

ization of styrene in carbon tetrachloride and of  $\alpha$ -methyl styrene in carbon tetrachloride and ethyl chloride by aluminium chloride. For these systems they have found that the rate is proportional to the first power of the catalyst and of the monomer concentrations, that neither water nor hydrogen chloride acts as co-catalyst, that the catalyst becomes inactivated, and that solvent transfer occurs. D. Clark (University of Birmingham) reported that the polymerization of styrene by boron trifluoride in carbon tetrachloride will not proceed in the absence of a co-catalyst and that it is very sensitive to traces of water, which is a co-catalyst. It was stated by R. O. Colclough (University of Leeds) that, when styrene is polymerized in nitrobenzene or cyclohexane by antimony pentachloride containing radioactive antimony, the catalyst does not remain attached to the polymer, even when this is purified under anhydrous conditions. Most of those engaged on this work were agreed that the polystyrenes and poly- $\alpha$ -methyl styrenes contain few, if any, double bonds and that the end-groups are probably substituted indanes. D. S. Brackman and P. H. Plesch said that, contrary to earlier work by others, they have been unable to isomerize *cis*-stilbene by boron trifluoride or titanium tetrachloride. In the absence of a co-catalyst there is no reaction; in the presence of one, both *cis*- and *trans*-stilbene polymerize. For the system *trans*-stilbene—titanium tetrachloride—trichloroacetic acid, the polymerization is zero-order in monomer up to high degrees of conversion, but these constant rates are, for a series of experiments, proportional to [titanium tetrachloride] [trichloroacetic acid] [stilbene]<sup>2</sup>. C. G. Overberger (Brooklyn Polytechnic) gave an account of the co-polymerization of various substituted styrenes by stannic chloride and showed that the monomer reactivity ratios follow, with few exceptions, the Hammett sigma constants. The monomer reactivity ratios are found to be almost independent of the temperature over the range  $-20^{\circ}$  to  $+30^{\circ}$  C., and of the dielectric constant of the solvent over the range 2.2–29.7, nor are they affected by the catalyst concentration or the presence of small quantities of water.

The fourth session of the conference was devoted to alkenes. K. E. Russell (University of Manchester) reported that, in the polymerization of *isobutene* in ethyl chloride by stannic chloride at low temperatures, water, nitroparaffins and halo-acetic acids are co-catalysts, but nitrobenzene is not. The rate is proportional to [monomer] [water] and the molecular weight to [monomer]/[water]. M. St. C. Flett (Imperial Chemical Industries, Ltd.) and P. H. Plesch demonstrated from infra-red spectra that, when *isobutene* is polymerized in hexane by titanium tetrachloride with trichloroacetic acid as co-catalyst, the predominant end-group is methylene, but that there are also smaller numbers of tri-substituted double bonds and of trichloro-acetate end-groups. A. Wassermann (University College, London) discussed the polymerization of *cyclo*-pentadiene by trichloroacetic acid to a highly coloured polyene. The rate in carbon tetrachloride solution is proportional to [monomer] [trichloroacetic acid]<sup>2</sup>. This polymer is a ready proton-acceptor and differs from that formed under the influence of metal halides. Possible structures for these polymers were discussed at some length. D. D. Eley and J. Saunders reported that the rate of polymerization of alkyl vinyl ethers by iodine is proportional to [monomer] [I<sub>2</sub>]<sup>2</sup>, but that at high monomer concentration the rate passes

through a maximum. The rate-constant at low monomer concentrations, and the maximum rate as well as the monomer concentration at which it is attained, are functions of the side-chain. G. W. A. Rijnders and C. G. A. Schuit (K. Shell Lab., Amsterdam) discussed polymerization and cracking on silica-alumina catalysts and directed attention to the dehydrogenation reactions which may accompany cationic polymerizations. L. Wall (National Bureau of Standards, Washington, D.C.) and C. G. Overberger presented three papers by C. M. Fontana *et al.* (Socony-Vacuum Laboratories, New Jersey). It was shown that in the polymerization of propene or butene-1 by aluminium bromide at low temperatures, a high concentration of co-catalyst such as hydrogen bromide is required to give high molecular weights, whereas *isobutene* under these conditions gives polymers of low molecular weight. The distribution of molecular weight of *polypropenes* and other evidence indicate that the transfer of tertiary hydride ions plays a dominant part in these reactions.

The discussions in the second, third and fourth sessions of the conference were mainly concerned with questions of technique, the reasons why co-catalysts are required in some systems but not in others, the effect of the dielectric constant of the medium and the relation between cationic polymerization and conventional Friedel-Crafts reactions. Prof. Dainton gave a final summing-up of the conference. The full proceedings of the conference will be published in book form. P. H. PLESCH

## TRANSPARENT CONDUCTING FILMS ON GLASS

BÄDEKER in 1907<sup>1</sup> made some of the earliest observations on non-metallic films, obtained by suitable after-treatment of sputtered metal films. He observed that some, particularly certain oxide films, had appreciable electrical conductivity. After a comparative lull in interest, modern evaporation techniques provided a new stimulus for the study of non-metal films. Attention was then directed first to their optical properties. Rather later, research on semi-conductors and photocells aroused increasing interest in the electrical properties of the films. It is curious, perhaps, that not many investigators have hitherto studied both the optical and electrical properties and attempted to relate them to each other. Recently, however, the importance of their inter-relation has been emphasized by commercial applications in which both good transparency and the possibility of dissipating considerable electrical power in the films are prerequisites. The American so-called NESA film, used for electrically heated windscreens and windows, is a case in point.

