New Materials Science of Carbon and Graphite

The National Science Foundation in the United States and the Japanese Society for the Promotion of Science in Japan were the principal "implementing agencies" that made possible a small symposium devoted to recent advances in the science and technology of carbon and graphite held in Tokyo on 9 to 13 September 1970 under the sponsorship of the Japan-U.S. Cooperative Science Program.

Among the topics discussed were structures, surface properties and reactivity, and electronic processes. Since carbons exist in a vast number of modifications—from crude carbonaceous materials to graphite—each of the above topics included consideration of a large number of materials; much effort has been expended in attempting to correlate properties with composition and form. Very sophisticated techniques have been developed to deal with these problems, and among the highlights of the structural studies were electron micrographs, taken by L. Ban (Cities Service Corporation), showing the bending of the carbon layer planes in graphitized carbon black.

The ancient problem of the changes taking place during carbonization and graphitization of various starting materials and how to control these processes in order to produce the desired finished product is still very much alive; several presentations dealt with various aspects of the complicated behavior of the intermediates occurring during carbonization and graphitization. Recent work by J. D. Brooks and G. H. Taylor (CSIRO, Australia) indicates the importance of spherules in the mesophase (the intermediate phase which solidifies into a graphitizable coke); thus, several groups of investigators have considered the properties of these spherules. One way to assess the importance of spherules in the formation of graphitizing cokes is to carry out studies of carbonization and graphitization under pressure; such experiments performed in the United States were described by P. Walker, Jr. (Pennsylvania State University), and T. Noda (Mie University) summarized the Japanese work. The present state of knowledge about the kinetics and mechanisms of graphitization was explained by D. Fischbach (University of Washington), who emphasized that, whereas it appears to be possible to characterize the high-temperature processes by a unique activation energy, a distribution of microstructures must be invoked to systematize the kinetic processes.

The sessions on surface properties and reactivities exhibited an interesting phenomenon in that all the Japanese presentations included studies of reactivity in which lamellar compounds of graphite were used, whereas the Americans concentrated on surface interactions. The intriguing lamellar compounds were shown to be efficient catalysts for many chemical reactions, including hydrogenation, isomerization, and ammonia synthesis, as well as being successful promoters of hydrogen-deuterium exchange. The communications which considered surface properties and reactivities emphasized the importance of absorption-desorption mechanisms.

The band structure of graphite is well understood on the basis of the Slonczewski-Weiss model. However, the parameters of the model are evaluated by comparison with experiment. The interpretation of recent experiments, primarily magneto-reflection, has led to a reassignment of the electron and hole carriers in the Brillouin zone. This and other current results were discussed by M. Dresselhaus (M.I.T.) and J. McClure (University of Oregon). Modern efforts to calculate the band parameters directly with the use of appropriate wave-functions were described by Y. Uemura (University of Tokyo). Experiments discussed at the conference which relate to the band structure of graphite include measurements of magneto-Seebeck and Ettingshausen-Nernst effects at low temperatures, the Esaki kink and phonon-drag effects, the Hall effect, magnetoresistance, and specific heats. The relevance of such measurements to band models of carbons was neatly summed by S. Mrozowski (State University of New York at Buffalo). Negative magnetoresistance in carbons and graphite drew much comment from the audience, and many individuals presented their own data and interpretations; this phenomenon appears to be a widely observed but little-understood attribute of carbons of various degrees of perfection.

The subject of radiation effects in graphite and their interpretation has a long history, and a brief discussion of advances in this field was given by W. Eatherly (Oak Ridge National Laboratory). Measurements of the threshold energy for displacement of carbon atoms in graphite made at the Japanese Atomic Energy Research Institute (T. Iwata), Argonne (G. Montet), and Oak Ridge (T. Noggle) appear to converge on a value near 30 electron volts; the correct value for the threshold energy has been the object of some controversy in the past.

The symposium was brought to a close by a general discussion of needs and prospects for carbon materials. A highlight of the discussion was a suggestion made by Professor Akamatu (University of Tokyo), the primary Japanese host of the conference, that studies of carbons and graphite should proceed from the viewpoint of aromatic molecules instead of their being considered idealized crystals, which is the usual approach. His suggestion was seconded, to some extent, by K. Sugihara (Matsushita Electrical Industries) who pointed out that recent research on disordered lattices should be pertinent to the study of carbons that have a unique type of disorder around the *c* axis. Calls for future developments of carbon materials for various uses were made by Eatherly, H. Suzuki (Tokyo Institute of Technology), Noda, and Y. Ishikawa (Nippon Carbon), who described his "dream" of future evolvement of the carbon industry. These calls were answered, partially at least, by K. Ouchi (Resources Research Institute, Japan), S. Otani (Gunma University), and M. Litt (Case Western Reserve University), who described research on new products. This discussion was summarized by Fischbach, who described the challenge of the new materials science of carbon.

All who attended the symposium expressed a debt of gratitude to Professor T. Tsuzuku (Nihon University) who was responsible for the arrangement of a very stimulating and rewarding meeting.

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