FUNDAMENTALS OF ADSORPTION

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Proceedings of the Fifth International Conference on Fundamentals of Adsorption

edited by

M. Douglas LeVan
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Editor

M. Douglas LeVan is Professor of Chemical Engineering at the University of Virginia. He received his B.S. in chemical engineering from the University of Virginia (1971) and his Ph.D. from the University of California, Berkeley (1976). After two years at Amoco Production Company's Research Center in Tulsa, Oklahoma, he joined the faculty of the University of Virginia, where he has been for 18 years. He has been Fulbright Senior Scholar to Portugal (1985-86) and France (1993-94). He is section editor of the Adsorption and Ion Exchange section of *Perry's Chemical Engineers' Handbook*, has edited 5 books, and has published about 70 technical papers.

Professor LeVan has been active in society programming within the AIChE and the International Adsorption Society. Within the AIChE, he has been Chair of Area 2e (Adsorption and Ion Exchange, 1985-87), Chair of Group 1 (Fundamentals, 1989-91), and is currently Second Vice-Chair of the Separations Division (Group 2). He was Meeting Program Vice-Chair of the AIChE 1989 Annual Meeting in San Francisco. He has been a Director of the International Adsorption Society since 1992 and is a member of the Editorial Advisory Board of the society's journal *Adsorption*.

His research considers several aspects of adsorption equilibria and fixed-bed adsorption. His group considers theory and experiments on adsorption equilibria for systems ranging from single components to nonideal mixtures such as coadsorbed vapors of hydrocarbons and water. The group has been involved in modeling various fixed-bed processes including dispersive phenomena. Recent interest has been on predicting the performance of systems over repeated cycles. Applications emphasize vapor-phase processes and include TSA, PSA, and adsorptive refrigeration.

Preface

The Fifth International Conference on Fundamentals of Adsorption was held May 13-18, 1995 at the Asilomar Conference Center, Pacific Grove, California. This conference continued the tradition, begun in 1983, of holding an international conference on fundamental aspects of adsorption every three years for scientists and engineers from various backgrounds and disciplines. Prior conferences were held at Schloß Elmau, Bavaria, Germany (1983), Santa Barbara, California (1986), Sonthofen, Germany (1989), and Kyoto, Japan (1992). This conference was organized completely under the auspices of the International Adsorption Society. It was attended by 196 conferees from 24 countries.

The technical program included two plenary lectures, 80 oral papers, 88 poster papers, and a panel discussion on industrial perspectives. The plenary lectures, with engineering and scientific orientations, were presented by Motoyuki Suzuki of the University of Tokyo and William A. Steele of the Pennsylvania State University. The panel discussion was organized by John D. Sherman with panelists J. P. Ausikaitis (UOP, Japan), T. Otowa (Kansai Coke & Chemicals Co., Ltd., Japan), J. D. Y. Ou (Exxon Chemical Co.), R. Pierantozzi (Air Products and Chemicals, Inc.), A. F. Venero (VTI Corp.), and U. von Gemmingen (Linde A.G. VA/EVA, Germany). This panel session resulted in a current effort, led by R. Pierantozzi and with the support of the National Institute of Standards and Technology, to establish a repository for well characterized adsorbents.

Many persons participated in the organization of the conference. The Conference Committee was made up of M. D. LeVan (Chair) of the University of Virginia, J. P. Ausikaitis (Vice-Chair) of UOP, Japan; B. K. Kaul (Vice-Chair) of Exxon Research and Engineering Co.; K. S. Knaebel (Registrar) of Adsorption Research, Inc.; D. K. Friday (Arrangements Coordinator) of Guild Associates, Inc.; M. Jaroniec (International Participation) of Kent State University; J. D. Sherman (Industrial Panel) of UOP; G. Carta of the University of Virginia; F. Meunier of LIMSI/CNRS, France; A. L. Myers of the University of Pennsylvania; A. E. Rodrigues of the University of Porto, Portugal; O. Talu of Cleveland State University; and K. Tsutsumi of Toyohashi University of Technology, Japan. As Conference Chair, I would like to express a very grateful thank you to Barbara, my wife, for all of her support and to Kent and Pam Knaebel, Dave Friday, Mietek Jaroniec, and John Sherman for all of their hard work and special efforts in working through the details of putting the conference together.

