

colonies of albino rats show porphyrin staining of the fur, particularly on the back of the neck—sometimes called 'red collar disease'—but this is seldom regarded as abnormal for it appears not to interfere either with growth or with reproduction. Yet it must be asked whether such a condition is normal; the fact that it is so widespread does not make it so, for it is not universal. Only the sight of a colony where it is never seen is likely to cause anxiety in one where it is prevalent.

Standardization of diets is obviously desirable; but to give a diet a name and a formula does not automatically achieve this end. It is here that the manufacturers and the consumers can profit each other by much closer collaboration than at present exists. If animals are to subsist on composite complete manufactured diets—and at least one speaker questioned the advisability or possibility of this—then the devising and the compounding of these feeds are interrelated. Nor will chemical standardization secure any useful purpose if the feed, as offered to the animal, is sub-optimal in composition. In this respect strain differences in dietary requirements should be noted and allowed for. The first task is still to provide a diet that gives the animal all that it needs, and if possible a little to spare; when this is achieved, standardization begins to have some meaning.

Finally, there is the humane aspect. We cannot do without our laboratory animals, and many would not wish to be deprived of this source of interest. For both scientific and humane reasons, they must be treated as well as possible, so that their lives, which serve us so well, shall not be a burden to them. Good feeding will help to this end.

The papers presented at this symposium will be published (a) in the *Proceedings of the Nutrition Society* and (b) in *Laboratory Animals Bureau Collected Papers*, Vol. 5 (obtainable from the Bureau at the Medical Research Council Laboratories, Holly Hill, London, N.W.3).

SEMICONDUCTORS AND PHOSPHORS

INTERNATIONAL COLLOQUIUM

AN international colloquium on semiconductors and phosphors was held at Garmisch, southern Germany, during August 28–September 1. It had the support of the International Union of Pure and Applied Physics, and was opened by Prof. W. Gerlach. Its scope may be judged from the following figures: ninety papers were read, there were about 450 scientific participants, and nineteen countries were represented, including the U.S.S.R., Eastern Germany, Czechoslovakia, Poland and Hungary.

W. Schottky, in his introductory lecture, distinguished (a) papers the main emphasis of which was on states and events which concerned the electrons, and (b) papers which dealt with experiments and considerations devoted in the main to the manipulation of substances.

Electronic Properties

The magnetic susceptibility contribution (χ_L) which arises from the current carriers in a semiconductor may be recognized by its dependence on temperature. Prof. G. Busch (Zurich), using a reduced representa-

tion in which this quantity is divided by a constant independent of temperature and characteristic of a given specimen, showed that germanium, InSb and $\text{InP}_{0.2}\text{As}_{0.8}$ appear to have abnormally low values of $|\chi_L|$ at low temperatures. The origin of this effect remains to be investigated. Since relatively little is as yet known of the effect of impurities on the magnetic susceptibilities of semiconductors, the experiments of D. Geist and T. Hehnen (Cologne) on iron-doped germanium were also of interest. Cyclotron resonance experiments on InSb at room temperatures were reported by H. A. Gebbie (U.S. Naval Research Laboratory), and were found to yield an effective electron mass $m^* = 0.015m$, as compared with the value $0.025m$ obtained from transport phenomena. Although different averages over the energy surfaces are involved, this difference is not clearly understood. Paramagnetic resonance experiments on silicon carbide crystals were reported from the Philips Laboratory by J. S. van Wieringen, who contrasted the effect of doping with nitrogen, when three resonance peaks are observed, with the effect of doping with boron or aluminium, when only one peak is found. Interesting speculations concerning the nature of the nitrogen impurities in the lattice (namely, that the trapped electron can be in an s-state and near a nitrogen nucleus) are possible. In another lecture the appropriate equilibrium probabilities for the trapping of electrons by singly- or multiply-charged defects which have several trapping levels were also discussed.

