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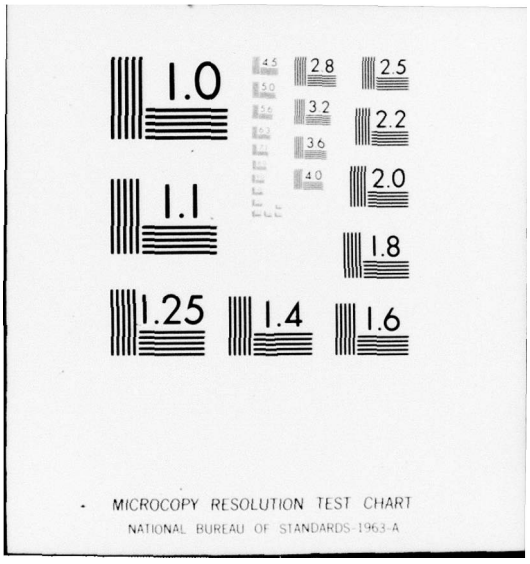
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S. R. Aspinall

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MOBILITIES OF ELECTRONS AND HOLES IN SEMICONDUCTORS

Dr. E.H. Putley of the Telecommunications Research Establishment, Great Malvern, Worcs., has recently determined the mobilities of electrons and holes in single-crystal samples of PbS, PbTe, and PbSe over the temperature range from 20 to 700°K. Over a large range of temperature all of the results follow the power law $v = v_0 T^{-5/2}$. At the lowest temperatures, below 100°K, the mobility increases less rapidly, probably because of crystal inhomogeneity. At temperatures above 600°K, mixed conduction obscures the results.

Since a number of the best PbTe specimens yielded identical results, it is believed that only lattice scattering was present, and the true single-crystal mobility was being measured. A value of 2,100 cm^2/volt-sec was found for the electrons and 840 cm^2/volt-sec for the holes in these samples at 290°K. In the best PbSe the mobility was 1400 for both the electrons and the holes at room temperature. It is interesting to compare this high value with the much lower ones ($\sim$50) found by Lothrop on thin layers of PbSe (Thesis, Northwestern Univ., 1949) suggesting that the properties of the thin layers are determined primarily by the barriers between crystals. The electron mobility was 640 and the hole mobility 800 in the best PbS at 290°K.

In the best PbTe the mobility of the electrons was about 2.5 times greater than that of the holes, in agreement with previous calculations done at T.R.E. With the PbS and PbSe, the fact that the mobility of the holes equalled or exceeded that of the electrons in some of the samples was interpreted as demonstrating the imperfection of the samples, since the Hall coefficient is known to be negative for all the compounds in the intrinsic region.

The experiments are not felt to clarify the validity of the Mott-Fröhlich formula, for the formula probably does not apply above 100°K (depending on the Debye temperature), and below 100°K residual resistance from various sources was apparently influencing the results. No samples have been found whose mobility increased with temperature. One sample of PbTe yielded an electron mobility of 2×10^5 at 20°K.

LEAD SULPHIDE PHOTODIODES

In a series of experiments by R. Lawrence at the Telecommunications Research Laboratory, Great Malvern, Worcs., the properties of PbS photodiodes have been measured. The experiments consisted in measurements of the photovoltage and photoconduction between a sharp tungsten probe and a freshly cleaved single crystal of PbS at room temperature in air. The influence of aging and the effect of changing the shape and pressure of the probe were determined.

Experimental Technique

Crystals of synthetic PbS grown at T.R.E. were used. They contain about 10^{18} carriers/cm^3. Each was clamped in a holder and a fresh surface produced by cleavage. A variety of wire contacts was studied whose points varied from 1 to 15 microns radius of curvature. Each point was pressed against the surface with a force that could be accurately adjusted from zero to about 24 grams. For each contact and each thrust six measurements were made: (a) the photovoltage at zero bias, (b) the resistance for forward voltages less than kT, (c) the resistance for a back voltage much greater than kT, (d) photosignal for (c), (e) the resistance for a forward bias much greater than kT, and (f) the photosignal for (e).

Aging in Air

The resistance of all the diodes was found to decrease with exposure to air. For p-type samples, the photovoltage also fell, but for n-type, it rose with time. Lawrence has suggested that the fall in photovoltage with time in the p-type samples might be due to a gradual sinking of the contact into the surface causing a short circuit of some of the photocarriers, but this will not explain the rise found with the n-type crystals. There must have been a change in the properties of the surface layer due to exposure to the air. The change in the properties of the p-type was practically complete at the end of a few hours, while that of the n-type continued much longer.

