The Structure of Rhodium

By E. S. Bale, A.I.M.

This note, a communication from the Johnson Matthey Research Laboratories, records an investigation into the crystal structure of high-purity rhodium carried out in an attempt to understand why this metal should present such difficulties in working

It is well known that rhodium, although having a face-centred cubic crystal structure, is much more difficult to work than most other metals of similar structure such as copper, silver, gold, platinum or palladium. It has been suggested that this difficulty might be due to the presence of impurities, while another suggestion which has been put forward is that a transformation takes place to some other crystal form (1, 2).

The present investigation was therefore undertaken into the behaviour of pure rhodium towards external stresses and into the possibility of a transformation taking place.

To obviate any anomalous behaviour due to the presence of foreign elements a specially prepared batch of chloropentammine rhodium dichloride was taken and after several recrystallisations a sample of rhodium oxide was obtained which gave the spectrographic analysis shown below.

Element	Per cent
Cu	0.0002
Fe	0.0001
Mg	0.0001
Si	0.0001
Ca	0.0002
K	0.0001
Na	0.0002

The following elements were not detected:

Ag, Al, As, Au, Ba, Cd, Co, Cr, Ir, Li, Mn, Mo, Os, Pb, Pd, Pt, Rb, Ru, Sb, Sn, Sr, Te, Ti, V, W, Zn, Zr.

By reduction of this oxide, rhodium containing less than 10 parts per million of metallic impurities was produced.

A sample of this metal was pressed, sintered in oxygen-free hydrogen and cold rolled with intermediate anneals to sheet 0.060 inch in thickness, from which a tensile specimen was prepared.

This specimen was annealed in high vacuum and tested using an extensometer capable of measuring to 0.00001 inch. The applied load was increased and no elastic region was observed, the stress-strain diagram being a smooth curve from the origin. The mechanical properties obtained from this test are shown in the table.

Mechanical Properties of Pure Rhodium

Proof stress *(0.01%), tons per sq. inch*	3.8
Proof stress *(0.1%), tons per sq. inch*	4.6
Ultimate tensile strength, *tons per sq. inch*	30.6
Elongation, *per cent, on 2 in.*	6.5
Modulus of elasticity, *pounds per sq. inch*	41.2×10^6
Vickers hardness	110

Another sample of the pure rhodium was used to obtain a work hardening curve, which showed that the hardness increased to over 300 VPN with about 15 per cent reduction by rolling. It was apparent from these tests that pure annealed rhodium is initially very soft, but that its rate of work-hardening is very rapid at room temperature.

As mentioned earlier, there seemed no reason why pure rhodium should behave in this manner as it has a face-centred cubic

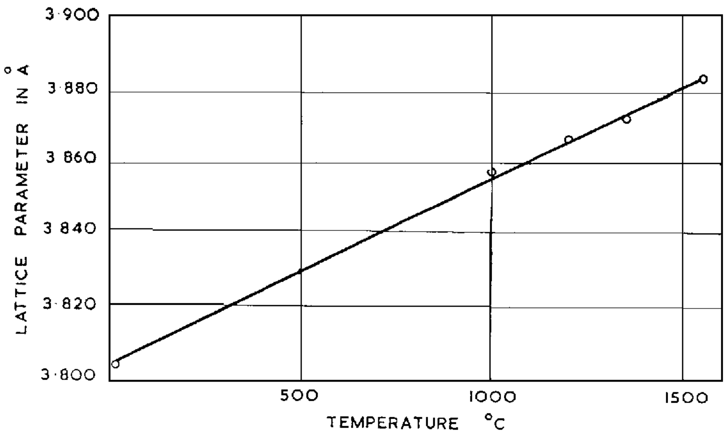

Fig. 1 Effect of temperature on the lattice parameter of rhodium

structure, but its behaviour towards mechanical working seemed like that of a material with a more complex structure.

In order to investigate the possibility that an allotropic transformation occurred with increasing temperature, an apparatus was constructed by which high temperature X-ray diffraction photographs could be obtained and examples of the crystal structure of rhodium were determined at temperatures up to 1600°C. Fig. 1 shows the relationship between the diffraction spacing and temperature, and as this relationship is a straight line it can be concluded that rhodium has a face-centred cubic crystal structure over the range from room temperature to 1600°C.

To confirm this result and to ensure that the atomic packing was consistently perfect, high temperature electrical conductivity measurements were made during heating to 1450°C and cooling to room temperature. Fig. 2 shows the curve obtained from these measurements and it can be seen that no significant change of shape or hysteresis occurs. These two experiments provided substantial evidence that the crystal structure of rhodium is face-centred cubic between room temperature and say 1500°C.