Transport phenomena. Among the non-equilibrium properties, considerable interest was shown in transport phenomena. Here C. Herring (Bell Laboratories) and J. E. Parrott (A. E. I., Aldermaston) discussed consequences of the fact that phonons of long wavelength are less likely to suffer collisions leading to change of direction than phonons of short wave-length, so that they can contribute strongly to thermal conduction. By exerting a drag on the charge carriers, they are also responsible for an additional term in the thermoelectric power. Good single crystals, low concentrations of impurity and low temperatures are required to show up the effects of these phonons. Considerable interest was also shown in the magneto-resistance ratios. Thus, a negative ratio was found for gallium arsenide below 40°K . (R. Broom, R. Barrie and I. M. Ross, Services Electronics Laboratory), and delicate micromanipulation to measure the effect in graphite was also reported (R. G. Breckenridge, National Carbon Co., U.S.A.). From the R.C.A. Laboratory (M. Glicksman) interesting results on germanium-silicon alloys were described which suggest that pure germanium galvanomagnetic properties occur up to a composition of 10 per cent silicon, and pure silicon galvanomagnetic properties occur above 25 per cent silicon. A paper (H. Weiss, Siemens Schuckert, Erlangen) and discussion on the thermal conductivity of InSb showed that further experimental clarification is required in this difficult field before all experiments can be reconciled with each other. Further work on the photoelectro-magnetic effect was reported by British workers (T. S. Moss, Royal Aircraft Establishment; G. G. Macfarlane and V. Roberts, Radio Research Establishment).

Barrier-layer physics. Some attention was given during the conference to those aspects of transport phenomena which may be grouped under the heading of barrier-layer physics. In a general report, E. Spenke (Siemens Schuckert, Pretzfeld) directed atten-

tion to large-area silicon rectifiers, designed by Siemens and ready for production, which pass about 250 amp. at 1 V. forward and 1 amp. at 1,000 V. reverse voltage. The advantages over germanium rectifiers may be traced back to some extent to the larger energy-gap in silicon. The manufacture of very pure silicon by the floating zone method is an essential factor in the production of these rectifiers, and the most suitable reactions for this purpose were reported to be:



Two papers from the University of Reading reported new work on germanium contacts (J. D. Nixon and P. C. Banbury; D. Hanemann and A. J. Mortlock).

Surfaces. Closely connected with barrier layers are investigations of surfaces. Here, J. Bardeen (Illinois) showed clearly that reasonably reliable methods for determining the distribution of surface states are now available, and that future work must try to determine the chemical nature of the fast and the slow states known to occur on etched surfaces of germanium and silicon.

Life-times of excess carriers. About eight papers dealt with another aspect of typically non-equilibrium properties, namely, the life-times of excess carriers in a semiconductor. A paper by W. Scanlon (U.S. Naval Ordnance Laboratory) seemed to show conclusively that the moving line of light method for the determination of life-times is unsuitable for natural single crystals of lead sulphide, unless they are cleaved in an inert atmosphere. A life-time (τ) of 1 $\mu\text{sec.}$ as obtained by this method (and judged to be the true volume life-time by comparison photoelectric-magnetic measurements) may be raised to many times this value by the admission of other gases. By using an etching solution containing thiourea to reveal densities of etch pits (N), a relation $\tau = \text{constant}/N$ was established, and the conclusion that life-time is independent of conductivity was also inferred. This important contribution will undoubtedly stimulate re-examination of previous work in this field.

Carrier trapping due to dislocations was discussed by H. Kawamura (Osaka, Japan). He inferred 2-3 \AA. as the effective width of a dislocation in germanium so far as trapping is concerned. The dependence of life-times in silicon on temperature were shown to be in contradiction with simple trapping models by M. Zerbst and W. Heywang (Siemens Halske, Karlsruhe).

Optical properties. If it is borne in mind that excess carriers may end their lives by radiative transitions, the connexion between life-times and optical properties becomes clear. J. R. Haynes and K. G. McKay (Bell Laboratories) spoke about this topic with special reference to the production of radiation in silicon due to processes involving thermal and high kinetic-energy current carriers respectively. Haynes showed that the energy spectrum of recombination radiation at liquid-nitrogen temperatures has a peak at 1.1 eV. (due to interband transitions), and that other peaks exist, the separation of which from this main intrinsic peak yields known impurity activation energies. This was found to be the case for indium, gallium and boron impurities, while doping with boron and arsenic jointly also produced unexplained peaks. The spectral distribution due to recombination processes which involve 'hot' electron and hole gases (that is, gases which are out of equilibrium with the lattice) was shown by McKay to be

due to band-band transitions as well as optical transitions in one and the same band. By applying reverse bias to a p - n junction formed on a p -type silicon crystal with a layer (2μ thick) of n -type silicon, it was possible to observe spots of red light near breakdown. The current-voltage characteristic near breakdown had a series of discontinuities and it seemed that at each discontinuity a new spot made its appearance. From a correlation of electrical and optical data the diameter of a breakdown region could be estimated at about 500 \AA. In germanium the current discontinuities, but not the light spots, have been observed to date.