Variation in Contact Force

As the contact thrust was increased, all the photoeffects were found to rise steeply to a maximum and then decrease slowly. A study of the influence of contact size indicated that the response was at a maximum in all cases for penetration of about one micron into the crystal surface. It was also found that for light thrust, the n-type diode rectified as though it were p-type, again indicating that exposure to the air had changed the properties of the surface layer. This conclusion was supported by other observations, for instance the depth of penetration of a conical point was found to be proportional to the force rather than the square-root of the force, indicating a surface layer harder than the original crystal. Lawrence got optimum photosensitivity when using a contact with a five micron radius of curvature.

Intrinsic Photoconductivity

With a sharp point contact and deep penetration, bias in the forward direction was found to give photoconductivity opposite in phase to the usual photoconductivity and with a very short time constant, about 3 microseconds. The response was quite reproduceable unlike the normal photoconductivity which is very sensitive to experimental conditions. It is suggested that this is evidence of an intrinsic photoconductivity in the interior of the crystal. It is interesting to note that the spectral sensitivity of the two types of photoconductivity was identical, while that of the photovoltage was more sharply peaked at 3.2 microns. The long wave-length cut-off was the same for all three.

A NEW THEORY OF SUPERNOVAE

Dr. W.H. Ramsey, University of Manchester, has proposed an interesting theory of the origin of supernovae and has applied it to the Crab Nebula which has been identified with the supernova of the year 1054.

He considers the relation governing the mass, radius, and pressure in a white dwarf star. As the radius of the star decreases, the pressure increases and at a certain critical pressure (of the order of 2×10^{23} dynes/cm^2) the reaction $p + e \longrightarrow n + \nu$ can take place. According to Ramsey this produces a change in the equation of state of the gas and a discontinuous reduction in the mass. A supernova or a nova is produced depending on the amount of hydrogen present in the star.

As the star collapses at the critical pressure, a core of neutrons is quickly formed which start a thermonuclear reaction giving more than sufficient energy to blow the star apart. At the same time an element building process takes place which produces many radioactive materials out of the neutron core. Ramsey considers that the energy source for luminosity of the Crab Nebula is this radioactivity.

Most of the radioactive materials decay in a matter of minutes; only a few last 900 years, the probable age of the Crab Nebula. The important processes are $C^{14} \longrightarrow N^{14}$ with a half-life of 5000 years, and $Cl^{36} \longrightarrow S^{36}$ with a half-life of 10^6 years. Be^{10}, which has a half-life of 10^6 years, is probably not produced in great abundance, and K^{40} which has a half-life of 10^9 years, has too low an activity to be important.

In the decay $C^{14} \longrightarrow N^{14}$ Ramsey considers that the N^{14+} ion is left with some 300 electron volts energy of excitation which is sufficient to put it into a ^3P or ^3D state. It then can go by radiation into the S state, a transition which is generally forbidden. Ramsey calculates that 0.5°/o of the mass of the Crab Nebula in the form of C^{14} would be sufficient to account for the present luminosity.

The predictions of Ramsey's theory agree very well with certain experimentl findings . From spectroscopic studies it is known that the Crab Nebula shows strong N^+ and S^+ lines, and the spectrum lines are obliterated in the core of the nebula presumably because of free electrons of very high temperature. These Ramsey assumes to be nuclear electrons originating in the radioactive decay.

Ramsey has also suggested that the Great Loop of Cygnus might be a supernova 20,000 - 30,000 years old. Its spectrum is now being examined.

A LOW SENSITIVITY NUCLEAR EMULSION FOR COSMIC RAY RESEARCH

Ilford, Ltd., has recently developed a new type of emulsion designated G-O, which has all the properties of a G-5 emulsion except sensitivity. It can be used in conjunction with G-5 emulsion to make up a nuclear plate sandwich having sensitive and insensitive regions.

