ÖGUSSA

FKS
Grain stabilized platinum materials

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Dispersion hardening: the „beneficial defect“

This brochure describes an innovation from Umicore which enables entire branches of industry to increase their productivity and save on costs at the same time through the use of a new, extremely resistant high-tech material.

We also hope that this brochure will provide you with a few ideas for the future.

Heat makes metals soft and coarse ...

Lattice defects are typical of crystallites, the microscopic crystals in a metallic structure. These defects are tiny stress centers which combine to define the strength of a metallic material. Basically, the more defects the harder the metal.

When a metal is deated, it loses this strength. If the heat treatment is maintained, this reaction, known as recrystallization, also results in an undesired formation of coarse particles.

Dispersoids keep metals hard and fine:

The fine nature of dispersion hardening prevents the formation of the softening coarse particles and stabilizes the hardening fine particles using different, finely distributed metal oxide dispersoids which are introduced into the metallic matrix of each and every crystallite.

In this way the status of the metal when cold, with its high mechanical strength, remains intact even when it is heated to temperatures near the melting point: The crystal structure retains its functional linear structure.

As a further important effect, the chemical behavior and most physical properties of the metal only undergo minor changes if at all following dispersion hardening.

Dispersoid requirements: „As you like it“ – from Umicore.

In general ...

The effectiveness of dispersion hardening depends upon the demands placed on the dispersoid regarding:

- maximum size
- size range
- concentration
- distribution in the metallic matrix
- distance from each other
- habitus
- chemical and heat resistance

While the last two features habitus and strength can be assured by selecting a metal oxide with the required stability, all others depend on the quality of the dispersion hardening and of the company carrying it out.

... and at Umicore

The process developed by Umicore uses zirconium oxide as the dispersing agent. Together with the special platinum dispersion-hardening method this allows:

- free choice of the most favourable dispersion content, depending on the use to which the material is to be put
- optimized particle size and spectrum
- extremely homogeneous distribution of the dispersoids.

This has been achieved, amongst other things, thanks to roughly 150 years of experience which Umicore possesses in the processing of precious metals.

FKS – dispersion-hardened platinum materials for Umicore.

Dispersion-hardened platinum materials from Umicore are known as FKS (from the German abbreviation for grain stabilized). To date three materials of this sort have proved to be highly significant:

- FKS 16 Pt (grain stabilized platinum)
- FKS 16 PtRh 10 (grain stabilized platinum alloy with 10% rhodium)
- FKS 16 PtAu 5 (grain stabilized platinum alloy with 5% gold)

(The 16 refers to the 0.16% zirconium oxide dispersion agent contained in our FKS product.)

FKS material structure – stability incarnate

The grain boundaries of a crystal structure are considerably reduced as a function of the amount and duration of heat to which the substance is subjected. This greatly increases the tendency of the structure toward intercrystalline fracture. Since platinum materials are used mainly at temperatures well over 1000°C, this process occurs very rapidly, thereby putting the mechanical strength of the object at considerable risk.

This danger is avoided with FKS materials.