Phosphors. Discussion of light emission by mono-atomic semiconductors leads on to the general problems of luminescence and phosphors, which are of technical importance for television screens, advertisements and, possibly in the future, for domestic illumination. W. Hoogenstraaten (Philips, Eindhoven) reviewed the non-electronic energy transport in phosphors. The possible importance of excitons was discussed rather speculatively here, and at various points throughout the meetings. Absorption spectra characteristic of excitons have been reported by H. Masakazu (Japan), E. Gross (U.S.S.R.) and S. Nikitine (France). Though some reserve must be maintained with regard to the interpretation of these spectra, there was lively interest in the properties of excitons. Thus, arguing from photoconductive experiments, the conjecture was even made that the life-time of excitons may possibly be as long as 10^{-3} sec. and their diffusion length as long as 3 mm. in single crystals of cadmium sulphide at room temperature (M. Balanski and I. Broser, Berlin). A theoretical paper concerning their stationary and non-stationary properties was given by H. Haken (Erlangen).

Manipulation of Substances

In the large group of papers dealing with the manipulation of substances, E. Billig (A.E.I., Aldermaston) gave a review of growth and defects of semiconductor crystals (supported by a short film on crystal growth). A number of problems raised here and in discussion (and also in connexion with a paper by I. P. Penning (Philips, Eindhoven)) concerned the possibility of the motion of a dislocation during etching, the deposition of copper at dislocations, the possible production of dislocations by thermal stress near the crystal-melt interface, etc. In a review of the related problem of the incorporation of foreign atoms in the lattice, a new notation for defects in crystals was suggested (F. A. Kröger and H. J. Vink, Philips, Eindhoven). The diffusion of defects was also considered; the effect of the surface was discussed by F. M. Smits, R. C. Miller and R. L. Batdorf (Bell Laboratories), the diffusion of activators in zinc sulphide by H. Ortmann (Berlin), and the diffusion of hydrogen in zinc oxide by J. J. Lander (Bell Laboratories).

Bombardment of semiconductors. A group of papers on manipulative techniques included some on the bombardment of semiconductors. H. Y. Fan (Purdue, U.S.A.) discussed recent work in this field, and compared the effects (which are not identical) of electron and α -particle irradiation of germanium, in addition to reporting results on the effects of irradiation on silicon, InSb and InAs. R. Gremmelmaier and H. Welker (Siemens Schuckert, Erlangen) described the use of InP as a detector of neutrons,

by taking advantage of an (n, γ)-process due to the reaction of slow neutrons with indium, and subsequent conversion of the indium isotope with the emission of β -radiation. The γ - and β -rays produce electron-hole pairs, so that at an InP p - n junction an e.m.f. is developed the decay of which after irradiation enables one to infer the neutron flux.

Papers on specific groups of materials included a discussion of the mechanism of luminescence in silver halides (Z. Matyaš, Prague). New ternary compounds with semiconductor properties were discussed briefly in two papers, and D. A. Wright (General Electric Co., Wembley) reported on the properties of bismuth telluride, which is suitable for studying the problems of thermoelectric refrigeration. Organic systems were also discussed. H. P. Kallmann (New York) put forward considerations which suggest that the energy transfer in liquid organic systems is by collision rather than by irradiation. He also reported experiments on photoconductive effects in organic crystals in which the motion of holes appears to dominate.

Papers submitted to the colloquium, but not read, included one on the electrical properties of some binary compounds by D. N. Nasledov (Leningrad) and another on the breakdown of p - n barriers by B. M. Wul (Lebedev Institute, Moscow), and participants of the colloquium were glad to be able to discuss with the authors recent Russian work in these and related fields.

