78. The Equilibrium Diagram of the Complete Ternary System, Copper-Antimony-Nickel.

Second Report :

The Equilibria in the Solid State of the Ternary System.

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In the present investigation the heterogeneous equilibria of alloys in the solid state of the whole ternary system Cu-Sb-Ni have been clarified mainly by differential dilatometric measurement and microscopic examination. As specimens, the alloys used in the thermal analysis were remelted and cast into metal mould, and in the regions of the ternary system in which detailed studies are necessary, specimens were further supplemented.

The differential dilatometric measurements were made by the

Fig. 1. The Complete Projectional Diagram of the Cu-Sb-Ni System.

dilatometer constantly used by the writer¹⁾, and from this result in collaboration with that obtained by microscopic examination, which was conducted in the same method as described in the former report, 17 sectional diagrams and an isothermal diagram at room temperature have been constructed. From these sectional diagrams the reactions of alloys occurring in a range of temperature from solidification down

TABLE 1. Reaction Curves and Reaction Fields.

Reaction Curve		Reaction	Field in which the Reaction Takes Place
Nature	Curve		
Binary Peritectoid	$A'B'$	$\beta(A'B') + \alpha(a'_1a''_1) \rightleftharpoons \delta_n(b'_1B')$	$a'_1A'B'a''_1$
Binary Eutectoid	$B'O'_4$	$\beta(B'O'_4) \rightleftharpoons \alpha(a''_1a'_2) + \delta_n(B'b'_2)$	$a'_1B'O'_4a''_2$
Binary Eutectoid	$C'O'_4$	$\beta(C'O'_4) \rightleftharpoons \delta_n(b'_3b'_2) + \theta_n(c'_1c'_2)$	$b'_3b'_2O'_4c'_2c'_1$
Binary Eutectoid	$D'O'_4$	$\beta(D'O'_4) \rightleftharpoons \alpha(a'_3a'_2) + \theta_n(c'_2c'_2)$	$c'_2c'_2O'_4a'_2a'_3$
Binary Eutectoid	$D'L'_1$	$\beta(D'L'_1) \rightleftharpoons \alpha(a'_3a'_4) + \theta_n(c'_2c'_3)$	$c'_2c'_3L'_1a'_4a'_3D'$
Binary Peritectoid	$E'L'_2$	$\beta(E'L'_2) + \gamma_n(d'_1d'_7) \rightleftharpoons \theta_n(c'_4c'_3)$	$E'L'_2d'_7d'_6$
Binary Peritectoid	$G'L'_3$	$\beta(G'L'_3) + \gamma_n(d'_5d'_7) \rightleftharpoons \theta_n(c'_9c'_8)$	$G'L'_3d'_7d'_5$
Binary Peritectoid	$G'O'_5$	$\beta(G'O'_5) + \gamma_n(d'_5d'_4) \rightleftharpoons \theta_n(c'_9c'_9)$	$G'O'_5d'_4d'_5$
Binary Eutectoid	$O'_1O'_5$	$\beta(O'_1O'_5) \rightleftharpoons \gamma_c(e'_9e'_8) + \gamma_n(d'_2d'_4)$	$O'_1d'_2d'_4O'_5e'_8e'_9$
Binary Eutectoid	$O'_5O'_6$	$\beta(O'_5O'_6) \rightleftharpoons \gamma_c(e'_8e'_7) + \theta_n(c'_9c'_{10})$	$e'_8e'_7O'_6c'_{10}c'_9$
Binary Eutectoid	$F'L'_4$	$\beta(F'L'_4) \rightleftharpoons \alpha(a'_5a'_4) + \theta_n(c'_8c'_8)$	$c'_8c'_8L'_4a'_4a'_5F'$
Binary Eutectoid	$F'O'_6$	$\beta(F'O'_6) \rightleftharpoons \alpha(a'_5a'_6) + \theta_n(c'_8c'_{10})$	$c'_8c'_{10}O'_6a'_6a'_5$
Binary Eutectoid	$M'O'_6$	$\beta(M'O'_6) \rightleftharpoons \alpha(a'_7a'_6) + \gamma_c(e'_6e'_7)$	$e'_6e'_7O'_6a'_6a'_7M'$
