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The Co-Ni-Sn (Cobalt-Nickel-Tin) System

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Introduction

Very little work has been done in the Co-Ni-Sn system. Only one pseudobinary has been established and reported here.

Binary Systems

The Co-Ni system [1991Nas] (Fig. 1) is a simple isomorphous system. In the fcc α solid solution, there are indications of formation of short range order near the $CoNi_3$ composition.

The Co-Sn system [1983Nis, Massalski2] (Fig. 2) has three intermediate phases, Co_3Sn_2 in two allotropic forms, Co_3Sn_2(HT) and Co_3Sn_2(LT); CoSn; and $CoSn_2$. The Co_3Sn_2 phase melts congruently at ~1170 °C and the other two phases form through peritectic reactions L + Co_3Sn_2(HT) ↔ CoSn at 936 °C and L + CoSn ↔ $CoSn_2$ at 525 °C. Co_3Sn_2(HT) → Co_3Sn_2(LT) transformation occurs at ~500 °C. Two eutectic reactions L ↔ (αCo) + Co_3Sn_2(HT) and L ↔ $CoSn_2$ + (βSn) occur at ~1112 and ~229 °C, respectively. The fcc (αCo) → hcp (εCo) reaction, possibly a eutectoid type reaction, occurs at ~420 °C.

The Ni-Sn system [1991Nas, Massalski2] (Fig. 3) has three intermediate phases, Ni_3Sn and Ni_3Sn_2, both of which exist in two allotropic forms, and Ni_3Sn_4. Both Ni_3Sn_2 and Ni_3Sn phases melt congruently at 1264 and 1174 °C, respectively, and the Ni_3Sn_4 phase forms through a peritectic reaction L + Ni_3Sn_2 ↔ Ni_3Sn_4 at 795 °C. Three eutectic reactions L ↔ (Ni) + Ni_3Sn(HT), L ↔ Ni_3Sn(HT) + Ni_3Sn_2(HT), and L ↔ Ni_3Sn_4 + (βSn) occur respectively at 1130, 1160, and 231 °C. The Ni_3Sn(LT) phase forms through a congruent transformation at 977 °C. The Ni_3Sn_2(HT) → Ni_3Sn_2(LT) transformation occurs at ~600 °C.

Binary and Ternary Phases

In the Co-Ni-Sn system, six intermediate phases form, of which three phases exist in two allotropic forms. No ternary intermediate phase has been reported in the Co-Ni-Sn system. The binary phases and their structure data are given in Table 1.

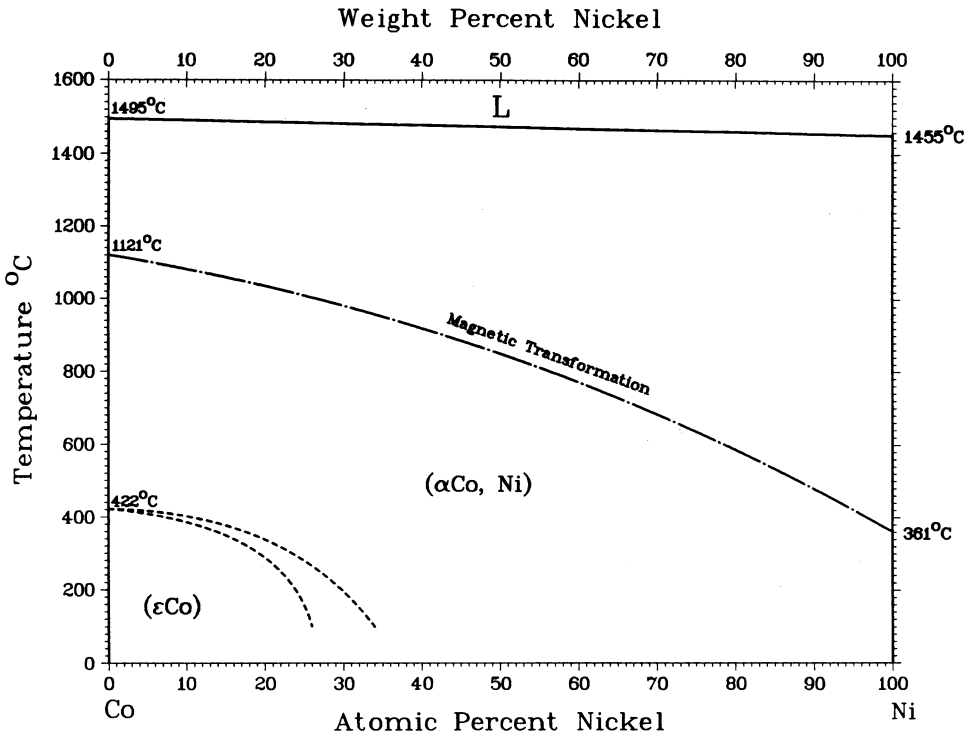

Fig. 1 Co-Ni binary phase diagram [1991Nas]

