

## BOOK REVIEWS

H. KALLMANN and M. SILVER (Editors): **Symposium on Electrical Conductivity in Organic Solids**. Interscience, New York, 1961. 398 pp., \$12.50.

STUDIES of charge-transport processes in organic solids are motivated mainly by the perspective of an almost limitless source of materials with easily controlled properties. The book, edited by KALLMANN and SILVER, is an outgrowth of one of the three conferences which have been held in the United States since January, 1960, and which were devoted entirely to this "new" area in solid-state research. The Symposium on Electrical Conductivity in Organic Solids took place at Duke University, Durham, North Carolina, in April, 1960, and was sponsored by the basic research branches of the Armed Forces. Proceedings of the Princeton University Conference on Semiconduction in Molecular Solids, 16-17 February, 1960, are also available. And a book entitled *Organic Semiconductors*, which collates the papers presented at the Armour Research Foundation affair held in April, 1961, was scheduled for publication by Macmillan in July, 1962. This literature, unfortunately, appears at a time when curiosity is fading away. To illustrate the case, A. CORNERETTO, of Electronic Design, recently referred to what he calls the tunnel-diode cycle: splashy debuts, followed by re-appraisals, and a rapid drop in interest. Though organic solids hold some promise of leading to materials that could become important for their conductive properties, difficulties traceable to the problems encountered in trying to describe the conduction mechanism are blocking the development of useful devices. Today, it is generally believed that conduction will not be understood for some time, barring an unexpected breakthrough. From this point of view, the present volume should provide a most useful tool for further research in organic solids. Broadly speaking, the twenty-eight contributions to the Symposium are concerned with three classes of organic systems: simple molecules such as anthracene, polymers and dyes, and charge-

transfer complexes. Some of the highlights are as follows:

(1) Anthracene has been most extensively studied, since it is readily available, fairly easily purified, and has a known crystal structure. Much of the recent work has been done by R. G. KEPLER, of DU PONT; his contribution to this volume deals with "Pulsed photoconductivity in anthracene." By applying short light pulses approximately 2  $\mu$ sec long, and then observing the current flow, Kepler shows that the mobility of electrons and holes can be determined with reasonable accuracy. This is because, if one illuminates the negative electrode, the current across the crystal will be carried by electrons, but, if the illuminated electrode is positive, then the current will be due to holes. It turns out that the mobilities found for both holes and electrons are in the range 0.3-3  $\text{cm}^2/\text{V-sec}$ . The mobilities vary with crystal orientation, and which carrier is more mobile depends on crystal orientation.

(2) Some time ago, BERNARD WILDI of Monsanto Chemical Company devised a point-contact diode incorporating a synthetic polycrystalline polymer called copper phthalocyanine; rectification of about 10 to 1 was achieved with this organic material. Further efforts to explore the feasibility of photoconductive and of thermoelectric devices led A. EPSTEIN and B. WILDI to prepare polycopper phthalocyanines and to investigate their electrical and thermal properties. EPSTEIN and WILDI's paper reports on the *n*- and *p*-type conductivity of these materials and discusses in detail some very interesting measurements of the Hall coefficient and its variation with heat treatment. Ionic dyes also exhibit *n*- and *p*-type characteristics; more precisely, it appears that cationic dyes are *n*-type photoconductors, while anionic dyes are *p*-type. Soviet workers, A. TERENIN of the University of Leningrad for instance, have shown much interest in these systems. They report that, in the dark, practically

all classes of dyes (more than a hundred varieties) have specific conductances that lie in the range from  $10^{-7}$  to  $10^{-14} (\Omega\text{-cm})^{-1}$ ; under visible light, however, the conductance of thin films increases by a factor of  $10^3$  or  $10^4$ , and many of the films exhibit a very fast initial response. In fact, R. C. NELSON's contribution, which is devoted specifically to cationic dyes, establishes that these organic photoconductors can be classified into two main groups according to the temperature dependence of their steady-state photoconductivity. Type 1 corresponds to an activation energy of 0.4–0.5 eV and can be described in terms of classical band models; type-1 films have slow responses, and take from minutes to hours to reach a steady state in light. Type 2 requires an activation energy of 0.1–0.2 eV, and transport is believed to proceed via intermolecular tunneling; type-2 films have time constants of only about  $10^{-5}$  sec.

(3) Organic compounds with resistivities as low as 0.01  $\Omega\text{-cm}$ , such as the derivatives of tetracyanoquinodimethane (TCNQ), are among the charge-transfer complexes that have been most carefully investigated. Other molecular complexes are those described by MORTIMER M. LABES and his associates at The Franklin Institute, and by KOMMANDEUR and SINGER of National Carbon, in two papers respectively entitled "Semiconductive properties of molecular complexes" and "Electric and magnetic properties of some low-resistance organic semiconductors." Much attention is being given to the perylene-iodine complex, which consists of alternate layers of perylene and iodine, the conduction taking place perpendicularly to the layer planes. By contrast, the coronene-iodine complex is thought to consist of juxtaposed stacks of coronene and of iodine, which may explain why the resistivity is about  $10^8$  times higher than with a perylene-iodine type of structure. Note that most of the measurements have been made on compressed powders. Though single-crystal studies on the perylene-iodine complex have given results essentially identical to those obtained from polycrystalline material, Dr. LABES emphasizes that powder measurements can be used only as crude indications of the electrical properties of molecular crystals.

In conclusion, it may be said that this volume offers a convenient reference tool for those now engaged in work along similar lines. It is not well suited for those who wish to learn about organic conductors: there is no general introduction to the field, no index, and little apparent logic in the way the twenty-eight contributions are stacked together. Interscience Publishers must be commended for the graphic elegance of the book. The proofreading, however, leaves much to be desired: the table of contents alone "exhibits" four misprints and two omissions!

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Waltham 54,  
Massachusetts,  
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C. A. KLEIN

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J. EVANS: **Fundamental Principles of Transistors.**  
Van Nostrand, New York, 1962. 332 pp., \$8.50.

*Fundamental Principles of Transistors* brings to this reviewer the mixed feelings which new books so often evoke. As the torch bearer of a crusade to keep small the number of books which the practitioner of an art must be familiar with in order to maintain his currency in the field, he inquires severely of each new book, "What does it really contribute to the advancement of the art or to the state of our knowledge concerning it?" When the answers to both parts of this question are as negative as in this case, the reviewer's commendation can only be "Take it or leave it, as you wish".

The book publishers continue to grind out new books at an ever-increasing rate, good, bad, or indifferent, but more books notwithstanding, using copy from wheresoever they can obtain it. The inevitable result is an enormous amount of duplication which is costly in both time and money to the conscientious reader who buys new books on the off-chance that in them he will find something he did not know before, or come upon some new approaches that will help him better to understand a phenomenon or better to teach it. It would be fatuous to say that *Fundamental Principles of Transistors* has no value for this purpose, but it is true that its pages contain almost nothing which is not available in other