site energy distributions of the hydrogen atoms (which are dependent on their metal atom environments), they deduced that in the glassy alloy, hydrogen atoms sit on Zr_4, Zr_3Pd and Zr_2Pd_2 type sites, whereas in the crystalline alloy, they sit only on the Zr_4 sites at low hydrogen contents.

O. Yoshinari from Nagoya Institute of Technology, Japan and R. Kircheim from Max Planck Institute, Stuttgart reported that the solubility of hydrogen in amorphous $Pd_{73.2}X_{8.8}Si_{18}$ (X = silver, copper, chromium, iron or nickel) alloys decreased in comparison with solubility in amorphous $Pd_{82}Si_{18}$. Diffusion coefficients were quite different in various ternary palladium-silicon alloys but this could be attributed to differing activation energies when a constant reference diffusivity was assumed.

Instrumental Techniques

A number of papers dealt with the use of various instrumental techniques for exploring aspects of metal-hydrogen interactions. A paper by D. H. W. Carstens and P. D. Encinias (Los Alamos National Laboratory, New Mexico) involved the use of Laser-Raman Spectroscopy for studying hydrogen isotopic exchange over palladium metal. A joint U.S. group from Washington University, St.Louis and Iowa State University, Ames (D. B. Baker, M. S. Conradi, R. E. Norberg, D. R. Torgeson and R. G. Barnes) presented a paper on novel measurements of nuclear spin cross-relaxation in metal hydrides using NMR. D. K. Ross, M. W. McKergow and D. G. Witchell (University of Birmingham) with J. K. Kjems (Riso National Laboratory, Denmark) reported the use of diffuse neutron scattering to monitor super lattice reflections as the deuterium atoms order at the 50 K anomaly in palladium-deuterium.

Applications

Promising practical applications involving the platinum metals were proposed in a number of papers presented. A group from the Max Planck Institute in Stuttgart (H. H. Uchida, H.-G. Wulz and E. Fromm) have observed remarkable enhancement of hydrogen dissociation if nickel, iron or palladium, acting as catalysts, are present on the surface of oxidised titanium or intermetallic storage materials. This may prove a significant advance in the development of poisoning-resistant hydrogen storage systems. A promising material for a hydrogen separation membrane was reported by M. Amano, M. Komaki and C. Nishimura (National Research Institute for Metals, Tokyo, Japan). Palladium plated vanadium-15 atomic per cent nickel alloy membranes show good resistance to hydrogen embrittlement while having superior hydrogen permeability compared to palladium.

Concluding Remarks and Future Developments

The conference concluded with a rapporteur session in which it was agreed that while some aspects of metal-hydrogen research have reached maturity, the future holds many openings and scope for development of new areas of study particularly, for example, examination of bonding theories including the idea of pairing interactions, and exploring the realm of new intermetallic materials.

Proceedings of the Symposium will be published in the *Journal of Less-Common Metals* in Spring 1991. The next International Symposium on Metal Hydrogen Systems is to be held in Uppsala, Sweden from 8th to 13th June 1992.

R.-A. MCN.

Palladium Membrane Reactors

The oxidative dehydrogenation of cyclohexane can take place with high yield when a palladium membrane is used to divide the reactor into reaction and separation sections. In order to establish the effect of the gas flow patterns when a sweep gas is used to remove the permeated hydrogen, five ideal flow models have been analysed and compared by N. Itoh, Y. Shindo and K. Haraya of the National Chemical Laboratory, Tsukuba, Japan (*J. Chem. Eng. Jpn.*, 1990, 23, (4), 420–426).

Concurrent, counter current, plug-mixing, mixing-plug and mixing-mixing models were considered. It was found that the highest performance was shown by the second of these, where the feed gas on one side of the palladium membrane flows in the opposite direction to the sweep gas on the other.