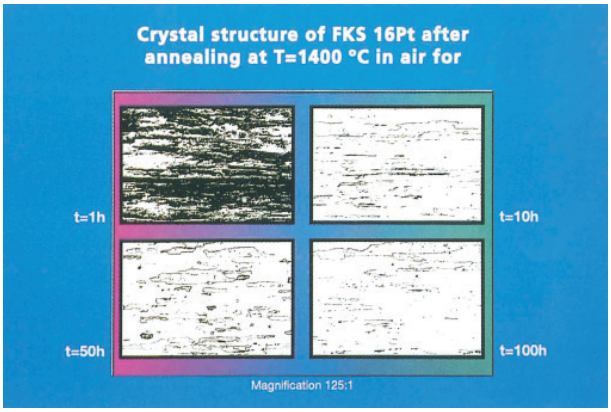

Figure 1

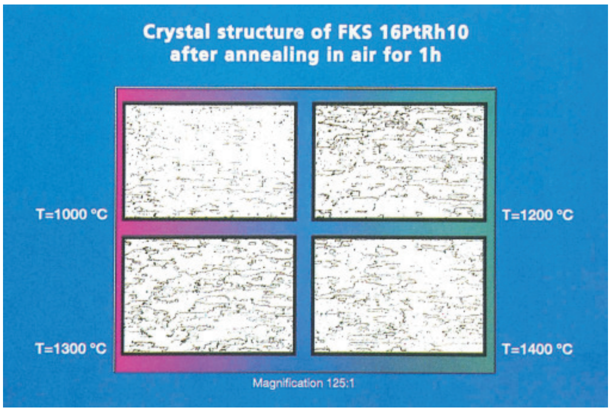

Figure 2

Figure 1 shows our FKS 16 Pt annealed at 1400°C. Although relatively slight recrystallization, i.e., minimal particle growth, occurs after one hour, the structure remains practically unchanged thereafter, even after being heated for several hours. The new platelet like structure with an extensive grain boundary network also can be seen clearly.

Even with annealing operations lasting well over 100 hours longer than our example, the much feared coarsening of the structure does not occur. While Figure 1 shows the reaction of our FKS 16 Pt material as a function of time, Figure 2 illustrates the behaviour of FKS 16 PtRh 10 as a function of temperature, a much more significant influence on recrystallization behaviour. As can be seen, the grain boundary network remains practically unchanged between 1000°C and 1400°C.

These laboratory findings have been thoroughly verified by numerous sample tests on appliances used in practice.

Cold strength and behaviour when hot – good marks for FKS

The Vickers hardness readings for our FKS materials in undeformed state are as follows:

125 HV5 for FKS 16 Pt
170 HV5 for FKS 16 PtRh 10
135 HV5 for FKS 16 PtAu 5

Deformation of 60 % or 90 %, through forging for example, yields:

150 185 HV5 for FKS 16 Pt
220 275 HV5 for FKS 16 PtRh 10
180 210 HV5 for FKS 16 PtAu 5

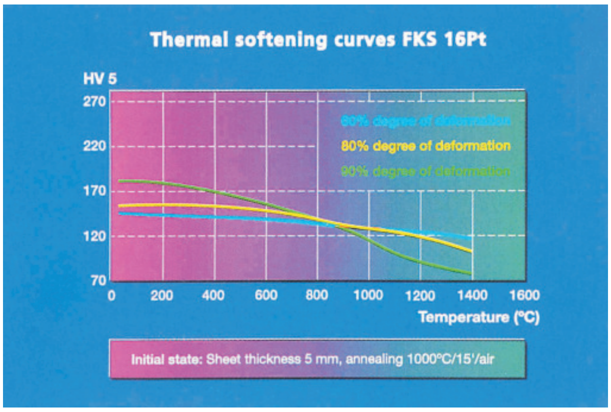

Figure 3

Figures 3 5 show how these materials gradually lose their strength as a function of temperature. Although the curves differ, the wide transition areas are a common feature of all FKS materials. This means that a desired hardness can be obtained much more easily by selecting the appropriate annealing temperature.

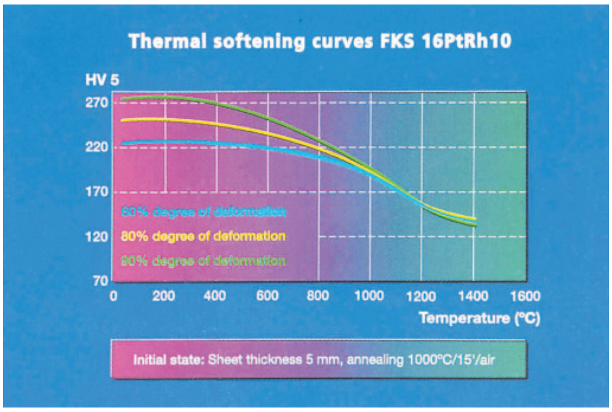

Figure 4

As with normal platinum materials which have not been dispersion-hardened, the cold strength depends on the degree to which the object has been deformed. It is most evident in our FKS 16 PtRh 10, which achieves the highest score of 270 HV5 with 90 % deformation.