Binary Peritectoid	$H'O'_7$	$\beta(H'O'_7) + \alpha(a'_{10}a'_9) \rightleftharpoons \eta(h'_1h'_2)$	$H'O'_7a'_9a'_{10}$
Binary Peritectoid	$I'O'_7$	$\beta(I'O'_7) + \eta(h'_3h'_2) \rightleftharpoons \delta_c(g'_1g'_2)$	$I'O'_7h'_2h'_3$
Binary Eutectoid	$O'_7O'_9$	$\beta(O'_7O'_9) \rightleftharpoons \alpha(a'_9a'_8) + \delta_c(g'_2g'_3)$	$g'_2g'_3O'_9a'_8a'_9$
Binary Eutectoid	$M'O'_9$	$\beta(M'O'_9) \rightleftharpoons \alpha(a'_7a'_8) + \gamma_c(e'_6e'_5)$	$e'_6e'_5O'_9a'_8a'_7M'$
Binary Eutectoid	$L'O'_9$	$\beta(L'O'_9) \rightleftharpoons \delta_c(g'_6g'_3) + \gamma_c(e'_4e'_5)$	$e'_4e'_5O'_9g'_3g'_6L'$
Binary Peritectoid	$K'N'$	$\beta(K'N') + \gamma_c(c'_2e'_2) \rightleftharpoons \theta_c(f'_3N')$	$K'N'e'_2e'_2$
Binary Eutectoid	$N'O'_8$	$\beta(N'O'_8) \rightleftharpoons \theta_c(N'f'_2) + \gamma_c(e'_2e'_3)$	$N'f'_2O'_8e'_3e'_2$
Binary Eutectoid	$J'O'_8$	$\beta(J'O'_8) \rightleftharpoons \delta_c(g'_4g'_5) + \theta_c(f'_1f'_2)$	$f'_1f'_2O'_8g'_5g'_4$
Binary Eutectoid	$L'O'_8$	$\beta(L'O'_8) \rightleftharpoons \delta_c(g'_6g'_5) + \gamma_c(e'_4e'_3)$	$e'_4e'_3O'_8g'_5g'_6L'$
Ternary Eutectoid	O'_4	$\beta(O'_4) \rightleftharpoons \alpha(a'_2) + \delta_n(b'_2) + \theta_n(c'_2)$	$a'_2b'_2c'_2$
Peritecto-Eutectoid	O'_5	$\beta(O'_5) + \gamma_n(d'_4) \rightleftharpoons \gamma_c(e'_8) + \theta_n(c'_9)$	$O'_5c'_9d'_4e'_8$
Ternary Eutectoid	O'_6	$\beta(O'_6) \rightleftharpoons \alpha(a'_6) + \gamma_c(e'_7) + \theta_n(c'_{10})$	$a'_6e'_7c'_{10}$
Di-Peritectoid	O'_7	$\beta(O'_7) + \eta(h'_2) \rightleftharpoons \alpha(a'_9) + \delta_c(g'_2)$	$h'_2a'_9O'_7g'_2$
Ternary Eutectoid	O'_8	$\beta(O'_8) \rightleftharpoons \delta_c(g'_5) + \theta_c(f'_2) + \gamma_c(e'_3)$	$f'_2e'_3g'_5$
Ternary Eutectoid	O'_9	$\beta(O'_9) \rightleftharpoons \alpha(a'_8) + \delta_c(g'_3) + \gamma_c(e'_5)$	$a'_8g'_3e'_5$
Conjugate Eutectoid	$\left\{ \begin{array}{l} a'_2a'_{15} \\ b'_2b'_5 \\ c'_2c'_6 \end{array} \right.$	$[a]a'_{24}15 \longleftrightarrow [\delta_n]b'_{25}5$	$(a'_{15}b'_5c'_6) - (a'_2b'_2c'_2)$
	$\left\{ \begin{array}{l} c'_9c'_{12} \\ d'_4d'_8 \\ e'_8e'_{10} \end{array} \right.$	$[\theta_n]c'_{9c'_{12}} \longleftrightarrow [\gamma_n]d'_{4d'_8}$	$(c'_{12}d'_8e'_{10}) - (c'_9d'_4e'_8)$
	$\left\{ \begin{array}{l} a'_6a'_{11} \\ c'_{10}c'_{11} \\ e'_7e'_{11} \end{array} \right.$	$[a]a'_{6a'_{14}} \longleftrightarrow [\theta_n]c'_{10c'_{11}}$	$(a'_{14}c'_{11}e) - (a'_6c'_{10}e'_7)$
	$\left\{ \begin{array}{l} a'_9a'_{12} \\ g'_2g'_8 \\ h'_2 \end{array} \right.$	$[a]a'_{9a'_{12}} \longleftrightarrow [\delta_c]g'_{2g'_8}$	$(a'_{12}g'_8h'_2) - (a'_9g'_2h'_2)$
	$\left\{ \begin{array}{l} g'_5g'_{10} \\ e'_3e'_{13} \\ f'_2f'_5 \end{array} \right.$	$[\delta_c]g'_{5g'_{10}} \longleftrightarrow [\gamma_c]e'_{3e'_{13}}$	$(g'_{10}e'_{13}f'_5) - (g'_5e'_3f'_2)$
	$\left\{ \begin{array}{l} a'_8a'_{13} \\ e'_5e'_{12} \\ g'_3g'_9 \end{array} \right.$	$[a]a'_{8a'_{13}} \longleftrightarrow [\gamma_c]e'_{5e'_{12}}$	$(a'_{13}e'_{12}g'_9) - (a'_8e'_5g'_3)$
		$[\delta_c]g'_{3g'_9}$	