In the Light Division of the National Physical Laboratory a study of this field started in 1947, in connexion with research on the selenium rectifier photocell. In this cell, the upper layer or film must of necessity be a fairly good conductor; but it must also be as transparent as possible if the sensitivity of the cell is not to be too much reduced by loss of light in transmission through it. In this study, Bädeker's experiments were repeated on a wider range of metals. His results—for example, on oxidized

cadmium films—were generally confirmed; but, in addition, unusual effects were noticed during the oxidation, by heating, of tin films on a glass substrate. A stage was reached, in certain cases, when the film had become transparent but shortly afterwards acquired appreciable electrical conductivity.

This observation is the basis of a new process proposed for the preparation of transparent conducting films. In it, a sputtered partially oxidized tin film on glass is subjected to suitable heat treatment. The initial film must be amorphous, it seems, while the final product after heating gives the electron reflexion pattern of stannic oxide. It is hard, adherent, and chemically as resistant as ordinary stannic oxide. Its optical transmission is in the region of 75 per cent. Resistance values of a thousand ohms, or rather less, between opposite edges of any square area, have been reached by this method, but still further reduction of this figure is expected as a result of work in progress.

The manufacture is as yet assured only on the laboratory scale. Application of the process to some commercial uses therefore awaits further development; but the present product is obviously suitable for a number of practical applications such as for anti-static windows in sensitive electrical instruments. It may also prove suitable for the manufacture of robust resistors, where the large surface area of the film should permit of an unusually large power-dissipation without undue rise in temperature.

Unlike the American process, the modified sputtering process used in making the tin oxide films is adaptable to a wide variety of substances, and other films now under study at the National Physical Laboratory show a great improvement on the American product in respect of electrical conductivity at a similar transparency. Some of their other properties remain still to be tested, and so it is too early as yet to forecast the precise field of application for these newer films.

<sup>1</sup> *Ann. Phys. Leipzig*, 22, 749 (1907).

## RESEARCH AND INVENTION IN THE UNITED STATES

### REPORT OF THE NATIONAL SCIENCE FOUNDATION

THE establishment of the National Science Foundation in the United States by Act of Congress on May 10, 1950, broke new ground, comparable possibly with the establishment in Great Britain of the Advisory Council for Scientific and Industrial Research thirty-five years earlier. Some of the functions of the Foundation, however, are more in the field of those of the Advisory Council on Scientific Policy and the Defence Research Policy Committee set up in 1947. The Foundation, for example, is authorized and directed to develop a national policy for the promotion of basic research and education in the sciences; to support basic scientific research and to appraise the impact of research upon industrial development and the general welfare; and, at the request of the Secretary of Defence, to support specific defence research activities. Other functions, such as awarding scholarships and graduate fellowships in the sciences, fostering the exchange of scientific information, evaluating scientific

research undertaken by Federal agencies, correlating the Foundation's research programmes with other such programmes and co-operating in international scientific research activities, follow the pattern of the activities of the Department of Scientific and Industrial Research or its Advisory Council in Britain; but the Foundation is also responsible for maintaining a register of scientific and technical personnel, and for serving as a clearing house for such personnel, a task which in Britain is in the hands of the Ministry of Labour and National Service.

The responsibility for disbursing Federal expenditure in this way is vested in a National Science Board of twenty-four persons eminent in science, medicine, engineering, agriculture, education and public affairs, appointed by the President of the United States and confirmed by the Senate; and the chief executive officer, the Director of the Foundation, is similarly appointed by the President and confirmed by the Senate. The first annual report of the Foundation\*, covering the year 1950-51, is, as Dr. J. B. Conant, the first chairman of the National Science Board, emphasizes in a foreword, essentially a record of progress in formulating plans, and it will be several years before concrete achievements can be listed. Even in the field of applied science, research is in the nature of a long-term investment, while in the basic sciences there may be an even more considerable time-lag. Dr. Conant suggests, as a personal point of view, that it would be wise to discard the terms 'applied research' and 'fundamental research' and substitute 'programmatic research' and 'uncommitted research' as making clearer the difference between these two possible forms of research. A like suggestion has been made elsewhere, and Dr. Conant insists that in the United States it is the uncommitted investigator who is in the greatest need of public support, and that besides more financial support he requires wider public recognition. One purpose of the National Science Foundation is to assist the United States to produce its proper share of such scientific pioneers, and to secure that provision is made for the educational and research facilities which will assist the development of such men. Much of this first annual report is occupied by an able exposition of the nature of fundamental research and the importance of prosecuting it adequately, even in times of national emergency. Examples are cited from electronics, biology and medicine, including penicillin, to illustrate the need for sustained support. This part of the report, with its emphasis in conclusion on the dwindling time-lag, seems admirably argued to counteract the lack of knowledge which must have been responsible for the sudden slashing of the Foundation's appropriation early last autumn. The immediate problem before the Foundation is, in fact, the relation of the present emergency to the support of basic research. The Foundation is planning its programme from the point of view that, since the degree and duration of the present emergency are uncertain, the United States must, with all dispatch, put itself into "operational readiness" and take the necessary steps to maintain itself in this state of readiness for an extended period, perhaps for many years. For science, this means that urgent military uses of science would be expedited where such uses could be put into practice in a short time, such as two or three years. This would involve careful selection

\* First Annual Report of the National Science Foundation, 1950-51. Pp. ix+31. (Washington, D.C.: Government Printing Office, 1952.) 20 cents.