The FKS 16 PtAu 5 alloy has a very interesting and practical feature. Because of the special segregation characteristics of this alloy, the curve does not peak until 400°C.

At temperatures in excess of 1200°C, all FKS materials have roughly the same degree of hardness.

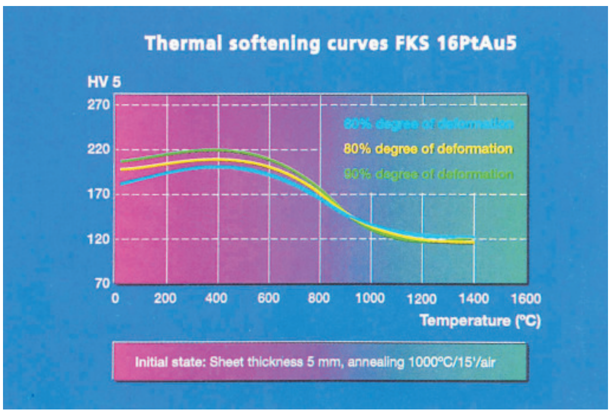

Figure 5

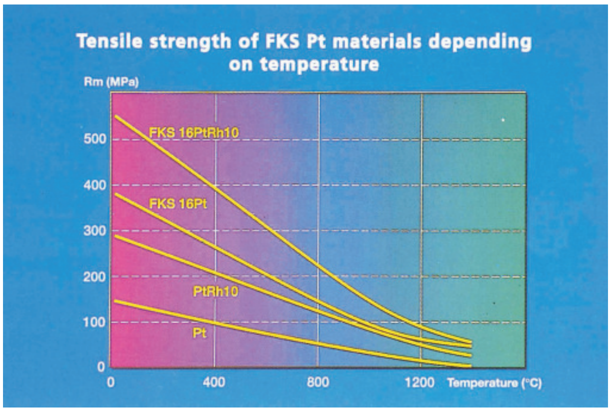

Figure 6

Chemically pure platinum is extremely soft and thus has very low Rm (tear strength) and Rp0,2 (tensile yield strength) values. In addition, these values are so dependent on temperature that platinum can be used only to a limited extent at working temperatures above 1000°C.
This disadvantage is generally countered by alloying it with the other five platinum-group metals, particularly rhodium and iridium.

Platinum alloyed with up to 30 % of these two elements achieves Rm values of up to 450 MPa and 1000 MPa (megapascal) respectively, measured at room temperature without deformation.

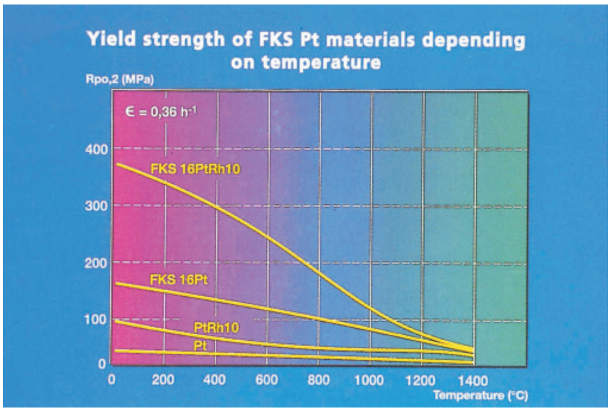

Figure 7

Since iridium has certain evident disadvantages, however, only the various binary platinum/rhodium alloys are of technical significance. It is for this reason that our dispersion hardening is used for the Pt10Rh alloy. As a result, FKS 16 PtRh 10 has Rm values far in excess of those which can be achieved with any non-dispersion-hardened platinum/rhodium alloys.

As can be seen in Figure 6, the tensile strength of our FKS 16 PtRh 10 is twice that of the standard PtRh10 material over the entire measuring range. I.e., from room temperature to 1400°C. Even our unalloyed FKS 16 Pt platinum material has much better Rm readings than the standard Pt10Rh alloy, and also achieves twice the strength of the rhodium-alloyed standard Pt20Rh material.

