levels as the temperature of heat treatment is increased.

Two mechanisms for the increase in acceptor concentration have been given, one postulating a change in solubility of an acceptor impurity, the other postulating the formation of acceptor centers by thermally produced lattice defects.

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Technical Note

Grain Boundary Effect In Surface Tension Measurement

by Harry Udin

IN 1948, the writer and his associates determined the surface tension of solid copper by balancing the force of surface tension in a very fine wire against an external load.¹ At that time we, in common with other early workers, assumed that grain boundary energy in a pure metal is very small in comparison to the energy of an external surface. Accordingly, we neglected the internal surface energy of the coarse-grained specimens.

Since that time, experimental evidence has accumulated showing that grain boundary energy, far from being small, is generally about one-third of the energy of an external surface.²⁻⁴ This is sufficient to introduce a significant error into our determination. The differential equation governing equilibrium is:

$$w dl = \gamma ds_1 + \gamma^* ds_2 \quad [1]$$

rather than

$$w dl = \gamma ds$$

as originally written. w is the balancing force in dynes, l the length of the specimen, s_1 the external and s_2 the internal surface area, γ the copper/copper vapor surface tension, and γ^* the grain boundary tension.

Fortunately, we had made for another purpose a careful study of the size and shape of the grains, and found that the boundaries, with rare exceptions, traversed the specimens and were perpendicular to the wire axis. For this case, eq 1 leads to

$$w = \pi r \gamma - \left(\frac{n}{l} \right) \pi r^2 \gamma^* \quad [2]$$

where r is the wire radius and $\left(\frac{n}{l} \right)$ is the number of grains per unit length. A count of some twenty 5-mil wires indicated that $\frac{n}{l}$ became 80 ± 10 after

a short anneal near the melting point, and remained nearly constant for as long as 96 hr at temperature.

An assumption of $\gamma^* = 1/3\gamma$ leads to a defining equation for γ :

$$w = \pi r \gamma \left[1 - \left(\frac{n}{l} \right) \left(\frac{r}{3} \right) \right] \quad [3]$$

The term in the brackets may be considered a correction factor applied to eq 11 of ref. 1. Upon applying this factor, the surface tension of solid copper at its melting point is found to be 1650 ± 100 dynes per cm, rather than 1370 as previously reported.¹ The new temperature coefficient is -0.55 dynes per cm per °C.

Grain boundary energy is more significant than surface energy to the physical metallurgist. It is evident from eq 2 that a series of experiments with wires of different grain size can lead to an evaluation of γ^* . The details of such an experiment are being worked out now.

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