HEAT TREATMENT OF SOLDERED COPPER JOINTS

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The heat treatment of soldered joints is of major importance for low-temperature and high-temperature soldering with low-temperature solders when the increase of the strength of the joints by other methods is limited or impossible. We have developed a low-temperature solder PSr 7.5, which is a multicomponent system. It was of interest to determine the influence of the individual components on the properties of copper joints.

We investigated samples of copper soldered with lead, tin, and PSr 7.5 solder at 850°C, with holding for 10 min in vacuum (1×10⁻² mm Hg). After soldering, the samples were cooled from 800°C in the furnace, in water, and in liquid nitrogen. The cooling rate was 0.5 deg/sec in the furnace, 40 deg/sec in liquid nitrogen, and 100 deg/sec in water.

The shearing strength was determined with samples 3×20×50 mm, with an overlap and a gap of 0.1 mm.

The variation of the shearing strength of the soldered joints with the cooling rate is shown in Fig. 1. As can be seen, the strength of the copper joints soldered with lead and with PSr 7.5 solder remains almost unchanged at different cooling rates. The structure of the joints remains unchanged at both the minimum (0.5 deg/sec) and maximum (100 deg/sec) cooling rates (Fig. 2, 1).

For copper soldered with tin (a component of PSr 7.5) the strength of the joint increases with the cooling rate (see Fig. 1).

The copper samples were soldered with tin and indium under identical soldering conditions. The phase diagrams of Cu–Sn and Cu–In are of the peritectic type, and thus one would expect similar structures or similar types of crystallization.

The strengths of copper joints soldered with indium and tin vary with the cooling rate in a similar way.

When copper is soldered with tin at 850°C and cooled in the furnace the structure in the joint consists of the α solid solution of tin in copper and the eutectoid α + δ (Fig. 2b). The initial crystals of α solid solution form at the base metal, while the middle of the joint consists of dendrites. The crystals of α phase do not disappear completely as the result of the peritectic reaction.

At a cooling rate of 40 deg/sec the joint also consists of α solid solution and the eutectoid, but no dendrites are formed in the middle of the joint. In the zone of fusion there are many fine crystals of α phase evenly distributed through the joint. With cooling at 100 deg/sec primary crystals of α phase are found only at the base metal. The middle of the joint consists of β phase, which has a cellular structure and does not undergo the eutectoid transformation.

When copper is soldered with indium (850°C) and cooled in the furnace the joint consists of α phase, a solid solution of indium in copper, and the eutectoid α + δ (Fig. 2c, d), with primary crystals of α phase near
Fig. 2. Microstructure of joints in copper soldered at 850°C in vacuum (1.10^-2 mm Hg) and cooled at different rates. a) Soldered with PSr 7.5 (× 200); b) soldered with tin (× 250); c) soldered with indium (× 250). I) Cooled at 0.5 deg/sec; II) cooled at 100 deg/sec.

the metal and the eutectoid in the middle of the joint. The strength of these joints is 4.5 kg/mm², failure occurring in the hard and brittle eutectoid.

When the joint is cooled in liquid nitrogen at the rate of 40 deg/sec the structure also consists of primary α phase and the eutectoid α + δ.

The primary crystals of α phase are located at the base metal and also remain in the zone of fusion. The crystals of α phase, reacting with the liquid in the peritectic reaction, are not completely dissolved, remaining as inclusions in the zone of fusion. The eutectoid forming in the peritectic reaction has a cellular structure at this cooling rate. The strength of the joints is higher in this case.

The formation of cellular structure has been noted in the crystallization of welded joints [1] and the solidification of ingots [2]. The type of crystallization (cellular or dendritic) depends on the cooling rate.