The differences in tensile yield strength are even more marked. Here our FKS 16 PtRh 10 material is almost four times as strong as the standard PtRh10 alloy up to 1000°C (Figure 7).

Our FKS 16 Pt platinum material also performs very well in comparison to pure platinum.

FKS and the all-important creep resistence …

Under thermal and mechanical stress, microstructural material damage known as creep occurs. The purpose of dispersion hardening is to limit this feared reaction.
This objective is achieved with our special hardening process. As Figure 8 shows, the required stress is so dramatically increased in our FKS materials that plastic deformations through creep are extensively inhibited. This reaction is even more striking with unalloyed platinum materials.

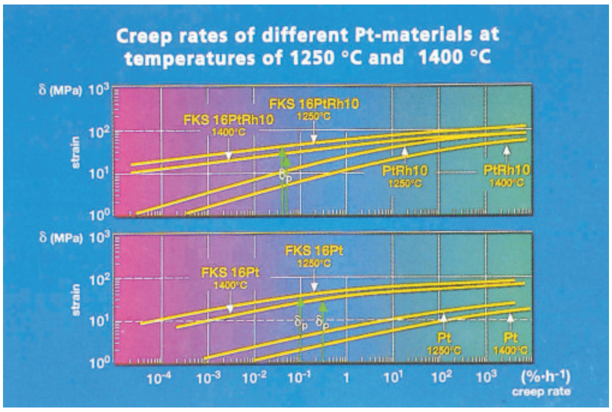

Figure 8

… and its effect on elasticity and shear modules

The characteristic elasticity module (E) of a metallic material as an expression of the extent of strain is derived from the linear course of the first part of the stress-strain diagram. It may also be defined as the amount of tension required to stretch a material to double its length and is hence a material-specific variable. In Figure 9 this value is shown as a function of both temperature and its relationship to the shear module (G)..

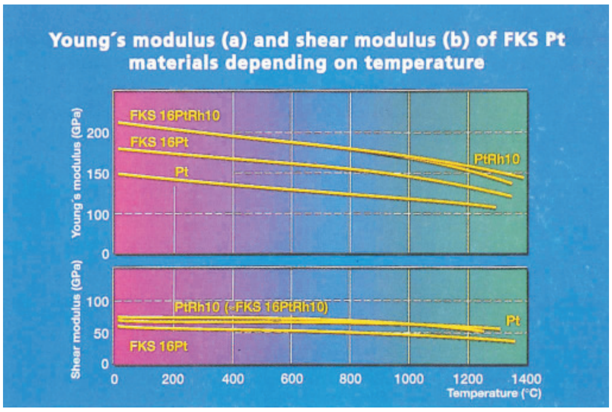

Figure 9

FKS: up to triple the stress rupture stength

The length of time a material will remain intact at high temperatures is often the most important characteristic when designing a component and estimating ist potential service life.

As platinum materials are mostly used at high temperatures, we tested the stress rupture strength at a temperature of 1400°C. The test was carried out on 5 mm wide and 0.5 mm thick material strips. The results are shown in Figures 10 and 11.

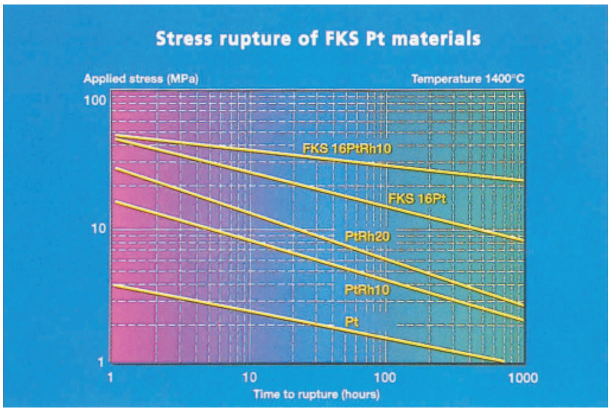

Figure 10

Looking at the significant 100-hour values, it can be seen that even the reading of 14 MPa achieved by our unalloyed FKS 16 Pt is more than three times as high as that obtained by the standard Pt10Rh material. The outstanding effectiveness of our dispersion hardening is shown particularly by the fact that it is only through FKS 16 Pt that the use of unalloyed platinum becomes technically feasible at all at 1400°C.

