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The metallography of cuboid-shaped inclusions in commercial Cu–Be–Co alloy

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Electron metallographic methods have been used to study the morphology and chemical composition of cuboid inclusions in a Cu–2% Be–0.3% Co alloy.

It is concluded that the inclusions are of mixed composition having the general formula (Co Cu Ni Fe) Be. When the inclusions are formed at high temperatures Cu is held in solid solution which then precipitates at lower temperatures so giving rise to the morphological changes.

1. Introduction

For reasons which are not yet fully understood, the addition of about 0.3% cobalt to the binary age hardenable Cu–Be alloy greatly reduces the rapid softening of the alloy during overageing [1] by spheroidizing the usually discontinuous equilibrium γ phase at the grain boundaries [2] (Fig. 1). The addition of cobalt also affects the microstructure by the formation of cuboid-shaped inclusions which, in turn, act as a grain refiner and so reduce the grain size of the cast alloy. This suggests that only a small amount of the added cobalt remains in solution.

Several attempts have been made by a number of investigators using optical and electron microscopy, and electron microprobe analysis, to determine the chemical composition and crystallographic structure of these inclusions.

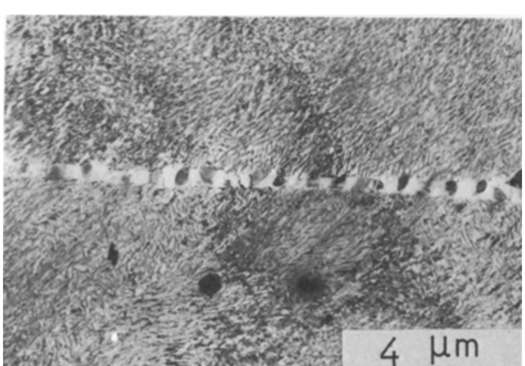

Figure 1 The spheroidized equilibrium γ at a grain boundary in an overaged Cu–Be matrix.

Using the optical microscopy, Entwistle and Wynn [1] were the first to suggest that these small pale blue inclusions might be Co Be. Later, Armitage [2] and Tanner [3], although able to see the inclusions with the electron microscope, were unable to obtain information about the crystallographic structure of the inclusions, as the structure had not electropolished evenly, and hence the cuboid inclusions were too thick for electron transmission. However, by employing electron microprobe analysis, Tanner [3] showed that the cuboids are rich in cobalt. Later investigations by Henmi and Nagai [4], using the same technique, proved that the inclusions are a solid solution of cobalt, copper and beryllium.

The present investigation was undertaken as part of a general study of the microstructural changes occurring during the ageing of Cu–Be alloys containing Co additions.

2. Experimental techniques

Cu–2% Be–0.3% Co alloy of commercial grade (Telcon 250) was supplied by Telcon Metals in as quenched condition in the form of 13 mm × 40 mm bars. Subsequent low-temperature ageing at 200° C for 16h was carried out in a silicone oil bath. The electron microscopy and microanalysis was carried out using the analytical transmission electron microscope (EMMA4) with spark-machined discs prepared by electropolishing and double jetting with a solution of 13% HNO_3, 7% H_2SO_4, and 80% CH_3OH.

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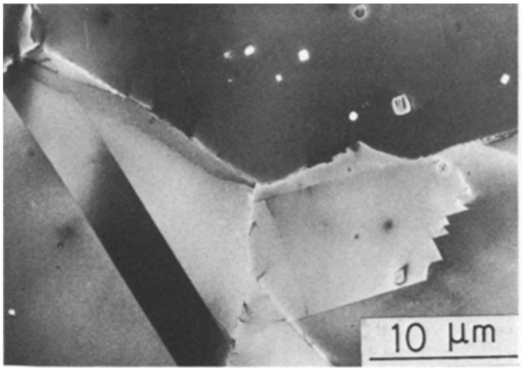

Figure 2 Cuboid-shaped inclusions in an underaged Cu–Be matrix.

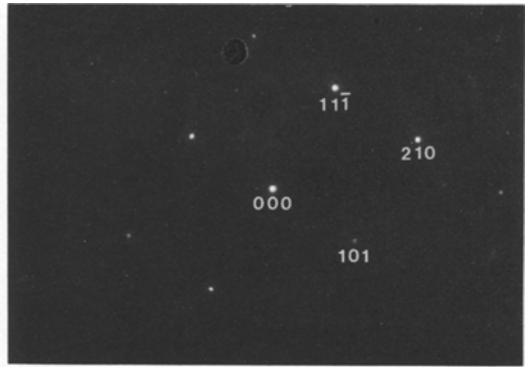

Figure 4 The unique $Z = [\bar{1}\,2\,1]$ diffraction patterns obtained from the cuboid-shaped inclusions.

3. Results

Fig. 2 shows several cuboid inclusions in an underaged Cu–Be matrix. Occasionally small plate-like particles were observed inside large cuboid inclusions. Fig. 3 is a higher magnification image from these inclusions. SAD patterns from inclusions are shown in Fig. 4. The microanalysis graphs of the matrix, inclusion and the particles inside some of the inclusions are presented in Fig. 5. The analyses were the same for cuboids with and without internal particles.

4. Discussion and conclusions

The analysis of the diffraction patterns suggested that they correspond to a simple cubic lattice parameter of 2.65 Å. Since the addition of small amounts of cobalt to the binary Cu–2% Be causes the formation of cuboid inclusions, they must be a Be Co intermetallic compound. By considering that the electron scattering factor of beryllium atoms is much less than that of cobalt atoms, the simple cubic structure obtained only shows the position of heavier atoms in the actual crystal. In fact, the structure is of the body-centred caesium chloride (CsCl) type with one beryllium atom and one cobalt atom per unit cell [5].