1) N. Sibata, Sci. Rep. Tohoku Imp. U., 27 (1938), 189.

to room temperature can be known, and from the isothermal diagram the kind of phase or phases at any composition can be inferred.

Fig. 1 shows the complete projectional diagram of the Cu-Sb-Ni system, including the results of investigation previously reported. In the solid state of this system there exist α , β , γ_n , γ_c , δ_n , δ_c , θ_n , θ_c and η phases, among which only α and β making continuous series of solid solution, and these nine phases take part in various reactions shown in Table I. Among these reactions mono-variant curves meet at six points, at which positions the following non-variant reactions occur:

It is to be noted in the diagram that the binary peritectoid reaction ($\beta + \alpha \rightleftharpoons \delta$) of the Ni-Sb system progresses, by addition of Cu, from A' as far as B' , at which the reaction changes to the binary eutectoid ($\beta \rightleftharpoons \alpha + \delta_n$), and then the reaction takes part in that of the ternary eutectoid at $0'_4$. Likewise, the binary peritectoid reaction ($\beta + \gamma \rightleftharpoons \theta$) of the Cu-Sb system changes, by addition of Ni, to the binary eutectoid reaction ($\beta \rightleftharpoons \theta_c + \gamma_c$), and thereafter the reaction takes part in that of the ternary eutectoid at $0'_8$. Further, the stable field of β phase lowers by addition of Cu, reaching room temperature at about 22.5 % Cu, 45 % Sb, 32.5 % Ni, and by a further addition of Cu it rises again. By the result of this change δ phase of the Ni-Sb system disappears by Cu addition more than about 30 %, and by the same reason, the formation temperature of θ_n phase lowers and finally disappears, but with the rise of the decomposition temperature of β phase, θ_n phase re-appears.

TABLE 2. A Tabular Representation of the Reactions of the Cu-Sb-Ni Alloy System.

Table 2 illustrates the reactions shown in Fig. 1 in a tabular representation, and from a correlational inspection of the figure and the table the nature of the reactions that occur in this whole ternary system can be known.

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