Workshop Notes

YOUR TECHNICAL PROBLEMS ARE ANSWERED BY OUR PANEL OF EXPERTS

These two questions are typical of many encountered during my recent visits to India and the Far East.

Question: How can I improve the strength of 22 carat gold jewellery? *(Manufacturer, India)*

This question was asked many times in India, often linked to the recent developments in high strength 24 carat golds, with the desire to obtain properties similar to those of 18 carat golds.

Answer: There are three usual ways of improving the strength of conventional carat gold alloys. Firstly, by cold working the alloy, e.g. by rolling, drawing and hammering. This improves strength and hardness but reduces ductility (malleability). Standard 22 carat gold (containing 5.5% silver and 2.8% copper), cold worked by 75% reduction in area, more than doubles its strength and hardness (HV138) from the soft annealed condition (hardness, HV 52), but ductility drops from 27% to less than 1% [data from *Gold Technology*, No.1, January 1990]. In practice, it is not always possible to produce finished jewellery in the cold worked state. Soldering, for example, will locally anneal the piece and soften it and, if produced by casting, it is rarely possible to work it further without destroying the shape.

Secondly, by refining the grain size of the alloy. A small grain size improves strength, hardness and also, in contrast to cold working, the ductility. The magnitude of improvement is not as large as cold working. Grain size can be refined in casting or during working and annealing, aided by use of very small amounts of grain refiners such as cobalt or iridium. [see papers by Mark Grimwade in *Gold Technology*, issue 2, June 1990 and by Dieter Ott in issue 22, July 1997]. The improvements in strength obtained in the new 'microalloyed' 24 carat golds is probably due, in part, to grain refinement.

Thirdly, in the case of 18 and lower carat golds containing copper, it is possible to substantially harden the alloy after production of the jewellery (preferably before final polishing) by an 'age hardening' heat treatment [see paper by Mark Grimwade in *Gold Technology*, issue 14, November 1994]. A standard 18 carat yellow gold can be hardened to a hardness of HV 230, similar to the value after 75% cold work but with a useful ductility of 15%. Annealed hardness is much higher than 22 carat yellow gold too (HV 150 against HV 52), illustrating the significant effect of alloying on the strength & hardness of gold. Unfortunately, the metallurgy of 22 carat golds does not permit age hardening.

As we can see, the strength and hardness of annealed 22 carat gold is substantially lower than that of 18 carat gold. However, based on the recent work on micro-alloying 24 carat gold and the 990 gold-1% titanium alloy, there is scope for new research to develop improved strength in 22 carat gold. Some unpublished work on the use of master alloys containing cobalt additions suggests that some improvement is possible in cast 22 carat alloys. We must await such developments*.

*__Footnote:__ Mintek, South Africa, have recently announced the development of a high strength 22ct gold alloy.

Question: Why does my jewellery suffer from an 'Orange peel' surface and how do I prevent it? *(Manufacturer, Mumbai)*

Answer: The 'orange peel' effect, so-called because the surface looks like that of an orange, is a rumpling caused by a large (or coarse) grain size in the alloy during cold deformation such as sheet pressing (stamping) or wire bending during chain production (see figure below).

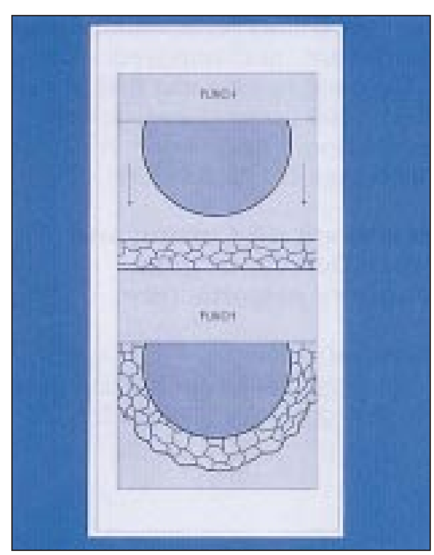

Figure - Schematic: The 'Orange Peel' effect on the outer surface of a carat gold sheet after deformation

Each grain - or crystal - in the alloy is oriented in different directions relative to the sheet rolling or wire drawing direction. During deformation, each grain changes shape through layers of atoms slipping past each other [it occurs by a complex mechanism of dislocation movement, but this need not concern us here] to accommodate the overall shape change. They get longer in one direction and thinner, but each grain changes shape in different directions which leads to a rumpling of the originally flat surface. When the grain size is large relative to the sheet or wire thickness, this rumpling is very marked and gives rise to the characteristic 'orange peel' appearance. When it is very small, with many grains across the sheet/ wire section, the scale of the rumpling is much smaller and the grains can compensate each others shape changes to some extent, so that the surface appears smoother overall.

The answer, therefore, is to maintain a fine grain size in the alloy. This can be done at the ingot casting stage (low melt superheat, metal moulds to cool rapidly, use of a grain refiner) - see article by Mark Grimwade in *Gold Technology*, no. 2, June 1990 for an explanation of solidification and grain size. Alternatively, it can be controlled during annealing ('recrystallisation' anneal) to soften the alloy after cold working. Grain size is reduced with increasing amounts of cold work (at least 50% reduction, preferably higher) and keeping the annealing temperature as low as possible, consistent with achieving recrystallisation of the deformed grain structure. Use of cobalt as a grain refiner can assist in a fine grain. The annealing process and its effect on grain size is also explained in a second article by Mark Grimwade in the same issue, no. 2, which also discusses the 'orange peel' effect, reproduced below.

Note: Back issues of *Gold Technology* are available from your local World Gold Council office.
If you have any technical questions that you would like answered on this page, send them to the Editor, Gold Technology, World Gold Council, Kings House, 10 Haymarket, London SW1Y 4BP, or by fax: +44 171 839 6561.