It has been appreciated for some time that a plate bearing two or more layers of emulsion of different sensitivities would be of use in many different types of experiment. For this purpose Bradt and Peters interleaved

electron-sensitive G-5 plates with very insensitive C-2 plates. This technique has the disadvantage that the two emulsions must be developed separately by different methods. The problem faced by Ilford was then to produce an insensitive emulsion which could be developed in the same vigorous manner as the electron G-5 emulsion. This was done by omitting the sensitising process from the G-s emulsion. The principal uses of the G-0 emulsion are to simplify the work of identifying heavy nuclei, to increase the accuracy for a given track length by allowing grain counting, and to increase the emulsion to glass ratio in stacks of plates.

Samples of the new emulsion have been supplied to Dr. Fremlin at the University of Birmingham, who has used it successfully as a moderately insensitive layer to insulate a layer of G-5 from the glass. In another experiment Mr. A.J. Herz of Imperial College has found the composite material to be useful for studying the heavy primaries of the cosmic radiation. Where the normal emulsion yields an excessively dense track, and grain counting is impossible, the insensitive emulsion allows grain counting. In a combination sandwich, both δ-ray counting and grain counting can then be done on the same track. The G-0 layer is usually made 200 microns thick and the G-5 layer 400 microns, although thicker layers of the latter have been made. For the time being these dimensions are being adopted as a standard and either of the emulsions can be put in contact with the glass. It is at present necessary to put a very thin layer (one to two microns) of gelatine between the two emulsions since otherwise a layer of very heavy background appears at the boundary.

An investigation has been undertaken by Herz and Waller on the relation between grain density and energy loss in the G-0 emulsion. Grain density (in grains/100μ) is numerically equal to energy loss (in kev/μ) up to a figure of 60 (approximately the value for a relativistic Neon nucleus). Beyond this point saturation becomes noticeable so that 200 kev/μ corresponds to only 100 grains/100μ.

ELASTIC PROPERTIES OF METALS

A Conference on the Measurement and Importance of the Elastic Properties of Metals was held at the National Physical Laboratory, Teddington, on 20—21 March 1952. Included in the program were papers of practical and theoretical interest, some of which are briefly summarized.

Variation of Young's Modulus with Temperature

Dr. E.G. Stanford, British Aluminium Co. Ltd., has investigated the variation of young's modulus from room temperature to the melting point in aluminum and several aluminum alloys by using a low frequency, longitudinal vibration method. The results show that the rate of decrease of modulus with temperature is nearly, but not quite, linear and is of the order of $5 - 6 \times 10^3$ $lb/in^2/°C$. If recrystallization occurs, a dip is produced in the modulus versus temperature curve, and at this temperature there is a corresponding maximum in the internal friction. Precipitation from solid solution causes a slight discontinuity in a similar curve for aluminum alloys of the age-hardening type. In general, cold work decreases the modulus of aluminum and its alloys. The recovery of modulus by annealing after cold work cannot always be achieved; and when recovery does occur, the degree of recovery is greater in super-purity than in commercial-purity aluminum.

Dr. D.A. Wooster, Cambridge University, has determined the elastic constants of aluminum at temperatures up to the melting point by the diffuse scattering of X-rays technique. This method, which involves no applied mechanical stress to the crystal specimen, depends upon determination of the thermal agitation of the atoms by measurement of non-Bragg X-ray reflections. Essentially the theory is that the thermal motions of atoms may be resolved into a series of waves travelling through the crystal with a wide range of frequencies. The waves which prove to be important for the diffuse scattering are those having wave-lengths from 50A to 300A. These wave-lengths are large compared with the size of a normal unit cell, and when superimposed on the lattice they modify it so as to make possible reflections in directions not coinciding with those occurring in an unperturbed lattice (i.e. non-Bragg).

The temperature dependence of the elastic constant C_{11} is similar to that determined by other methods, i.e. a moderate decrease with increase in temperature and a more marked decrease in the range approaching the melting point. References to this work are: G.N. Ramachandran and W.A. Wooster, Acta Crystallographica 4, July 1951, and September 1951.

Professor N.F. Mott, Bristol University, pointed out that no one has calculated the temperature dependence of Young's modulus for metals from theory. Born and coworkers

have made such calculations for the case of solid rare gases, and the details of this work were reviewed. It was shown how the shear and bulk moduli are related to thermal expansion and the change in volume.

Young's Modulus for Copper and Its Alloys

H. Pursey and T.H. Schofield, National Physical Laboratory, have measured elastic moduli for a series of alpha solid solutions of copper with elements from Zn to As in the periodic table. The depression in Young's modulus and the modulus of rigidity increases with atomic percentage and also with the number of valence electrons of the solute atoms. However, a plot of Young's modulus against electron concentration (assuming that the valence electrons of Zn, Ga, Ge, and As are completely free) does not bring all of the curves into coincidence. Better agreement is obtained by using Zener's theory which is based on the difference in the atomic radii of solute and solvent. Similar research on a series of silver alloys is to be started soon.