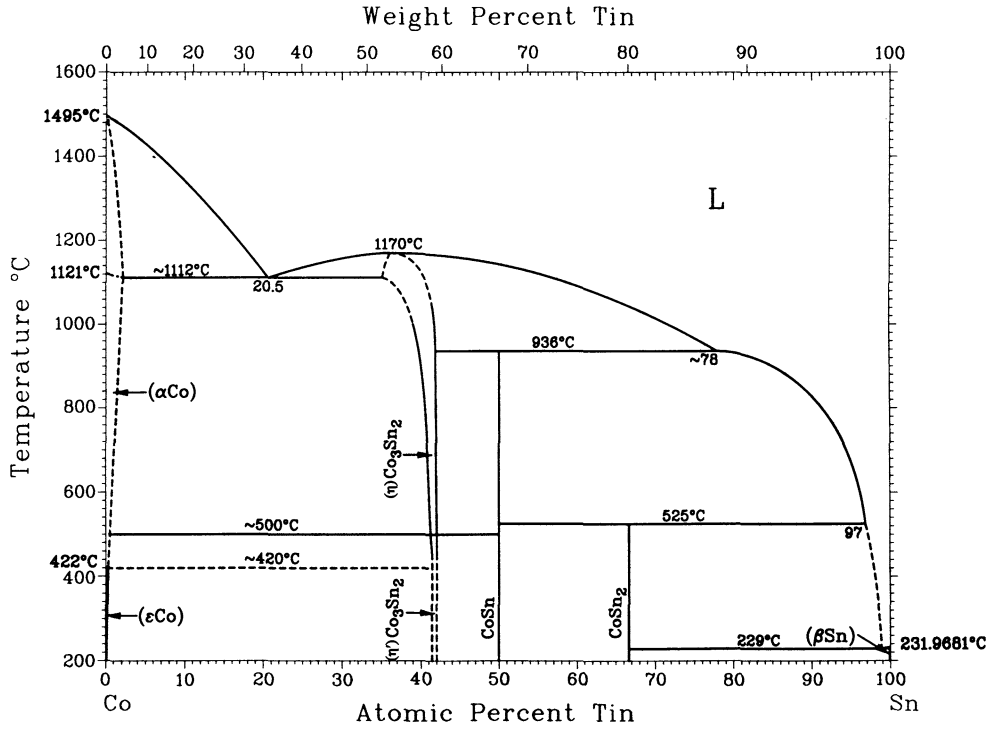

Fig. 2 Co-Sn binary phase diagram [Massalski2]

