

hand cobalt seems to have diffused even less than platinum. The irregularities on the copper curves are explained by the hole formation. From similar measurements made on platinum top layer diffusion couples it is concluded that platinum and also cobalt form a tin-rich intermediate phase on diffusion with copper-tin alloys. Apparently the cobalt "getters" some of the tin away, forming a platinum-(cobalt-copper)-tin phase faster than platinum does on its own. As yet it is not known if this platinum-(cobalt-copper)-tin layer is a true separate intermediate phase, but it will be studied later.

The Vickers microhardness of these ternary platinum-cobalt-tin or quaternary platinum-(cobalt-copper)-tin phases is about 380 HV, significantly higher than those of the starting metals. It is surprising that this high hardness of the diffusion layer did not show up as an adhesion problem during cold rolling of the diffused sandwiches.

From the gradients of the relevant elements, shown in Figure 13, platinum and cobalt seem to diffuse differently, as do copper and nickel. Apparently there is a relationship between the changing slope of the copper and of the cobalt curves near the top layer, since the platinum and nickel curves show no change in the gradient of their concentration/distance curves. From Figure 14 one can deduce that nickel and platinum diffuse evenly into each other. But

during copper/nickel diffusion the well known Kirkendall holes form within the copper, as is shown in the dip of the copper curve on the concentration/distance graph, see Figure 14.

Conclusions

Investigations of the diffusion behaviour of various copper- and nickel-based components in contact with layers of platinum, platinum-5 per cent cobalt and platinum-5 per cent iridium have been made by various methods, and have shown a consistent picture of pronounced diffusion of copper into platinum. This causes voids to form on the copper side of the interface due to the Kirkendall effect and results in adhesion problems. However these can be overcome by using nickel as the base metal, by incorporating an electrodeposited nickel layer or by using a nickel-rich copper-nickel alloy.

Acknowledgements

We wish to thank Impala Platinum Mines Limited for their support of these investigations, and Dr. A. Bischoff of W. C. Heraeus G.m.b.H. for assistance with the microprobe investigations.

References

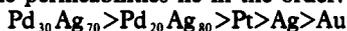
- 1 D. Ott and Ch. J. Raub, *Platinum Metals Rev.*, 1986, 30, (3), 132
- 2 W. Seith and T. Heumann, "Diffusion in Metallen", 2 Edn., Springer-Verlag, Berlin, 1955
- 3 A. D. Smigelskas and E. O. Kirkendall, *Trans. AIME*, 1947, 171, 130

Hydrogen Permeability at Elevated Temperatures

The study of the reactivity of minerals in fluid media under conditions of high temperature and pressure has important implications for their industrial utilisation. In such hydrothermal experiments the precious metals are commonly used as containment materials; platinum and silver-palladium being employed as semi-permeable membranes for hydrogen while gold and silver serve as hydrogen barriers. To date the lack of reliable data on the permeation rates of hydrogen has caused difficulties in the selection of materials and experimental conditions.

Now, however, a study by I-Ming Chou of the U.S. Geological Survey has remedied this deficiency (*Am. J. Sci.*, 1986, 286, 638-658).

Using an oxygen-buffered, double capsule technique, Chou has measured the permeation of hydrogen through platinum, two silver-palladium alloys, gold, and silver at a pressure of 2 kilobar (29,000 psi, 200 MN/m²) in the temperature range 450 to 812°C. He showed that the permeabilities lie in the order:



The activation energies increase in this order.

This study shows that the addition of palladium to silver increases its hydrogen permeability exponentially, and extends the data on the silver-palladium system, where the palladium-rich alloys are used commercially as diffusion membranes for the purification of hydrogen.

C.W.C.