

INTERACTION OF TUNGSTEN WITH COPPER,
MANGANESE, SILVER, AND TIN

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Tungsten is insoluble in liquid copper, manganese, silver, and tin [1, 2, 3]. The "alloys" of tungsten with these elements in commercial use are prepared by powder metallurgy or by adsorption of these metals in the pores of sintered pieces of tungsten.

This work concerns the interaction of tungsten with copper, manganese, silver, and tin used as solders.

The materials used in the experiments were VA-3 tungsten with 0.10% impurities; MB copper; MO manganese; Cr. 999.9 silver; and OV-4-000 tin.

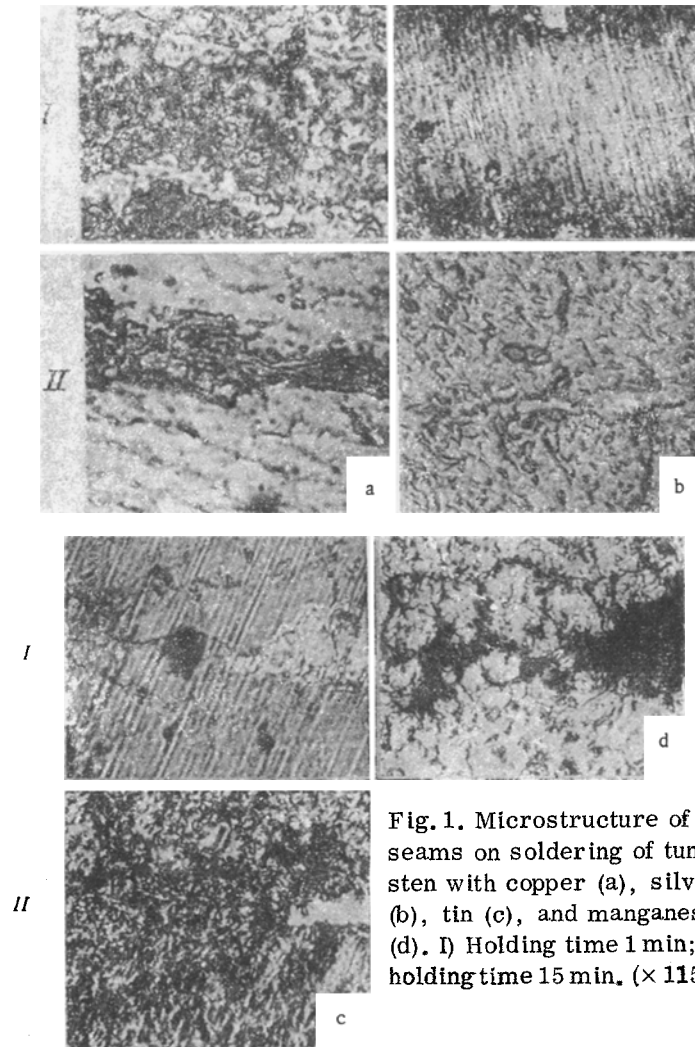


Fig. 1. Microstructure of seams on soldering of tungsten with copper (a), silver (b), tin (c), and manganese (d). I) Holding time 1 min; II) holding time 15 min. ($\times 1150$).

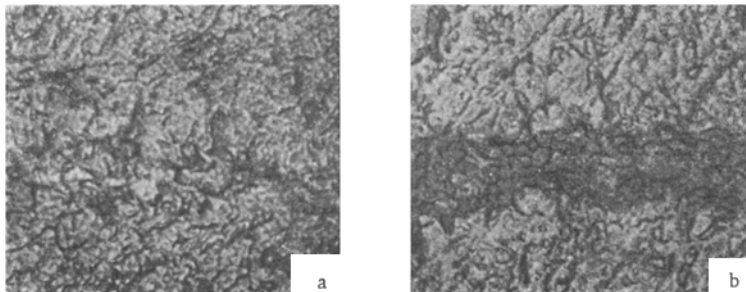


Fig. 2. Microstructure of joint in tungsten soldered with holding 15 min ($\times 1150$). a) Soldered with silver — copper eutectic; b) with Cu + 35% Mn.

The soldering was done in an atmosphere of hydrogen (dew point -50°C) with no more than 0.005 vol.% oxygen. Tungsten samples 6 mm in diam. and 2.5 mm high were cut from rods and stacked one on top of another to form a terrace on which the solder was placed. Before soldering, the samples were cleaned with very fine sandpaper, washed in acetone, and degreased in alcohol. The soldering time (holding time) was 1 and 15 min.

On reaching the soldering temperature the copper, manganese, silver, and tin wet the surface of the tungsten quite well, flow into the capillary gap, and form fillets. The silver begins to run at 1130°C and spreads completely at 1300°C .

On soldering with copper (soldering temperature 1120°C) one observes the highest solubility of tungsten in the solder. Copper also penetrates rapidly into the base metal, and tungsten grains at individual points in the gap are already joined after holding 1 min.