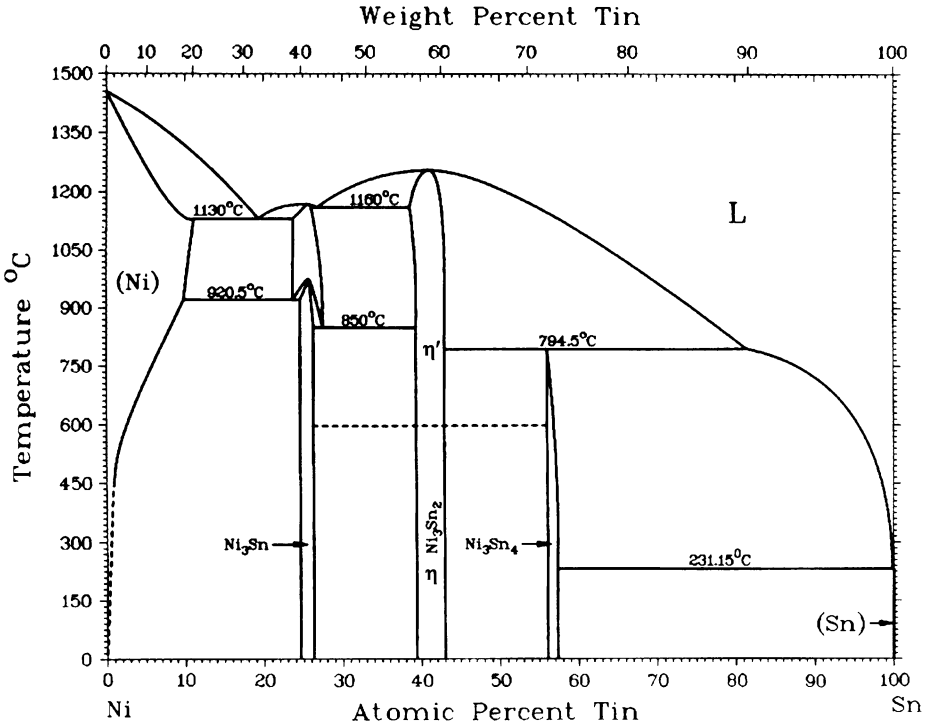

Fig. 3 Ni-Sn binary phase diagram [1991Nas]

Ternary System

In the Co-Ni-Sn system a pseudobinary section Co-Ni_3Sn_2 has been established by [1973Pan]. The alloys were prepared using 99.99 mass% pure Co and Ni and 99.999 mass% pure Sn powder, pressed and sintered under an inert atmosphere. Differential thermal analysis of alloys was used to determine the phase transformation temperatures.

Table 1 Binary phases and their structure data

Phase designation	Composition	Pearson's symbol	Space group	Type	Lattice parameters, nm		
					a	*b*	*c*
α	(αCo), (Ni), (αCo, Ni)	*cF*4	$Fm\bar{3}m$	Cu	...	...	...
ε	(εCo)	*hP*2	$P6_3/mmc$	Mg	...	...	...
β	(βSn)	*tI*4	$I4_1/amd$	βSn	...	...	...
η	Co_3Sn_2(HT)	*hP*4	$P6_3/mmc$	AsNi	0.411	...	0.5183
η′	Co_3Sn_2(LT)	*oP*20	*Pnma*	Ni_3Sn_2	...	...	...
π	CoSn	*hP*6	*P6/mmm*	CoSn	0.5279	...	0.4259
ζ	$CoSn_2$	*tI*12	*I4/m*	Al_2Cu	0.6361	...	0.5452
γ′	Ni_3Sn(HT)	*cF*16	$Fm\bar{3}m$	BiF_3	0.598	...	...
γ	Ni_3Sn(LT)	*hP*8	$P6_3/mmc$	$CdMg_3$	0.5286	...	0.4243
η′	Ni_3Sn_2(HT)	*oP*20	*Pnma*	Ni_3Sn_2	0.711	0.521	0.823
$η_1$	Ni_3Sn_2(LT)	*hP*4	$P6_3/mmc$	AsNi	0.4125	...	0.5198
ξ	Ni_3Sn_4	*mC*14	*C2/m*	...	1.2223	0.4061 α = 103.5°	0.5187

(HT) and (LT) indicate high temperature and low temperature, respectively

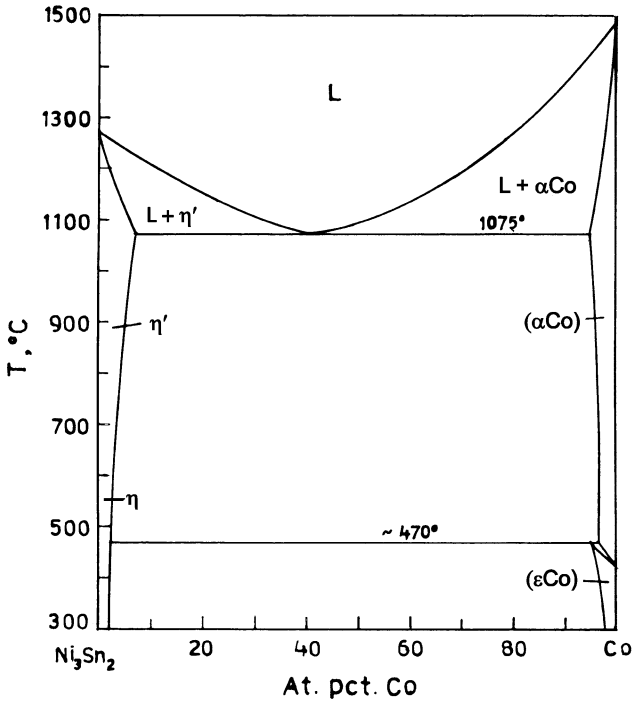

Fig. 4 Pseudobinary Ni_3S_2-Co [1973Pan]