An Abnormal After-Effect

Professor C.S. Barrett, Birmingham University and University of Chicago, has detected an abnormal after-effect in torsion experiments on mono- and polycrystalline zinc wires. The normal after-effect is a movement in a direction opposite to that of the applied strain, and this relaxation follows a logarithmic decay curve. In the experiments zinc wires with an oxide film (produced by exposing to steam for one hour) were twisted sufficiently to produce some slip bands, the load was released, and the normal elastic after-effect began. While this recovery was proceeding, the oxide film was removed by etching with a dilute acid solution; whereupon the wire suddenly twisted in the same direction as the originally applied strain, and thereafter followed the normal after-effect behavior but at a slower relaxation rate. The effect is observed in both mone- and polycrystalline zinc specimens whether of super-purity or containing interstitial nitrogen. Similar experiments on iron wires with thin blue oxide films are in progress and preliminary results indicate essentially the same behavior.

The effect is attributed to dislocations piled up at the barrier of the oxide-metal interface. During loading, the stress concentration at the ends of the slip bands may be sufficiently great to break through the barrier

allowing dislocations to move to the free surface. If the applied load is released, the dislocations which have escaped contribute to the permanent deformation while those that are blocked are available for the after-effect. The reverse movement of these dislocations from the barrier toward the body of the metal relaxes the stresses in their vicinity and produces the normal after-effect. If, however, the oxide film is removed before relaxation is complete there is a further escape of dislocations to the free surface and a consequent abnormal after-effect of the same sign as the original strain. The fact that the relaxation rate following the abnormal after-effect is slower than initially is accounted for by the reduction in the number of piled-up dislocations.

Cottrells and coworkers have previously obtained evidence of the validity of this theory. For example, the creep rate of cadmium with an oxide film is markedly increased during test when the surface oxide is removed by etching.

ONCHOCERCIASIS AND SIMULIUM IN AFRICA

Dr. D.S. Bertram of the London School of Hygiene and Tropical Medicine has recently presented a paper and an illustrated film at the Royal Entomological Society on onchocerciasis and Simulium in Africa. The studies conducted by Bertram during his investigations in Africa have led to the discovery of a new host for the immature forms of the Simulium.

Onchocerciasis is one of several filarial infections affecting man in Africa. In severe cases it may lead to total blindness. In 1926 it was established that the helminth parasite causing the disease was transmitted from man to man by Simulium damnosum. This blood-sucking fly occurs in its immature stages in the turbulent, fast-flowing waters of streams and major rivers, including large rivers like the Nile and Congo. The larvae and pupae occur attached to rocks, stones, and vegetation stems submerged beneath the water. In the case of onchocerciasis in hilly regions of Kenya, near Lake Victoria, the vector was found in 1940 to be S. neavi and not S. damnosum. The adult female of S. neavi had been known since 1911, but larvae and pupae had never been discovered. Between 1940 and 1950 several competent workers tried to find these larvae and pupae in the hill streams, but without success. Finally, in March 1950, the larvae and pupae of S. neavi were found not attached to fixed objects but to crabs living in these streams. This discovery was due to the work of Mr. J.P. MacMahon, of the Division of Insect Borne Diseases, Kenya, who has done much of the arduous field work required in the study and control of onchocerciasis in Kenya.

EUROPEAN NUCLEAR PHYSICS LABORATORY

At a meeting in Geneva February 12 - 15, 1952, the proposed European Nuclear Physics Laboratory under UNESCO sponsorship was discussed by delegates from 12 European countries. As a result of this meeting the countries represented will commit themselves formally to the establishment of a European center for nuclear physics and to certain financial contributions.

The countries represented at the present time are the United Kingdom, Norway, Sweden, Denmark, Holland, Belgium, France, Western Germany, Switzerland, Italy, Yugoslavia, and Greece. At a previous meeting held at UNESCO headquarters in Paris in December 1951 it was decided to establish as a first step some preliminary cooperation in European nuclear physics research. To this end the facilities of the Institute of Theoretical Physics in Copenhagen were chosen to furnish some theoretical guidance for experimental work in high energy nuclear physics. The British delegation offered to make available the Liverpool 400 Mev proton synchrocyclotron, which is expected to be in operation by next year.