At the boundary between the base metal and the seam a narrow weakly etching layer is visible; it results from the interaction of tungsten and copper (Fig. 1, a, I). The formation of these layers as the result of the interaction of impurities in the tungsten and copper is not very probable, since the total impurity concentration does not exceed 0.13%.

The microhardness of the layer is 120; the microhardness of the copper is 80.

In the case of soldering with manganese (Fig. 1, d, I) the higher soldering temperature (1500°C) has a substantial effect on the solubility. In the molten state the manganese penetrates to a great depth along the grain boundaries. In the process of solution the coarse grains of tungsten break off and pass into the solution. The shape of the grains passing into the solution indicates intensive solution at the soldering temperature. Finely dispersed tungsten also exists in the molten manganese along with the coarse grains. No intermediate phase was observed in the seam. Relatively coarse grains of tungsten pass into the solution when it is soldered with copper and manganese; when soldered with silver finely dispersed particles of tungsten pass into the molten silver, which are quite visible at large magnification (Fig. 1b). It is also characteristic of silver that it penetrates the tungsten along the grain boundaries. With copper this penetration into the grain boundaries appears as an unusual saturation of the tungsten with copper, whereas in the case of silver the jagged boundary of the metal in contact with the zone of fusion is easily overlooked.

An eroded highly etched band is visible at the boundary with the base metal (Fig. 1, b, I). Apparently it results from fractioning diffusion during crystallization of the metal in the fusion zone. The microstructure of the unetched seam soldered with tin is shown in Fig. 1, c, I. Tin wets the tungsten quite well at a soldering temperature of 930°C . As can be seen in the microstructure, the layer of tin in the seam is interrupted at many points, where the tungsten is joined together. The microhardness of the tungsten is 200–270 and that of the tin 31.2, while the microhardness at the points in the seam where the tungsten is joined is 66–82.5. The passing of tungsten into the molten tin that occurs during soldering is clearly visible at large magnification. In the fillet area of the seam, where there is an excess of tin by comparison with the capillary gap, one can see that extremely fine particles of tungsten bridge the gap. At the boundary between the base metal and the solder the tin penetrates the tungsten.

From the character of the tungsten particles in the solders of copper, manganese, silver, and tin it appears that the tungsten is not dissolved in the solder but is dispersed in particles of colloidal size due to the great reduction of the free surface energy at the boundary between the molten metal and solid metal [4]. This is particularly clear in the case of soldering with copper, silver, and tin. These elements, being surface-active, break up the tungsten due to the fact that the crystal lattice of tungsten in the solid state is under stress. When the interphase surface energy is reduced the crystal lattice of tungsten breaks up primarily due to the lattice defects. The colloidal particles resulting from the breaking up of the lattice are easily wetted by the solders. The gap is completely bridged by the large numbers of them and is joined as the result of crystallization. The formation of a soldered joint in this case, particularly on prolonged holding at soldering temperature, is similar to the process of sintering powders with a liquid phase.

The microstructure of joints soldered with copper, silver, and tin with holding 15 min is shown in Fig. 1, II. As can be seen, the process is intensified when the holding time is increased. On soldering with copper a line of separate phase is observed in the seam (Fig. 1, a, I); coalescence occurs on prolonged holding, resulting in separate inclusions (Fig. 1, a, II). Almost complete joining occurs in the case of soldering with silver (Fig. 1, b, II). On prolonged holding during soldering with tin the tungsten passing into the zone of fusion completely bridges the gap (Fig. 1, c, II). Prolonged holding during soldering with manganese leads to its evaporation.

Alloys of the metals investigated have different effects on the dispersion of tungsten during soldering. The eutectic alloy of silver and copper forms a fused zone similar to that formed in soldering tungsten with silver and copper (Fig. 2a), although there is less dispersion of the base metal. An alloy of copper and manganese (35%) with a much lower melting point also induces less dispersion of tungsten, which is partially explained by the lower soldering temperature as compared to soldering with pure manganese or copper.

CONCLUSIONS

1. Tungsten can be soldered with copper, manganese, silver, and tin to produce joints of high strength. Under the influence of the molten solders the finest defect-free crystals of tungsten are dispersed. When the seam is saturated with them and they solidify in the capillary gap under conditions excluding interaction with the surrounding atmosphere the joint is strong.
2. At soldering temperatures tungsten is intensively dissolved in molten copper, manganese, silver, and tin. Solution is due to adsorption reduction of the strength of tungsten under the influence of the molten solders.
3. The absence of interactions in the tungsten — copper, tungsten — manganese, tungsten — silver, and tungsten — tin systems needs further investigation.
4. In soldering tungsten with copper a presumably independent phase is formed. It forms a layer in the seam at the boundary between tungsten and the fusion zone or separate inclusions on prolonged holding at soldering temperature.

LITERATURE CITED

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