The Effect of Palladium Additions on the Flaking of Steels

RUSSIAN RESEARCH MAY HAVE WIDE APPLICATION

It is well known that the presence of hydrogen in steels adversely affects their ductility, due to hydrogen embrittlement, and that it may lead to cracking and fracture if the steel is in a state of tensile stress. In the case of high-strength steels this phenomenon of hydrogen-stress cracking is frequently referred to as "delayed failure", since there is an incubation period before cracking occurs; this incubation period is considered to be due to the slow diffusion of hydrogen to the region of maximum triaxial stress.

Flaking is another form of hydrogen induced cracking which occurs when steels are cast, hot worked or welded in an atmosphere containing gaseous hydrogen. The flakes appear on fractured surfaces of the steel as round or oval spots that are often of a bright appearance; if the surface of the metal taken in a direction perpendicular to the fracture is examined microscopically hair-line cracks may be observed, and for this reason the phenomenon is also referred to as "hair-line cracking".

In spite of the tremendous amount of work that has been carried out on the various aspects of hydrogen embrittlement the mechanism is still far from clear. It is recognised, however, that both the hydrogen present interstitially and that adsorbed at surfaces of traps play a role in the mechanism of fracture. The precise nature of the trap sites is not clear, and different workers in the field attach varying degrees of importance to such heterogeneities as dislocations, stacking faults, interfaces between phases (particularly those between carbides and ferrites), inclusions, etc. It is also widely accepted that a proportion of the hydrogen adsorbed at trap sites is mobile and damaging, and that it is this mobile hydrogen which can diffuse interstitially to areas of maximum triaxial stress and so lead to cracking. If this is the case it is not unreasonable to believe that it should be possible to modify the existing traps, or introduce new ones, in such a way that their adsorptive properties are increased sufficiently to immobilise the damaging hydrogen.

This philosophy has been applied by two groups of Russian workers, at the Ural Polytechnic Institute and at the Donetsk State University, (1,2) to the problem of flaking, and studies have been carried out on the effect of alloying additions of palladium, and other metals such as titanium, cerium and zirconium which form stable hydrides, on flake formation in steels (Russian designations 34KhN3M and 34KhN3T). Alloys containing various concentrations of these metals have been heated at 1100°C for 5 hours in an atmosphere of hydrogen gas and then cooled at different rates by quenching in water, oil or cold air. They were allowed to stand for an incubation period of 10 days at room temperature before being annealed at 650°C and then cooled in air. After etching, the flake density was determined by counting the number of flakes on an area 1 cm square. The results obtained showed that (a) flake density increased with the diameter of the specimen and with the rate of cooling (b) all alloying metals decreased flake density, the decrease depending on, and increasing with, concentration of alloying metal and (c) in the case of the air-cooled specimens complete elimination of flaking was achieved.

In the case of palladium-containing alloys quenched in water, the flake density clearly decreased with increase in palladium content and became zero at 0.3 to 0.5 weight per cent palladium. Studies of the total apparent solubility of hydrogen, and of the proportion of absorbed hydrogen evolved during heating at various temperatures, showed that whereas solubility was unaffected by the presence of palladium the proportion of hydrogen evolved at 400°C, the temperature at which hydrogen evolution was a maximum, was considerably less for the 0.3 to 0.5 weight per cent palladium than for those of lower palladium contents. This indicates that palladium in this range of concentration is modifying the existing trap sites, since the authors consider that trapping by substitutional atoms of palladium, or other additions, is very unlikely. They consider that the ferrite/carbide interfaces are the most important trap sites in steels and that these trap sites are modified by the alloying elements so that they adsorb hydrogen more strongly.

These studies of the effect of hydride-formers on flaking may have a wider application and should stimulate further work on the effect of these metals on the hydrogen stress cracking of high-tensile steels.

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References

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Novel Electronic Materials

THEIR DEPENDENCE ON THE PLATINUM GROUP METALS

Many of the electronic devices which have emerged during the last one and a half decades rely for their operation on the use of single crystal oxides, which possess high structural and chemical perfection. The melt growth temperatures of these oxides range from 738°C for lead germanate to 2105°C for magnesium aluminate (spinel). The high melting points of both the single metal-oxide compounds and mixed systems, coupled with their high reactivity and their growth dependence on an oxygen or neutral atmosphere, severely limit the choice of materials available for containing their melts.

The chemical stability of platinum and iridium at elevated temperatures, 1500 and 2200°C respectively, and the chemical compatibility of these two platinum group metals with most oxide systems make them an obvious choice as container materials for the growth of oxides.

At the "Chemistry in Industry—the Way Ahead" Conference held at Wembley in November 1976, P.M. Welch of Johnson Matthey Chemicals Limited reviewed the use of platinum group metals in crystal growing in a paper entitled "High Purity Chemicals for Electronic Applications".

One development in platinum metal metallurgy, highlighted in the paper, which could be of paramount importance to crystal growers—in particular for laser and electrooptic materials with melting points below 1500°C—is the introduction of a zirconia grain-stabilised grade of platinum. This material has increased strength at elevated temperature and better contamination resistance compared with pure platinum.

One category of magnetic materials that promises to be a major outlet for single crystals in the next decade is bubble domain devices used as a data storage and manipulation medium. The devices comprise a single crystal insulating substrate of $Gd_3Ga_5O_{12}$ (GGG), on to which is deposited an epitaxial layer, 3 to 6 μm thick, of a ferromagnetic garnet of the type $R_xY_{3-x}Fe_{5-y}Ga_yO_{12}$, where R is one or more rare earth ions.

The GGG has a melting point of 1725°C, and is grown by the Czochralski technique at a typical pulling rate of 5 to 8 mm/h from an iridium crucible under a slightly oxidising gaseous environment. GGG single crystal boules are now being produced commercially up to 7.5 cm in diameter, and weighing about 4 kg.

The magnetic thin films are grown at about 1000°C in platinum from a supersaturated solution of the garnet in a PbO/B_2O_3 flux.

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