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U.S.-Swedish Workshop on Photodegradation and Photostabilization of Polymers

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In Stockholm, Sweden, a U.S.-Sweden Workshop on "Photodegradation and Photostabilization of Polymers" was held from December 7-10, 1981, at the Park Hotel, Karlavagen. This Workshop was sponsored by the Swedish National Board for Technical Development (STU) and the National Science Foundation (NSF). Dr. F. H. Winslow (Bell Laboratories) and Professor B. Ranby (Royal Institute of Technology) acted as Co-chairmen. There were 10 participants from the United States—Amitava Gupta, P. P. Klemchuk, S. S. Labana, F. R. Mayo, D. C. Neckers, S. P. Pappas, A. M. Trozzolo, O. Vogl, S. E. Webber, and F. H. Winslow; and a similar number from Sweden—A. Holmstrom, K. Abbas, B. Ranby, J. E. Rabek, J. Lucki, A. Hult, S. Gothe, T. Skowronski and G. Ramme. In addition, Professor J. E. Guillet from Canada and Professor J. Kops from Denmark, also participated in the conference.

The program consisted of overview reports on photochemical research on polymers in Sweden (by B. Ranby) and the U.S.A. (F. H. Winslow), a number of official and informal presentations, a session in which the priorities in research and cooperations between Sweden and the U.S. on photodegradation and photostabilization of polymers were discussed and a concluding session. Time was also set aside to visit important academic laboratories in both Stockholm and Uppsala.

While the sponsorship of this meeting was jointly handled by the NSF and STU, the actual proceedings of the meeting were in the hands of the International Department of STU. Mr. Paul Forsgren, Head of the Department of Industrial Processes, STU, gave the introduction. Also present from the STU organization were Dr. Ingela Agrell from the International Department and Mr. Kjell Lindman, Head of the Polymers and Composites Program. STU was host for local arrangements and hospitality.

Dr. Winslow summarized the activities in the United States of polymer research, the present state of polymer research and polymer education in the United States primarily based on the recently published National Academy of Science report "Polymer Science and Engineering: Needs, Opportunities, Challenges." He also discussed the activities in polymer photochemistry and photophysics that are being carried out in laboratories other than those represented by the participants of the symposium, the importance of photochemistry and photophysics in solar energy projects and industrial research and presented specific activities in industrial laboratories. He also mentioned some U.S. research programs on photoresists, and on photodegradation of various polymeric materials including acrylates and PVC. B. Ranby discussed the photophysical and photochemical work on polymers in Sweden with particular emphasis on flash photolysis and high-speed spectroscopy which started in Uppsala in the 1950's, and the sensitized photodegradation and photooxidation studies including ESR spectroscopy of radicals and singlet oxygen reactions, which started in Stockholm in the 1960's, and the more recent studies of photolysis of aromatic and unsaturated polyesters.

Five main lectures on "Photodegradation and Photostabilization of Polymers" were then presented. S. P. Pappas paid particular attention to the sensitization and excitation in polymeric systems including the degradation of aliphatic polymers, photo-catalytic activity of TiO_2 and the photostabilization of aromatic polymer films. S. E. Webber discussed "Energy Transfer in Polymer Systems" which was divided into the behavior of the singlet state, where the excitonic transport between neighboring groups, the Forster transfer to "trap," and the segmental collisions were considered and compared it to the triplet state where only excitonic transfers are likely. Discussed were also the photochemical implications of energy transfer, the energy transfer to reactivate stabilizer sites which can enhance or retard photodegradation or the fact that polymer coils could act as "antenna" for photochemical reactions.

B. Ranby discussed the many problems involved in singlet oxygen generation and reactions of singlet oxygen with polymers and brought up some unsolved problems. J. F. Rabek, in his discussion on "Photodegrada-

