distinction has to be made for grain refining obtained during casting and grain refining during soft annealing after cold working.

All the aforementioned grain refining additions act in a similar way. They form really fine dispersed nuclei as starting points for the formation of grains (crystals) at solidification (crystallisation) or at soft annealing (recrystallisation). In all cases, small concentrations are effective. In Table 1, the grain refiner additions are classified according to the field of application and the working mechanism. More detailed information is available from literature, for example, references (6) and (7).

'Strengthener'

There is no great demand for additions which increase hardness and tensile strength of 14 and 18 ct alloys, especially considering that the potential provided by age hardening of conventional alloys are not fully used. The situation is different with high carat alloys (21, 22 ct and higher). Investigations have shown that attempts to increase strength with conventional alloying elements are not effective. A solution is the use of systems which provide age hardening effects. The systems gold- zirconium and goldtitanium have been investigated. Gold-titanium alloys (‚990' gold) with 1 to 1.5% titanium proved to be very useful. However, modified working conditions are necessary, which have restricted the general acceptance of these alloys by industry.

A more recent development is the so called 'pure gold' (or 24 carat gold) with increased hardness. A better term for such materials is micro-alloyed gold. Additions of calcium, rare earth and other elements at a very low level of addition significantly increase the hardness and strength. These additions lead to a twophase structure which results in dispersion hardening.

Grain refining itself can increase hardness and tensile strength to a limited extent.

Improvement of standard yellow gold alloys

In the following the use and the effect of some frequently used additions are treated in more detail.

Zinc

Application

Zinc is by far the most widely used addition to carat golds. In low carat gold (8 to 10 ct) and in nickel white gold alloys, zinc is a normal constituent that has been used since the early development of these alloys, typically in the concentration range up to approximately 10%. It influences the colour and improves the castability. However, the alloys are not homogeneous. Segregation on grain boundaries favour, for example, intergranular corrosion and/ or stress corrosion in 8 to 10 ct alloys. The effect of zinc additions on the quality of 14 and 18 ct yellow gold investment castings has been well known for many years (8). High concentrations of zinc are used in low-medium carat wrought alloys to improve alloy workability, through contraction of the two phase field, and in carat gold solders where it reduces the melting range.

Zinc can be alloyed into gold and gold jewellery alloys to a limited extent without changing the microstructure. The specific amount of zinc which can be tolerated depends on fineness (gold content) and the silver:copper ratio. Gold itself can dissolve approximately 3% Zn (by mass) without any change in microstructure. Higher concentrations cause the formation of second phases including intermetallics. A detrimental influence on properties can be expected. In 14 and 18 ct alloys, higher concentrations of zinc are possible due to the solubility of zinc in silver and copper.

In this paper, zinc is considered only in the context of a small addition for improving of yellow gold alloys. Its main effect lays in casting properties in investment (lost wax) casting.

Dosage

The best effect will be obtained with a maximum of 3% zinc. Normally 2% will be sufficient for good form-filling and a bright cast surface. Higher concentrations have been used at times. They change the colour and reduce the melting range. However, unwanted side effects have to be taken into account too.

Effects on the investment casting of yellow gold (9) Zinc as an addition in casting alloys has several very beneficial effects, if used in the right concentration. The effect can be summarised as follows:

Increased the form-filling