It is a tribute to the work of the organizers that the texts of most of the invited papers and the abstracts of most short papers were in the hands of the participants before the meeting. Nevertheless, there was comparatively little discussion in the open meetings; though, if time had been allocated explicitly to discussion, there would have been numerous contributions from the floor, judging from the many fruitful private conversations which were proceeding between meetings.

It is regretted that several interesting papers cannot be mentioned here, but enough has probably been said to indicate that a very wide field was covered. While it is true that no new band structure calculations were reported, and impurity band conduction was touched on only incidentally, it is in fact difficult to think of any other basic topic which was not raised in one or other of the papers submitted. The proceedings will be published early in 1957 as volume 4 of "Halbleiterprobleme" (Friedr. Vieweg u. Sohn), with each contribution in its original language.

P. T. LANDSBERG

EXTRUSION AND ROLLING PROCESSES

THE September conference of the British Society of Rheology held in Sheffield during September 27-28 had as its title "Extrusion and Rolling Processes". The varied interests of members of the Society were fully illustrated by the wide scope of the papers presented. Each had in common some particular aspect of rheological behaviour. The conference, consisting of the presentation of six papers and the attendant discussions, was opened by the president, Prof. J. G. Oldroyd (University College of Swansea).

"Some Applications of Rheology in the Investigation and Practice of Polymer Extrusion" was the title of a paper by W. F. O. Pollett (Henley's Research Laboratories). The simple screw extruder is extensively used in the electric cable industry for the application of dielectric and protective coverings, composed essentially of high polymers. Standard quantitative treatments of the theory of screw operation in conjunction with viscous materials have been based, erroneously, on the assumption that the thermoplastics and rubbers used in the cable industry exhibit Newtonian behaviour. The Ostwald de Waele relationship provides a somewhat closer approximation to practice within certain limits of screw design.

The use of different coloured materials is a standard method for mapping flow-paths in an extruder and can be supplemented by two complementary techniques. Strains can be 'frozen in' many high polymers by a reduction in temperature, and elastic recovery will afterwards occur if the temperature is again raised. The recoverable strains produced in plasticized polyvinyl chloride during its passage through the extruder can be stabilized in this way and their distribution studied by the reheating of suitable samples. Further, the temperature at which recovery occurs depends upon that at which the polyvinyl chloride was deformed. These methods have greatly assisted the correct design of T-heads used for the application of extruded wire and cable coverings. It has been shown that when material emerges from the screw channel, it converges towards the axis of the barrel in consequence of the Weissenberg effect. Unless the boundaries are suitably shaped, this will result in stagnant zones leading to decomposition of the polymer or to premature curing in the case of vulcanizable compositions.

When the conditions at the die are such as to favour the formation of high recoverable strains, there is a tendency for the exudate to exhibit a characteristic type of surface roughness probably caused by the stretching of the surface layers as the velocity gradient existing in the die is dissipated in the vicinity of the die mouth. This effect can often be avoided by an increase in temperature; or, if this is impracticable, by maintaining by special die design a shear-rate of 10^4 - 10^6 sec.⁻¹ for a sufficiently long time.

The determination of extrusion variables and the principal features of press design can be treated theoretically as shown by P. Feltham (University of Leeds) in his paper "A Simple Theory of the Criteria of Press Design and Process Efficiency in the Industrial Extrusion of Metals". In the direct extrusion process, work done by the ram is expended on useful plastic work in reducing the dimensions of the metal from A_0 to A , where A_0 is the cross-sectional area of the billet and A that of the extruded bar. Work is wasted due to friction at the billet/container interface, as well as on plastic work which does not yield a final plastic deformation. Since flow during extrusion is essentially streamlined, useless work of this latter kind is very small and is neglected in the theory. The maximum extrusion pressure can be shown to be: $\sigma_{\max.} = Y_a \{ \ln(A_0/A) \} \exp(4 \mu L'/D)$, where Y_a is the tensile yield stress of the fully work-hardened material at the extrusion temperature, μ is the effective coefficient of friction at the billet/container interface, L' is a length slightly smaller than the billet length and D is billet diameter. The strain-rate in the 'virtual die' formed by 'dead metal' near the true die orifice is approximately equal to