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tion and Photooxidation Reactions," brought the participants up to date with the newest development in this field; he discussed degradation mechanisms, initiation of photooxidation and various new methods to study photodegradation. P. P. Klemchuk discussed the "Ultraviolet Degradation and Stabilization of Polymers." He presented the various aspects by which polymers can undergo degradation and the use of stabilizing additives, for example, ultraviolet absorbers, hindered amine light stabilizers, nickel compounds as quenchers, benzoate esters, trivalent phosphorous compounds, hindered amines and thiosynergist combined. In addition, specific subjects were discussed by J. Kops on the "Photodegradation of Polystyrene-Poly(2,6-dimethyl-1,4-phenylene oxide) Blends." J. E. Guillet discussed "New Aspects and New Approaches for Prediction of Photooxidation of Synthetic Polymers." This work involves the computer modeling of 31 reactions involved in the photooxidation and the initial successes in predicting the reaction products on the basis of the knowledge of individual reaction constants. A. Gupta discussed the "Excitation of Photostabilizers and the Mechanism of Photodegradation of Copolymers of Methyl Methacrylate and Vinyl Derivatives of Ultraviolet Absorbers." An additional talk was given by O. Vogl on "Polymerizable and Polymerbound Ultraviolet Absorbers," who discussed the rapidly growing interest in the nonleachable and nonmobile ultraviolet screening agents.

After the discussion of all the individual subjects, the participants were divided into three groups. One group consisted of those interested in singlet oxygen and other excited states with A. M. Trozzolo and B. Ranby as the coordinators. It was concluded that not only singlet oxygen but all activated forms of oxygen should be taken into consideration when discussing interaction of photoexcited oxygen with polymeric materials. Studies of specific importance would be the interaction of polydienes with polynuclear aromatics as sensitizers, particularly how sensitization occurs to each singlet oxygen; it was also suggested in discussions that the triplet states, especially those of high energy, should not be limited to the carbonyl group. Additional studies of model compounds for polystyrene with singlet oxygen but also the reaction of singlet oxygen with 1,2-polybutadiene, and with polymers with furan-containing units and the general desensitization and utilization of singlet oxygen should be carried out.

The group on energy transfer was coordinated by S. E. Webber who discussed the various ways that energy transfer could be and should be studied. It concluded that in this field the most important probl the interaction of polymer chemists, people that synthesize well-defined and pure polymer systems, the photophysicists to test new ideas and to study systems. The problem of "antenna" was found to particular interest and well-defined copolymers traps in the polymer chain or as end groups wou desirable for further studies.

By far the largest group was organized by F. M and J. F. Rabek (11 participants) on photooxidation photostabilization. It was found that the investig of the methods of accelerated aging and understan of performance lifetime of polymers is of greatest in tance; the comparison of individual test methods their practical and theoretical value has been an and some of the predictions of accelerated tests sh probably be coordinated with the development of puterized techniques for the investigation of the pearance of individual chemical groups in the poly Also of great importance were found to be the probl and developments of attached and built-in ultrav stabilizers and this is presently the field of greates rect interest for photostabilization. Other problem substantially less interest but also important in field is the effect of morphology on photodegradat the effects of pigments on photostability and phot gradation and the mechanism and "turn over" on rad scavenging. Of lesser but still of some interest was implication of the stability of natural polymers for prediction of lifetime of synthetic polymers, but also general effect of hydrolysis, the light-induced hydrol degradation and a review of the relative importanc photooxidation on hydrolysis.

Time was also set aside for a visit to the Departm of Polymer Technology, the Royal Institute of Tech ogy in Stockholm, where the ongoing work on ph chemistry was presented and the equipment for photochemical research program was demonstra The remainder of the day was set aside for a visit to Department of Physical Chemistry, the University Uppsala (Professor S. Claesson) where the flash eq ment, the ultra-fast spectroscopy particularly the ec sion spectroscopy, was demonstrated by Dr. G. Ram A visit was also made to the Department of Physics, University of Uppsala (Professor Siegbahn's laborat who is the 1981 Nobel Laureate in Physics) where ESCA spectrometer was shown by Dr. U. Gelius.

The final conclusions of the meeting on "Photodeg dation and Photostabilization of Polymers" were t the possibility of further research cooperation betw the United States and Sweden on photodegradation polymers should be explored and current research p jects expanded. It was found that enhanced exchang information, the possibility of fellowships for gradu students and visiting scientists should be pursued. was concluded that this meeting had been very time stimulating and most successful.

The week of the U.S.-Sweden Workshop included a the day when the Nobel Prizes were awarded. Arran ments had been made by Professor Ranby for the f eign participants of the Workshop to be invited to t Nobel ceremony at the Concert Hall where the awar were presented by the King of Sweden and to the Ci Hall of Stockholm for the Nobel banquet and the subs quent Nobel Ball. The event made this meeting an u usually rare and memorable occasion.