This confirms our assertion that dispersion hardening of more highly alloyed platinum/rhodium materials is an unnecessary expense. Not only does it fail to significantly improve the stress rupture strength, it can also involve some undesirable properties as well.

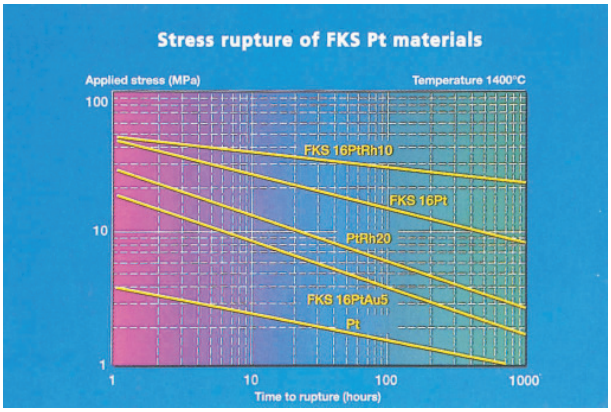

Figure 11

Figure 11 shows the stress rupture strength of our gold-containing FKS 16 PtAu 5 platinum alloy in comparison with the two materials in Figure 10. The strength is approximately the same as that of the non-dispersion-hardened Pt10Rh alloy in Figure 10, making it an excellent alternative in cases where rhodium is to be avoided or where the much lower wetting capability of platinum/gold alloys is to be employed.

Welding without difficulty: the outstanding joining behavior of FKS materials

When a metallic matrix with homogeneously distributed, nonmetallic particles of much lower specific gravity as with zirconium oxide, for example is melted, the dispersoids normally concentrate and are deposited on the surface of the melt, thereby nullifying the effect of dispersion hardening and causing the material to weaken.

For this reason the only techniques which could be used to date were ones such as hammer, diffusion, spot or roll-seam welding, in which the material remained extensively unchanged, at least in the area of the join. Combinations of these and other techniques also produce joins which were as strong as the basic material.

These techniques can still be used without difficulty.

Umicore has also looked carefully into the problem of fusion welding of platinum materials.
Thanks to extensive research and development at Umicore, it is now possible to use all known fusion welding techniques with the FKS platinum alloys available today without any risk that the joins will be weakened in the slightest.

One of the main reasons for this is again that the size of the submicroscopically small dispersoids is kept within a very narrow spectrum. In this way the agglomeration process and hence the segregation which usually occurs during fusion welding can be slowed almost to a standstill.

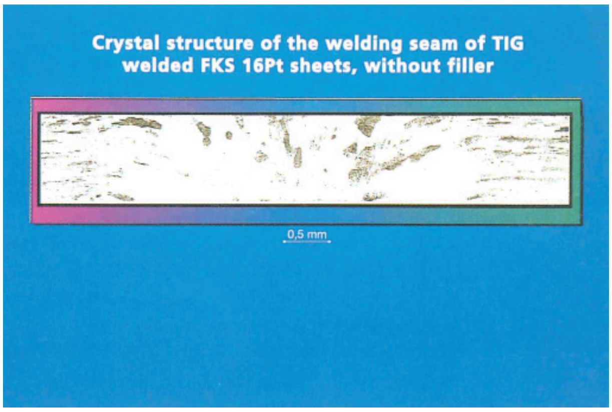

Figure 12

The illustrated structure in Figure 12 of an FKS platinum material with WIG-welded seam and different types of finishing shows a homogeneous transition from the welding joint to the basic material matrix.

FKS materials also have greater chemical strength.

Apart from the known reduction/oxidation (redox) reaction of metallic matrices, the structure and stress status of a material also determine the extent of corrosion that can occur. With a fine-crystalline structure, for example, the corrosion process is slowed down.