At the same time study groups were set up to plan a European Nuclear Physics Laboratory which will probably be located at Geneva. Its main piece of equipment will in all likelihood be an accelerator to produce protons of several Bev (bevatron) and possibly a 500 Mev machine.

As soon as the necessary number of countries ratify the draft agreement passed in the Geneva Conference, a Council of Representatives will be set up as the governing body.

PUBLICATION OF ASTRONOMICAL CONTRIBUTIONS FROM THE UNIVERSITY OF MANCHESTER

The University of Manchester has recently announced new publications to be called "Astronomical Contributions from the University of Manchester". They are to consist of three series:

Series I (Annals) will include observational data obtained from the continuous operation of the meteor, solar, and galactic noise equipments at the Jodrell Bank Experimental Station. They may also contain from time to time contributions to theoretical astronomy from the University and its mathematical laboratory. Publication will commence during 1952.

Series II (Jodrell Bank Reprints) will be reprints of papers on radioastronomy, including 68 contributions to date.

Series III (Contributions to Theoretical Astrophysics will also be made up of reprints.

The publications will be distributed on request to observatories, astronomical institutions, and individual scientists, on an exchange basis when possible.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington, since the last issue of ESN. Copies may be obtained from the Technical Information Office, Code 250, Office of Naval Research, Washington 25, D.C.

ONRL-11-52 "Conference On Processes On Crystal Surfaces, Berlin, Germany, January 10-13, 1952" by G.J. Szasz

ONRL-17-52 "The Thermodynamics of Elasticity in Biological Tissues" by G.J. Szasz

PERSONAL NEWS ITEMS

Mr. K.F.H. Murrell, Joint Honorary Secretary of the Ergonomics Research Society, and formerly Director of the Naval Motion Study Unit of the British Admiralty has joined the staff of T.I. (Group Services) Ltd., which is the service company to the Tube Investments Group. He is the head of the Department of Ergonomics, which will serve in an advisory capacity to the 33 companies which make up the Tube Investments Group. He and his staff will provide advice and conduct research on time and motion studies, the layout of equipment and controls, human factors in engineering design, and operational research.

The new director of the Naval Motion Study Unit will be Donald Wallis.

FORTHCOMING EVENTS

SYMPOSIUM ON MICROWAVES AND OPTICS

A symposium on optics and microwaves is to be held on June 9 - 11, 1952, in Milan under the auspices of the International Commission of Optics. The meeting is under the direction of Professor Giovanni Polvani, Via

Saldini 50, Milano (Italy). There will be papers on microwave spectroscopy, diffraction theory, microwave optical devices, and related topics.

THIRD INTERNATIONAL CONGRESS ON ASTRONAUTICS

The Third International Congress on Astronautics which is being organized by the Gesellschaft für Weltraumforschung will take place at Stuttgart, Germany, from September 1 - 6, 1952. The general theme of the Congress will be "Fundamental Problems of Space Travel Research".

SYMPOSIUM ON PHASE CHANGES

An International Symposium on "Phase Changes" will be held in Paris on June 2-7 under the auspices of the Societé de Chimie Physique and the Commission on Thermodynamics of the International Union of Physics.

The provisional program lists the following topics: (1) Condensation, (2) Critical Phenomena, (3) Phase Changes in Solutions, (4) Cooperative Phenomena in Solids, (5) Polymorphism and Rotational Transitions, (6) Ferromagnetism and Lambda Points, (7) Fusion, (8) Transitions in Amorphous Substances, (9) Transitions in Surface Layers.

General introductory lectures will be given by E. Bauer (Paris), H.A. Kramers (Leiden), J. de Boer (Amsterdam), J.E. Mayer (Chicago), I. Prigogine (Brussels), G.S. Rushbrooke (Newcastle), H. Frohlich (Liverpool), K. Clusius (Zurich), L. Neél (Grenoble), F.E. Simon (Oxford), R.F. Boyer (Midland, Michigan) and D.G. Dervichian (Paris).

Although no further contributions can be accepted, visitors will be welcome to attend and those intending to do so should communicate with Professor E. Bauer, Laboratoire de Chimie Physique, 11, Rue Pierre Curie, Paris.

Prepared by the Scientific Staff
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