It follows, therefore, that either rhodium is susceptible to the presence of impurity atoms of an order unknown in any other face-centred cubic metal, or that the mechanism of its plastic behaviour is unlike that of metals with a similar crystal structure.

It appears most likely, therefore, from the present work that pure rhodium has an intrin-

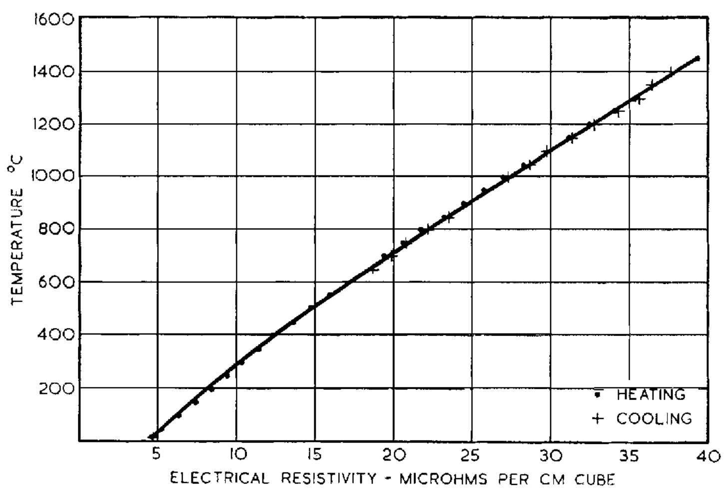

Fig. 2 Effect of temperature on the electrical resistivity of rhodium

sically high rate of work-hardening and that this is due to a different mechanism of slip processes than occur in other face-centred cubic metals. Further experimental work based on a study of slip line formation combined with a suitable X-ray diffraction technique would be necessary to define the operative slip system.

References

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Vacuum Casting Uranium Reactor Fuel Elements

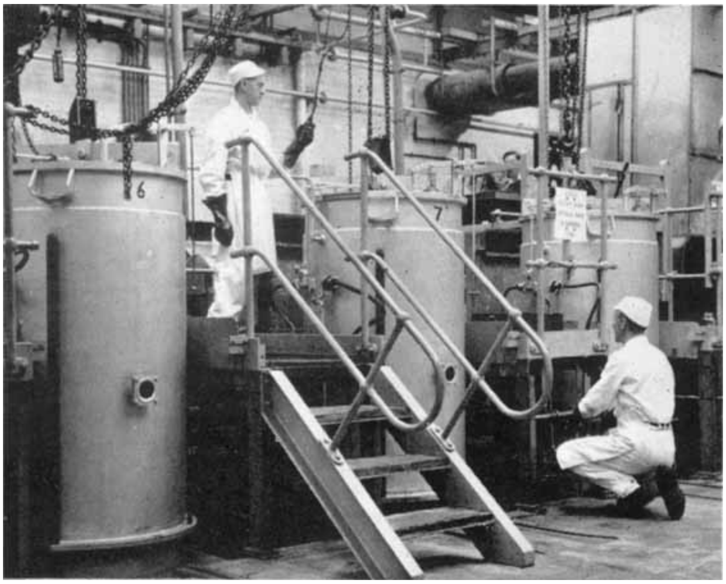
TEMPERATURE CONTROL WITH PLATINUM THERMOCOUPLES

Among the final operations at the Springfields Works of the United Kingdom Atomic Energy Authority is the vacuum casting of high-purity uranium into rods for use as reactor fuel elements.

The Springfields Works undertakes the preparation of almost all the uranium refined in Britain, starting from the ore. After a series of chemical treatments, uranium tetrafluoride is reduced with metallic calcium by firing in a reduction mould.

To produce the reactor fuel elements in the required shape and size, and also to remove metallic and non-metallic impurities, the uranium is then melted and cast in a group of high-frequency vacuum furnaces. These are of the stationary-crucible, bottom-pouring type, the base of the crucible being pierced by a pouring hole, closed during melting by a graphite or alumina bung.

For successful casting the pouring temperature is critical, and is controlled by means of platinum : rhodium-platinum thermocouples led in through the top of each furnace. When correct pouring temperature has been attained, the bung is removed by means of a graphite rod and a system of bell cranks, push rods and levers, and the molten uranium runs through a launder into the moulds stationed in the lower part of the furnace.



A battery of three high-frequency vacuum casting furnaces for the production of uranium reactor fuel elements at the Springfields Works of the Atomic Energy Authority. Temperature control during melting and casting the uranium is effected by means of platinum: rhodium-platinum thermocouples