Preface

Diffusion is an important topic of materials science. It is fundamental and ubiquitous in the art and science dealing with solid materials at elevated temperatures. Diffusion processes play a key role in the kinetics of many microstructural changes that occur during the processing of materials. Typical examples are nucleation of new phases, diffusive phase transformations, precipitation and dissolution of a second phase, recrystallization, high-temperature creep, and thermal oxydation. Direct technological applications concern, e.g., diffusion doping during fabrication of microelectronic devices, solid electrolytes for batteries and fuel cells, surface hardening of steel t hrough carburization or nitridation, diffusion bonding, and sintering.

The atomic mechanisms of diffusion are closely connected with defects in solids. Point defects like vacancies or interstitials are the simplest defects and often mediate diffusion in an otherwise perfect crystal. Dislocations, grain-boundaries, phase boundaries, and free surfaces are other types of defects of crystalline solids. They can act as diffusion short circuits because the mobility of atoms along such defects is usually much higher than in the lattice.

These proceedings contain papers presented at the international conference on ' Diffusion in Materials (DIMAT-96)' held at Schloss Nordkirchen, Germany from August 5 to 9, 1996. The conference was attended by 272 scientists, 110 from the host country and 162 from not less than 25 countries all over the world. Due to this overwhelming response of the ' international diffusion community' DIMAT-96 was the largest international diffusion conference so far. Among the participants were also the organizers of previous conferences on diffusion in materials: D. L. Beke and F. J. Kedves (DIMETA-82, Tihany, Hungary and DIMETA-88, Balatonfiired, Hungary), S. M. Klotsman (DIMETA-91, Moscow/Perm, Russia), M. Koiwa and H. Nakajima (DIMAT-92, Kyoto, Japan).

During the five-days programme of the conference, 27 invited talks were presented covering the general topics of diffusion , defect concentrations, diffusion-controlled phenomena, and applications of diffusion i11 various materials. In addition, 41 oral contributions and 248 poster contributions were presented in 18 oral and 4 poster sessions including 2 evening sessions.

The scientific spectrum covered by tbe conference was very broad. From the materials point of view, metals, alloys, intermetallics, elemental and compound semiconductors, amorphous materials, nonmetals like fast ionic conductors, oxides, ni t rides, polymers and to some extent also melts were subjects of the conference. From the viewpoint of phenomena the whole spectrum from basic to application-oriented topics was considered: self-diffusion, interdiffusion, reactive diffusion, grain-boundary diffusion, surface diffusion, diffusion barriers and diffusioncontrolled phenomena. The Conference Proceedings include 24 invited and 229 contributed papers (oral or poster). The scientific aspects of DIMAT-96 are only partially represented in these Proceedings because the invited and contributed papers cannot fully capture the verbal presentations and lively discussions.

The Organizing Committee had decided to locate the conference in buildings of the Nordrhein-Westfalen college of finances. The college is situated inside the beautiful park of Schloss

Nordkirchen. This location offered a pleasant ambience, ample space for the scientific programme, an efficient college restaurant, and the possibility of accommodation for all participants and accompanying persons within walking distance to the conference rooms.

The scientific programme was completed by a social programme with several highlights: a baroque concert, a conference dinner, two informal meetings, and a conference excursion to the medieval castle Burg Vischering and to the ancient city of Miinster where the Mayor of Munster gave a reception in the famous 'F'riedenssaal'.

As editors of the proceedings and organizers of the conference we wis h to express our gratitude to many persons and organizations. Ou r thanks go to all speakers, co ntributing authors, and chairme n for their excellent contributions during the conference and for their cooperation in providing manuscripts. The members of the I nte rnational Advisory Boa rd were of invaluable help in suggesting topics for the conference and names of speakers. The members of the Programme Committee worked hard to cope with more than 100 s uggestions for invited talks and with about 350 abstracts. Many participants o f the conferen ce acted as re ferees for conference papers. We very much appreciate their help. We are grateful to t he t eam of the o rdrheinWestfalen college of finances and in particular to Mr. Thier for efficient cooperation. We also acknowledge financial support by the organizations and companies mentioned above.

