



## SOLID STATE SYMPOSIUM

EWALD TO HEAD PHYSICS AT BROOKLYN POLY.

As a means of welcoming Paul P. Ewald, formerly of Queens University in Belfast, to the chair of physics of the Brooklyn Polytechnic Institute, an all day conference was held last October 15 on the physics of the solid state. The conference, which was sponsored jointly by the Institute and the Metropolitan section of the American Physical Society, was opened with a paper by Professor Ewald, in which he reviewed the program and placed the various scheduled topics in the general context of crystal physics.

He then got the discussion itself under way by examining the matter of whether an integrating and simultaneous treatment of the properties of the solid state by wave mechanics is to be preferred to a splitting of the theory into separate treatments of the different properties. The latter seems to be simpler in many cases as far as practical interest is concerned. He also mentioned the possibility of a generalization and amplification of the space-group theory of Schoenflies by applying the symmetry operations to vectors and tensors.

Slater in his lecture faced the audience with the most interesting problems still unsolved in the field of solid state (these being superconductivity and the superfluidity of helium which presumably is closely connected to the former). Such problems as the exact computation of lattice energies and elastic constants also require further mathematical treatment, although considerable progress, as Slater pointed out, has been accomplished during the last years. Besides these problems which deal with the "ideal" crystal, many other unsolved problems exist for the solution of which the "real" crystal with its imperfections must be considered.

This real crystal may differ from the ideal by irregularities, deformations, and distortions of the lattice, by migration of atoms, molecules, or excited electrons, and by the transfer of excitation energy along surfaces or through the crystal lattice. Such matters belonged to the main topics of the symposium.

According to Rideal a migration of molecules along a surface of a crystal can easily be demonstrated and measured when a crystal of benzophenone is brought into contact with a metal surface. As long as this contact perseveres, in addition to the loss of weight of the crystal by ordinary volatilization, an escape of molecules along the metal surface takes place. This loss of material can further be increased by running a flow of mercury over a part of the metal surface, because the moving mercury surface carries molecules with it.

The migration of electrons, excited within the crystal, or the transfer of excitation energy, plays an important role in light emission as described by Kallmann. The freed electrons or the excitation energy travel through the crystal and collide on their paths with impurities, irregularities, or distortions. Such collisions may cause

a transformation of the excitation energy into heat. Thus a competition exists between this transformation and the reaction of light emission which determines the amount of light actually emitted. Without such a migration of electrons and excitation energy, no quenching would occur and sometimes even no light emission would take place, since, when the light is not emitted by the bulk material but by impurities only, the excitation of these impurities is also attributable to the migration process.

Smekal made it clear in his lecture that imperfections of atomic arrangement determine even the total mechanical behavior of "real" solids. The "ideal" solid with a perfect lattice would considerably deviate from the properties actually observed with crystals in nature. It requires much skill and work to realize the ideal crystal in the laboratory and the slightest deviations of these ideal conditions would produce a thorough change in the behavior of the crystal. In particular Smekal described investigations on hardness by means of a micro-scratcher and showed how the results are related to the type of chemical binding.

A first approach to the mathematical treatment of distortions was given by Shockley. He discussed the behavior of solids under plastic deformations and gave a detailed description of crystal gliding and distortion from an atomic and energetic point of view. His arguments resulted in the formulation of a condition which allows such a point of distortion or imperfectness to be described or characterized mathematically.

The lecture of Burgers chiefly dealt with the phenomenon of recrystallization. In a conglomerate of crystals a single crystal can grow at the expense of the neighboring ones. For such an amalgamation of different crystals to a single one the orientations of these crystals relative to each other must fit into certain conditions. Crystals which do not fulfill those conditions do not take part in the process of amalgamation. The neighboring crystals then grow together enclosing the misorientated one without absorbing it in their own lattice. Burgers started his lecture with an experiment which demonstrated how the diffraction of x-rays by a linear grating may be interpreted in its reciprocal space.

Although the problems were treated from a purely scientific point of view, without dealing with practical applications, it became obvious that the scientific results obtained are already of the greatest practical interest, e.g. as far as the mechanical behavior of the real crystal, or the light emission of crystals, etc. are concerned. This combination of scientific and practical interest found its expression in the large attendance as well as in the extended discussions which followed the different lectures.

—R. Brill and Hartmut Kallman

AAAS SYMPOSIUM ON PHYSICS  
SEMICONDUCTORS AND FERROELECTRICS

Physics of the solid state was the subject of one of the four symposia on physics held at the AAAS meeting in New York City last December. Three talks were given on Friday morning, December 30, two of which were de-

voted to semiconductors and one to ferroelectrics. These materials are of interest not only because of their technological importance, but also because much progress has been made in recent years toward an understanding of their unusual properties in terms of their atomic structure. Each of the three speakers, Karl Lark-Horovitz of Purdue University, John Bardeen of the Bell Telephone Laboratories, and Arthur von Hippel of the Massachusetts Institute of Technology, reviewed some aspects of research done by the groups with which they are associated.