Members of the Scientific Advisory Board, together with the Conference Committee, selected papers for presentation from the large number (226) of proposals-to-present received and served as session chairs. This Board was formed from Officers and Directors of the International Adsorption Society. Participating were A. L. Myers (President), M. Suzuki (Vice-President), K. S. Knaebel (Secretary), S. Sircar (Treasurer), J. P. Ausikaitis, G. V. Baron, D. Basmadjian, A. S. T. Chiang, M. D. LeVan, Y. H. Ma, A. B. Mersmann, F. Meunier, A. E. Rodrigues, W. Rudzinski, D. M. Ruthven, W. A. Steele, Y. Takeuchi, and D. Tondeur.

Ten Ph.D. student aides helped with the operation of the conference. We are grateful to Scot Appel, Yuri Berezinsky, Roberta Brown, Brian Dela Barre, Eric Engwall, Peter Gordon, John Peck, Scott Savitz, Suzanne Sowers, and Thieu Vuong.

The conference, especially the high level of international participation, would not have been possible without the generous financial support from many organizations. These included the National Science Foundation, the International Science Foundation, the Japan Society on Adsorption, Air Liquide, Air Products & Chemicals, Inc., The BOC Group, Exxon Research and Engineering Co., Guild Associates, Inc., Praxair, and UOP. In addition, considerable foreign travel support was received by delegates from organizations in their home countries.

The International Adsorption Society was formed at the Third International conference on Fundamentals of Adsorption held at Sonthofen in 1989. The Society co-sponsored the 1992 conference in Kyoto. It has grown rapidly and currently draws members from many disciplines including material science, chemistry, physics, biochemistry and biotechnology, and chemical, civil, mechanical, and environmental engineering. In 1994, the Society launched its own journal, "Adsorption," edited by K. S. Knaebel and published by Kluwer Academic Publishers.

This proceedings volume contains both of the plenary lectures and 131 of the oral and poster papers presented at the conference. All contributions were subjected to a rigorous review process, with almost all papers receiving two reviews from a panel of approximately 100 reviewers. In what follows, the plenary lectures are presented first, in their order of presentation, followed by the oral and poster papers arranged alphabetically by first author.

The Sixth International Conference on Fundamentals of Adsorption is being organized by Francis Meunier for 1998. It will undoubtedly have a wonderful French flavor, magnificent surroundings and, of course, incomparable subject matter.

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December 1995, Charlottesville

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Dr. Motoyuki Suzuki, Professor and Director General of the Institute of Industrial Science, University of Tokyo, graduated from the Department of Chemical Engineering, University of Tokyo in 1963. He finished Ph.D. courses and dissertation work on transfer processes in packed beds at Professor Daizo Kunii's Laboratory. Beginning in 1969, he spent two years as a postdoctoral research fellow with Professor J. M. Smith at the University of California, Davis, where he worked on adsorption kinetics using chromatographic technique. He started his laboratory at the Institute of Industrial Science in Roppongi after he returned from the USA in 1971 and has been working since on environmental and chemical engineering research and graduate education.

His current activities cover application of adsorption technologies in the field of environmental control and management, development of adsorptive separation processes, development of new membranes from the standpoint of adsorptive fouling, molecular simulation of adsorption and diffusion kinetics, mathematical modeling of water quality in natural environment, carbon cycle modeling of terrestrial ecosystems, fundamentals of mammalian cell attachment and growth, development of artificial liver module, etc.

Dr. Suzuki is the President of the International Adsorption Society. He has authored more than 200 papers and in the area of adsorption, published *Adsorption Engineering* (Kodansha/Elsevier, 1990) and *Kasseitan-Kiso to Oyo* (*Activated Carbon - Fundamentals to Application*, Kodansha, 1992). He was editor of *Fundamentals of Adsorption* (the proceedings of the Fourth International Conference on Fundamentals of Adsorption, held at Kyoto in 1992). He was awarded the Doctoris Honoris Causa from University of Veszprem, Hungary in 1991 and was honored by the Society of Chemical Engineers, Japan with the Distinguished Paper Award (1976) and Research Award (1994) and by the Japan Society of Water Environment with its Academic Award (1995).