1984.

Duties: will include monitoring, registration of experiments, record keeping, supervision of storage and disposal services, training and technical advice to departments.

Applicants should be graduates in physical sciences or occupational hygiene with preferably plenary membership of the Australian Radiation Protection Society and experience in the handling of ionising radiation. A working knowledge of personal computers would be an advantage. Further training may be available for a lower level appointee.

Salary Range: $20,623-$28,077 (Professional Officer 1), $29,746-$32,803 (Professional Officer 2).

Further enquiries to the University Safety Officer, Mr John Oldfield, on (03) 479 2186.

Applications quoting reference number ADM/492 including the names and addresses of 2 professional referees to:

Staff Officer,
La Trobe University,
Bundoora, VIC 3083.


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Further details from:
Professor A.R. Poletti,
Head of Department,
Department of Physics,
University of Auckland,
Private Bag, Auckland,
New Zealand.

Applications close: 30-9-87 for appointment in 1988.
CSIRO

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LINDFIELD N.S.W.

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Duties: The appointee will undertake research into the production properties and industrial applications of amorphous metals and will be expected to collaborate closely with industry in exploiting these materials.

Qualifications: Applicants should possess a PhD or equivalent qualification in physics or materials science/metalurgy. They should have demonstrated research ability in this or a closely related area, knowledge of the properties and uses of amorphous metals, and the ability to liaise effectively with industrial collaborators, a commitment to commercialization of research results, and the ability to organize and supervise collaborative projects with industry. Well-developed communication skills and experience in the design of devices using amorphous metals would be an advantage.

Conditions: Appointment will be for a term of 3 years with Australian Government Superannuation benefits available.

More Information: Prospective applicants are invited to telephone Dr John Collins or Dr John Denton (02) 467 6611 for further information. They can also provide a copy of the detailed job description and selection criteria.

Applications: Applications should be submitted by 28 August, 1987 and quote reference number A4308. They should be framed against the selection criteria, and should state relevant personal particulars including details of qualifications and experience. Applicants should nominate at least two professional referees, and address their application to:

The Chief,
CSIRO, Division of Applied Physics
PO Box 218, Lindfield, N.S.W. 2070

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Applications should be framed against the selection criteria, and should state relevant personal particulars including details of qualifications and experience. Applications should be complete. For further information contact Dr P M Kelly, Deputy Director, Research. Applications should contain full personal and professional details and the names of at least three professional referees. Application forms, service conditions and selection criteria may be obtained by writing or phoning.

Recruitment Officer
Australian Nuclear Science & Technology Organisation,
Lucas Heights Research Laboratories,
Private Mail Bag 1, Menai NSW 2234 Australia
Telephone (02) 543 3064. Telex AA 24562.
Fax (02) 543 5097.
Closing Date: 21 August 1987.

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The Australian Physicist, Vol. 24, 1987-Page 179
Conferences and Meetings

1987

Conference Secretariat, The Institution of Electronic and Radio Engineers, 99 Gower Street, London WC1E 6AZ.

Sept 14-18  14th Int. Conf. on X-ray and Inner-Shell Processes, Paris.
Secretariat, 887-Pierre Lugard, LURE, Bâtiment 209 d, Université Paris-Sud, 91405 ORSAY Cedex, France.


Sept 17-18  Innovation Outlook 87, Sydney.

Sept 26-29  General Physics Meeting, Physical Society of Japan, Tohoku University.
Physical Society of Japan, Room 211, Kikai-Shinko Building, 3-3-8 Shiba-Koen, Minato-Ku, Tokyo 105, Japan.

Sep 30-Oct 3  Elementary Particles Meeting, Physical Society of Japan, Onsuiomiya University.
Physical Society of Japan, Room 211, Kikai-Shinko Building, 3-3-8 Shiba-Koen, Minato-Ku, Tokyo 105, Japan.

Oct 6-9  Int. Conf. on Electrical Machines and Drives, Adelaide.

Oct 14-16  International Conference on Modelling and Simulation, Melbourne.
H. Salem, Swinburne Institute of Technology, PO Box 218, Hawthorn, VIC 3122.

Oct 14-17  ASPEN Physics Education Conference, Kuala Lumpur.
Secretary, Dept of Physics, Universiti Kebangsaan, Malaysia, 43600 UKM Bangi, Selangor, Malaysia.

Nov 4-6  5th Conference Nuclear Techniques of Analysis, Lucas Heights.
J. Watson, Lock Mail Bag No. 1, Menai, NSW.

Nov 12-13  Annual Conference of the Australian Acoustical Society, Hobart.
Mr. S.E. Samuels, ARR 8, PO Box 156 (Bag 4), Nunaawading, VIC 3131.

Nov 15-19  International Conference on Lasers, Xiamen, China.
Professor Deng Xi Ming, P.O. Box 821, Shanghai, China.

Dec 6-9  12th Aust. Conf. on Optical Fibre Technology, Surfers Paradise.
Conference Secretary, IREE, Unit 3, 2 New McLean Street, Edgecliff, NSW 2027.

Dec 7-11  10th Int. Conf. on Lasers & Applications, Lake Tahoe.
Lasers '87, P.O. Box 245, Mclean Va 22101, U.S.A.

Dr. B. Bibby, Physics Dept, Victoria University, Private Bag, Wellington, New Zealand.

1988

Jan 2-16  Session A. and
Jan 16-30  Session B., AIDC National Science Summer School, Canberra.
Executive Director, School of Applied Science College of Advanced Education, PO Box 1, Belconnen, ACT, 2617

Dr. S. Collocoq, CSIRO Division of Applied Physics, GPO Box 218, Lindfield, NSW 2070.

Feb 14-18  NMR '88, Thredbo.
Ms. Lesley Harland, Research School of Chemistry, A. N. U., GPO Box 4, Canberra City, ACT 2601.


Feb 24-26  Symposium Image Analysis Society, Adelaide.
SAPMEA, GPO Box 498, Adelaide, SA, 5001.

Apr 4-8  International Workshop on Radiological Protection in Mining, Darwin.
Dr. J. Krasnicka, Dept. of Mines & Energy, GPO Box 2901, Darwin, NT 5794.

Apr 5-8  International Non-Ionizing Radiation Workshop, Melbourne.
T. Bola, PO Box 4057, Melbourne, VIC, 3001.

Apr 6-9  8th General Conference of the Condensed Matter Division of EPS, Budapest.
N. Kroo, Central Research Institute for Physics, POB 49, H-1525, Budapest, Hungary.

Apr 10-17  7th International Congress on Radiation Protection Practice, Sydney.

May 11-15  Int. Conference on Transition Metals, Kiev.
Inst. of Metal Physics, Ukrainian Academy of Sciences, Vernadsky Str. 36, SU-252680, Kiev-142, USSR.

May 16-20  ANZAS 1988 Centenary Congress, Sydney.
B. O'Rourke, Organising Sec., 1988 ANZAS Centenary Cong., 118 Darlington Rd, Unv. of Sydney, NSW. 2006.

June 20-24  Third Asia Pacific Physics Conference, Hong Kong.
K. Young, 3rd Asia Pacific Phys. Conf., Dept. of Physics, The Chinese Univ. of Hong Kong, Shatin, Hong Kong.

July 12-14  4th National Space Engineering Symposium, Adelaide.

Aug 8-12  5th Marcel Grossmann Meeting, Perth.
Dr. D. Blair, Physics Dept, University of W.A., Perth, WA 6009.
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