Lark-Horovitz (who is secretary of the AAAS) traced the history of our knowledge of semiconductors and showed how the electrical properties can be understood in terms of the concentrations and mobilities of the current carriers. He presented some interesting data on effects of radiation on the conductivity of germanium. Acceptor type impurity levels are introduced in two different ways: by displacement of atoms from their normal lattice positions as a result of elastic collisions with fast incident particles and by transmutation. Prolonged exposure of germanium in the nuclear reactor at Oak Ridge leads to the formation of gallium atoms in lattice positions by capture of slow neutrons and subsequent beta decay. Gallium, having one less valence electron than germanium, acts as an acceptor impurity, and the concentration may be sufficiently large to produce marked changes in conductivity. A brief discussion was given of the high transparency of germanium and silicon in the infrared region beyond the fundamental absorption bands.

Research at the Bell Telephone Laboratories associated with the development of the transistor has shown that the concentration of current carriers, and thus the conductivity of a semiconductor, can be altered by current flow. For example, positively charged holes can be introduced into n-type germanium in which the carriers normally present are conduction electrons. The space charge of the added holes is compensated by an increase in the concentration of electrons. Bardeen discussed the flow of electricity in semiconductors in which appreciable numbers of both holes and electrons are present. The importance of both electric fields and concentration gradients in determining the flow was illustrated by several examples.

Ferroelectrics are materials in which domains are electrically polarized. They exhibit hysteresis effects in electric fields similar to those of ferromagnetic materials in magnetic fields. Examples are Rochelle salt, potassium hydrogen phosphate, and barium titanate. The latter material has been extensively investigated by von Hippel's group at MIT as well as at other laboratories, originally because of its high dielectric constant and more recently because of its importance as a ferroelectric and piezoelectric material. Von Hippel described research on the domain structure of single crystals of barium titanate. He showed very beautiful pictures of domains observed by P. W. Forsbergh, Jr. and designated by such descriptive terms as "church window patterns" and "Persian carpet patterns." Barium titanate is of interest from a theoretical standpoint because its structure is simpler than that of other ferroelectrics.

—J. Bardeen

#### ELECTRONS, COSMIC RAYS, AND FLASH BULBS

In the AAAS session on elementary particles, P. Kusch, who gave a very good discussion of the electron's magnetic moment, had the added distinction of being the only speaker who talked about elementary particles. The audience was only a little distracted by the continual flashing of newspapermen's flash bulbs until the end when a lantern slide was obscured by the photographic equipment in transit. A lively discussion afterwards was initiated by K. K. Darrow's comments about the "heuristic" nature of the theory which predicts the added moment of the electron. In defending the theorist's position Professor Breit pointed out that the theory that gave the right answer was one of the simpler forms but admitted that another answer could have been obtained if it were necessary.

J. C. Street presented a very well organized summary of our knowledge of cosmic rays at the present time. His general viewpoint was that we are in possession of enough facts about cosmic radiation to be able to give a qualitative explanation of almost all of the phenomena that are observed, even though this explanation may not be correct in detail. His lucid description of the birth and death of mesons stimulated the audience (most of whom were not physicists) and gave them some understanding of this important phase of physics. He showed a beautiful collection of slides from laboratories throughout the world to demonstrate the important discoveries.

In my talk I tried to summarize the work at Minnesota and to review the present knowledge about heavy nuclei in primary cosmic rays. We talked a little about the conditions the heavy nuclei impose on any theory about the origin of cosmic rays. Professor Korff suggested in the discussion that, even though one found an explanation for the origin of heavy nuclei, two separate mechanisms might be necessary to account for all the primaries. Professor Vallarta discussed the similarity of the energy spectrum of the protons and the heavy nuclei. Anyone who talks about cosmic rays in the future can amuse the audience with this Darrow quotation. "Millikan used to think that cosmic rays were the 'death-cries' of atoms and now we find that they are the atoms themselves."

—E. P. Ney

#### MICROSCOPY WITH X-RAYS

##### EXPERIMENTAL INSTRUMENT MODELS DESCRIBED

Reports from Stanford University and the General Electric Research Laboratory give new encouragement to the hope that some form of the x-ray microscope may one day be able to compete on a mature level with its older cousins, the light microscope and the electron microscope. The familiar optical microscope is limited to describing very thin and transparent specimen samples, or simply the surfaces of objects. The electron microscope, while capable of much higher magnifications, is also severely limited in that specimens to be examined must be prepared as extremely dry, thin slices which must furthermore be studied under conditions of high vacuum.

Although still in the laboratory stage, the x-ray micro-