Thirty- two people joined t he programme for a cco mpany ing persons. We are grateful to Mrs. M. Funke and Mrs. K. Mehrer for the organization of this programme.

Last but not least, we express our deepest appreciation t o all members of the Munster conference team: t he secretary Mrs. Niehues-Korouma, the technicians, the diploma and PhD students of the ' Munster diffusion group' at the Io stitut fiir Metallforschung.

January 1997 H. Mehrer

Chr. Herzig

N.A. Stolwijk

H. Bracht

Foreword

It is a great honour and privilege to write this foreword to the Proceedings of DIMAT-96.

During the previous conference, DIMAT-92 held in Kyoto, Japan, we agreed to have t he next one in Germany. Both the numbers of participants and papers showed a large increase, from 174 to 272 and from 153 to 317, respectively.

Recognizing that this conference was the celebration of hundred years of diffusion research in materials, the program committee rightly organized a session on the 'History of Diffusion'. Sir William Chandler Roberts-Austen reported the first systematic study of solid state diffusion in 1896. The experiments were made on Au diffusion in Pb; it is surprising to observe that the values of the diffusion coefficients reported by him are similar to those determined by moder::I techniques in the 1960's and 1970's using radioactive isotopes. The choice of the system PbAu was really fortunate to demonstrate the otherwise generally slow diffusion processes in solids; the diffusion of noble metals in lead is now known to be exceptionally fast, the detailed mechanism of which is still subject of investigations.

The first self-diffusion experiment on a solid metal (212Pb in Pb) was performed by G. von Hevesy and his coworkers in 1921. G. von Hevesy (1895 - 1966) was of Hungarian origin. In 1926 he continued his research at the University of Frei burg in southern Germany. He received the Nobel prize in 1943 for his work on the use of isotopes as tracers in the study of chemical processes. In Germany there are several strong groups active in diffusion studies. One of them, the 'Munster school of diffusion' started with W. Seith, a coworker of von Hevesy. The book "Diffusion in Metallen" by Seith was first published in 1939 (the 2nd edition in 1955 was coauthored by Th. Heumann) and remained as a standard textbook in this field for a long time.

It was translated into Japanese by R.R. Hasiguti. Th. Heumann was appointed as the first director of the lnstitut fiir Metallforschung, which was established at the University of Mi.inster in 1959. Extensive investigations on various problems of diffusion in solids have been carried out at the institute by a number of scientists, in particular by Chr. Herzig, Th. Hehenkamp (now at University of Gottingen), and W. Gust (now at Max-Planck-Institut fi.ir Metallforschung, Stuttgart). After the retirement of Th. Heumann in 1984, H. Mehrer was appointed as the director of the institute. A number of contributions to these Proceedings from the 'Munster school' confirm that the institute is one of the leading teams in diffusion research.

Finally, *I* would like to recall the fact that the renowned Fick's law was postulated by the physiologist Adolf Eugen Fick who was born in Kassel, and educated in Marburg and Berlin. The historical paper entitled "On Liquid Diffusion" (Phil. Mag., 10 (1855) 30, see also Poggendorf's Annalen der Physik 94 (1855) 59) was written when he was Demonstrator of Anatomy at Zurich. In the paper he showed that " the law for the diffusion of a salt in its solvent is identical with that according to which the diffusion of heat in a conducting body takes place; upon this law Fourier founded his famous theory of heat."

In summary, German scientists have contributed greatly to the study of diffusion. DIMAT- 96 has been held in the mother country of diffusion and owes its success to the hard work of the 'Munster school' headed by H. Mehrer. These Proceedings represent the state of the art in the 'field of the science of diffusion and will be invaluable for materials scientists.

Masahiro Koiwa

Department of Materials Science and Engineering

Kyoto University