Metallische Werkstoffe

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umicore
Platinum Engineered Materials

Strengthening Mechanisms and Oxidation Behaviour in Platinum and Platinum Alloys

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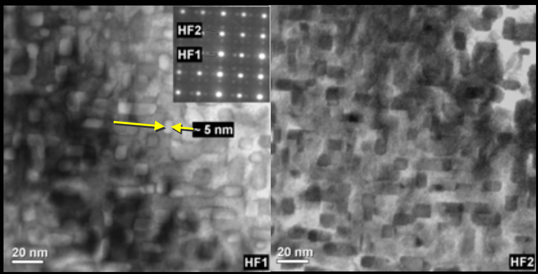
The chemical resistance against aggressive media even in the high temperature range and the catalytic properties qualify platinum as a material for a wide range of technical applications. Since the low mechanical strength of pure platinum is limiting its applicability, the use of suitable platinum alloys becomes indispensable. In binary systems precipitation hardening alloys have so far not been developed. Some ternary precipitation hardenable alloy systems that are reported in literature exhibit a high mechanical strength and seem to be promising candidates for technical use in the high temperature range. In contrast to the reputation of having an excellent oxidation resistance of Pt alloys it became evident that their oxidation behaviour is not sufficient yet and that degradation close to the surface of the alloys needs to be prevented.

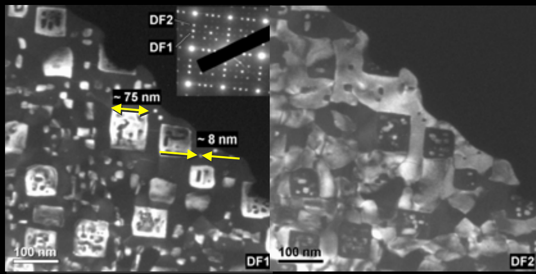
Bulk Material and Microstructure of the System Pt-Ti-Al

The present work shows Pt-Ti-Al-alloys that form ordered Pt_3Ti phases and fulfil one of the prerequisites for technical applicability. In this work the Pt concentration is designed to be as high as possible (> 96 weight%). In spite of the low alloying element concentration the microstructures yield a hardness raise up to 500 HV (compared to 50 HV of pure Pt).

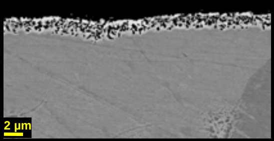


Lattice fringes can be seen in the secondary phase; Beginning particle formation

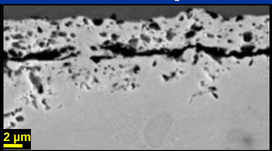
Cuboidal precipitates with edge lengths from ~ 8 nm to ~ 80 nm; Large precipitates contain finer precipitates that show the same phase contrast as the matrix



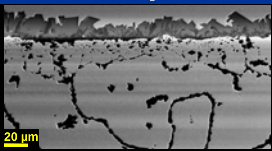
Oxidation Behaviour in Air, Dependence on Temperature and Time



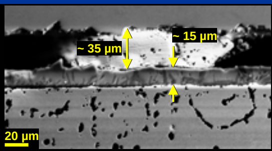
900 °C / 4 h; Internal nucleation of small oxide particles directly beneath the surface



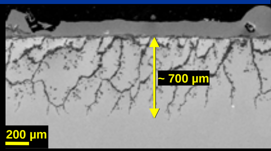
900 °C / 100 h; Formation of small oxide bands beneath the surface



1100 °C / 100 h; External oxide layer with jagged surface contour; Formation of oxidation paths

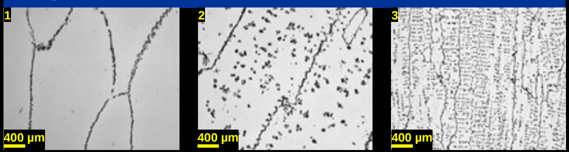


1100 °C / 100 h; Dense oxide layer beneath the surface

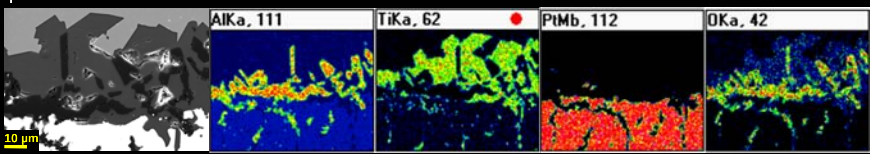


1300 °C / 100 h; Penetrating oxidation preferably along grain boundaries

Dependence on Al Concentration



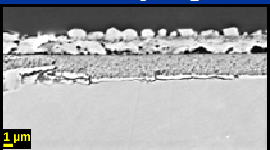
Binary Pt-Ti alloy: Intergranular oxidation only (1); Ternary Pt-Ti-Al alloy: Raising intragranular oxidation with increasing Al concentration (2), (3)



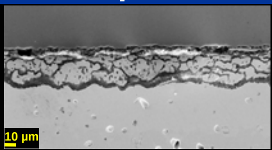
1100 °C / 100 h; Surface oxide layer: mixture of Al_2O_3 and TiO_2. The surface structure shows that outward diffusion of alloying elements is strongly contributing to the oxide formation. Element mapping: Al_2O_3 forms directly at the surface as well as inside the bulk. TiO_2 forms on top of Al_2O_3. Some Al_2O_3 particles are incorporated into the TiO_2 layer.

Substituting Ti by other Alloying Elements, Dependence on Composition

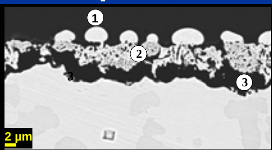
Finely dispersed oxides beneath the surface; Crystallographic orientation of oxide needles



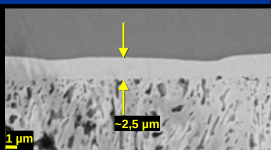
Arrangement of 3 layers with Pt nodules at the surface



Linked oxidation paths; Formation of a dense oxide layer beneath the surface

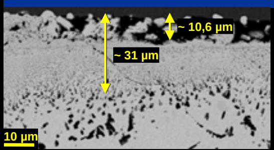


Pt nodules at the surface (1); Zone with internal oxidation (2); Oxide band separating oxidation zone from bulk (3)

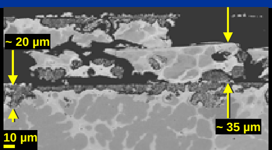


Pt nodules at the surface have combined to a closed layer of pure Pt

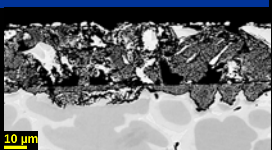
Influences of Mechanical Deformation



Internal Oxidation; Spalling of metal/oxide layers close to the surface



Separated material layers; Internal oxidation starting from the surface and from the separation lines



Beginning separation of a material layer with pronounced internal oxidation

Conclusions

A variety of morphologies of oxide particles and oxide layers can form on Pt alloys. Dense oxide layers are observed at or beneath the suface depending on composition, temperature and time. The morphology of the oxides can be influenced by different alloying elements. Mechanical deformations strongly change the oxidation behaviour and promote the formation of material layers that can show extensive spalling.