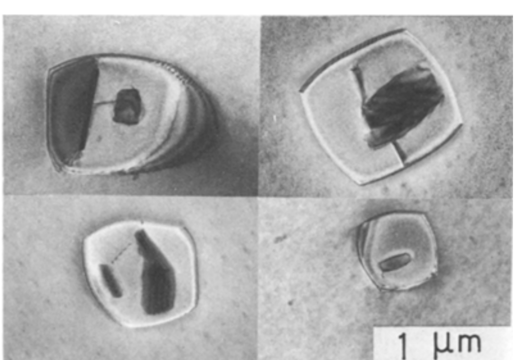

Figure 3 Small plate-like particles inside some cuboid-shaped inclusions.

Microanalysis results indicate that the inclusions contain cobalt, nickel, iron and possibly copper supporting the results obtained from the diffraction patterns. Owing to its low atomic mass, beryllium could not be detected. Consequently, it can be convincingly concluded that the cuboid-shaped inclusions are as (Co, Cu, Ni, Fe) Be intermetallic compound. This conclusion is further strengthened by the observation that the lattice parameter and crystallographic structure of Co Be, Cu Be and Ni Be are rather similar.

It was thought that investigating the nature of the plate-like particles inside some of the cuboid inclusions might help to clarify the origin of the cuboid inclusions; for instance, if nucleation and then epitaxial growth of cuboids were occurring on these tiny inclusions during the melt. Chemical analysis suggests that they contain the light elements and possibly copper. No complete SAD patterns could be obtained from these particles. However, it was noticed that their frequency of occurrence increased with low-temperature ageing. Occasionally, dislocations were seen to be associated with these particles and since, in some cases, two or three of these particles were observed inside one inclusion, these suggest that the particles, are in fact, precipitates rather than inclusions. Therefore, it rules out the possibility of epitaxial growth of cuboids on these particles.

The evidence suggests that the particles are copper-rich and this would be consistent with producing cuboids initially at the high temperature which have copper in solid solution. During ageing the (Co Cu) Be could then decompose to precipi-

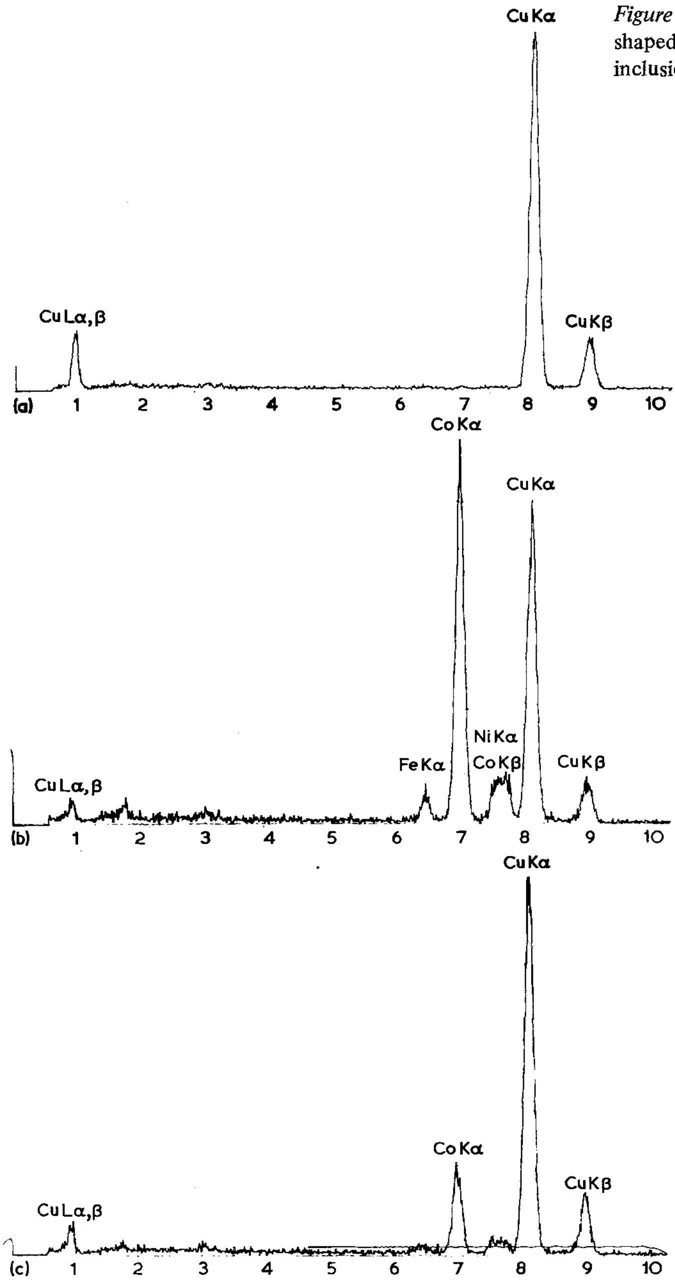

Figure 5 Microanalysis results of (a) matrix, (b) cuboid-shaped inclusions, and (c) particles inside cuboid-shaped inclusions.

tate either CuBe or Cu. The evidence favours the latter since the lattice parameter and crystal structure of CuBe is similar to that of the cuboid and, therefore, CuBe should precipitate as a spherical particle. The cobalt and nickel peaks in the analyses of the plate-like particles are likely to be interference effects from the cubic matrix.

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