With their platelet- or lancet like structures, FKS materials have much longer diffusion paths, and their susceptibility to chemical reactions is correspondingly small. The penetration of damaging materials is delayed.

In all other chemical respects, dispersion-strengthened materials behave like their unstrengthened counterparts.

FKS – physical properties are also very acceptable.

Since the chemical reaction of dispersoids is relatively slow, the immediately surrounding host crystal lattice deforms without changing its electron potential. For this reason minor deviations are only to be expected if at all in those physical properties which are affected by lattice tensions and structural design.

According to the data available, the specific electrical resistance, linear thermal coefficient of expansion and thermal e.m.f. only increase slightly.

Because of their exceptional properties dispersion-strengthened platinum materials are the ideal substances for special requirements.

Their advantages are appreciated in applications where the investment return on conventional platinum materials cannot be improved or where unstrengthened materials have failed in the past. Some examples are described below.

Increased service life:

High temperatures and high mechanical stresses are typical of centrifuges for glass wool manufacture. The high heat and stress rupture strength and reduced creep of our FKS platinum materials lead to an improvement in dimensional stability, with the result that the service life of such centrifuges can be extended considerably.

For the same reasons, crucibles for high-temperature glasses and frits are made preferably using FKS materials.

Higher stress:

The properties described above are also effectively demonstrated in laboratory engineering, where melting crucibles are subject to considerable thermal stress as the result of a rapid of analyses. Here again, our FKS platinum materials have proved to be ideally suited.

Less expensive material:

Apart from guaranteed dimensional stability even under extreme conditions, the possibility of reducing the precious metal content is also of considerable significance. Thanks to the improved strength characteristics of our FKS materials, costs can be decreased by cutting the amount of precious metal which must be used.

For example, the base plate as the load-bearing component and determining factor in the service life of a bushing for making textile fiberglass can be made with FKS platinum without any geometric modifications but with a much thinner side thickness. Around one-third the amount of platinum normally required for the component could be saved.

Weight savings and longer service life are the basic and most economically significant features of FKS platinum materials.

New application potential through new properties ...

In many cases, new possibilities opened up by FKS materials also come to bear:

Avoidance of rhodium-containing materials - no product discoloration:
For example the glass industry and particularly the laser glass sector use unalloyed platinum to avoid discoloration. Since pure platinum is not adequate to meet the increasing demands of this industry, however, our FKS platinum has now become an indispensable material.

Possibility of increasing working temperatures for short periods to 1600 C without risk to the structure - no structural changes:
When platinum materials are used in conjunction with ceramic materials, short periods of heating up to just under the melting point of the metal are not uncommon. However, only if the structure remains extensively unchanged can the functional capability of this quasi-composite be assured. One particularly well-known example in this respect in vehicle spark plugs with FKS platinum electrodes.

Prevention of penetration of harmful contaminants - greater resistance:
When disposing of radioactive waste by vitrification, the melting of synthetically composed glass is an important preparatory laboratory process. With the vast number of different melt additives there is always a certain danger, even with the utmost care, from released metal particles. Here, too, FKS platinum crucibles have proved to be more resistant, even with thinner sides.

Improvement of product quality through the use of FKS materials:
More and more reports from industry confirm that the quality of the products themselves is often improved through the use of appliances made with FKS materials. In the optical glass industry, for example, there have been reports of improved transmission coefficient with certain types of glass.

Trouble-free FKS

Mastery of the metallurgical and production engineering aspects of dispersion-strengthened materials has helped a growing number of user industries to find new ways of solving a variety of problems.
With its intensive research activities in this area, the Metal Sector at Umicore, a renowned worldwide material specialist, is proud to have made an important contribution through the development of FKS materials and their associated technologies.

This brochure provides a short survey of our FKS materials which may be regarded as state-of-the-art in their field.

If you would like to know more about this material and its new application potential, its extreme resistance and durability, high utility, long service life and savings which can be achieved with it, the reduced precious metal requirement and costly spare parts supplies and production down times in other words, of you would like to find out more about how to increase productivity and functional reliability while reducing tool costs, just give us a call. Our experts would be glad to provide you with any assistance that you might require.

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