The other methods that were used to characterize the alloys are microscopic analysis, hardness, and magnetic susceptibility measurements. The Co-Ni_3Sn_2 pseudobinary section, as determined by [1973Pan] is given in Fig. 4. It shows a simple eutectic system with a eutectic reaction L ↔ (γCo) + Ni_3Sn_2(HT) occurring at 1075 °C. The eutectic composition is with 40 at.% Co in Ni_3Sn_2(HT). At lower temperature, a thermal effect was observed at ~470 °C. Since the accepted (γCo) ↔ (εCo) transformation temperature is 422 °C, a eutectoid reaction is not possible. A peritectoid reaction (γCo) + Ni_3Sn_2 ↔ (εCo) with peritectic temperature ~470 °C is more probable and is shown in Fig. 4. At the Ni_3Sn_2 end of the pseudobinary the allotropic transformation of the Ni_3Sn_2 phase should occur but has not been determined. The pseudobinary section is thus incomplete at lower temperatures.

Even though no other information is available for the Co-Ni-Sn system, it may be possible to suggest what kinds of reactions involving the liquid phase are to be expected. The Co-Ni system is a simple isomorphous system and no ternary intermediate phases have been reported in the Co-Ni-Sn system. In the low Sn side of the Co-Ni_3Sn_2 pseudobinary, only two eutectic reactions, e_1 and e_2, occur in the Ni-Sn binary. On the basis of this information, the probable liquidus projection for the Co-Ni-Ni_3Sn_2 region is expected to have a U-type reaction U_1, and the resulting three phase equilibrium triangle. L + α + η′ should terminate at the eutectic line of the Co-Ni_3Sn_2 pseudobinary at 1075 °C (Fig. 5 and 6). On the higher Sn side of the Co-Ni_3Sn_2 pseudobinary, one eutectic reaction e_3 occurs in the Co-Sn binary which is close to the pseudobinary. The liquid composition from the three phase equilibrium in the Co-Sn binary, however, cannot terminate at e_4 at 1075 °C because the Co_3Sn_2(HT) and Ni_3Sn_2(HT) phases have different crystal structures. Both Co_3Sn_2 and Ni_3Sn_2 phases melt congruently and it may be possible that a Co_3Sn_2-Ni_3Sn_2 eutectic type pseudobinary exists. In such a case a U-type reaction U_2 may occur in the composition region Co-Co_3Sn_2-Ni_3Sn_2 and the resulting three phase equilibrium triangle L + α + η′ finally terminates at the Co-Ni_3Sn_2 eutectic line at 1075 °C (Fig. 5 and 6a). If, on the other hand, no Co_3Sn_2-Ni_3Sn_2 pseudobinary exists, the liquid composition coming down from e_3 and e_4 may give a

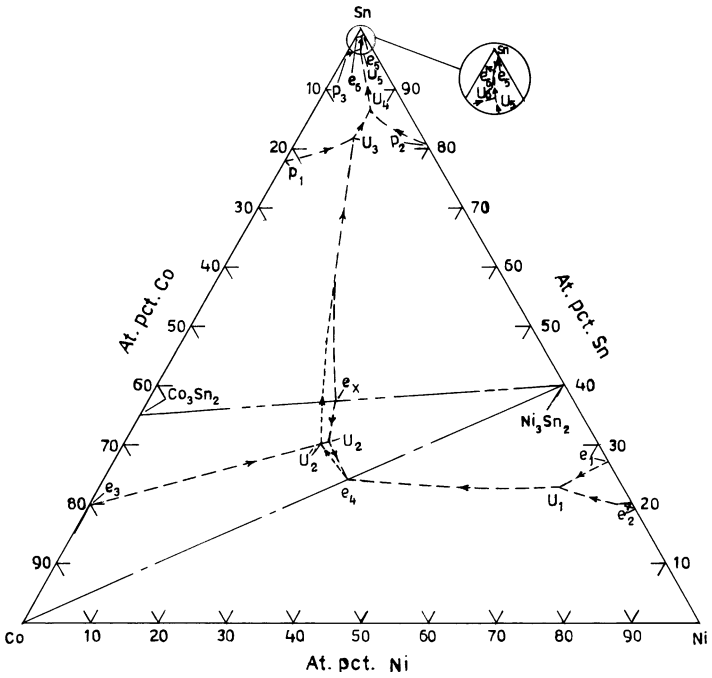

Fig. 5 Probable liquidus projection (Schematic) for the Co-Ni-Sn system ———–———. Experimental pseudobinary line ———–———, probable pseudobinary line ——— —. Probable (alternate) liquid composition lines –––––

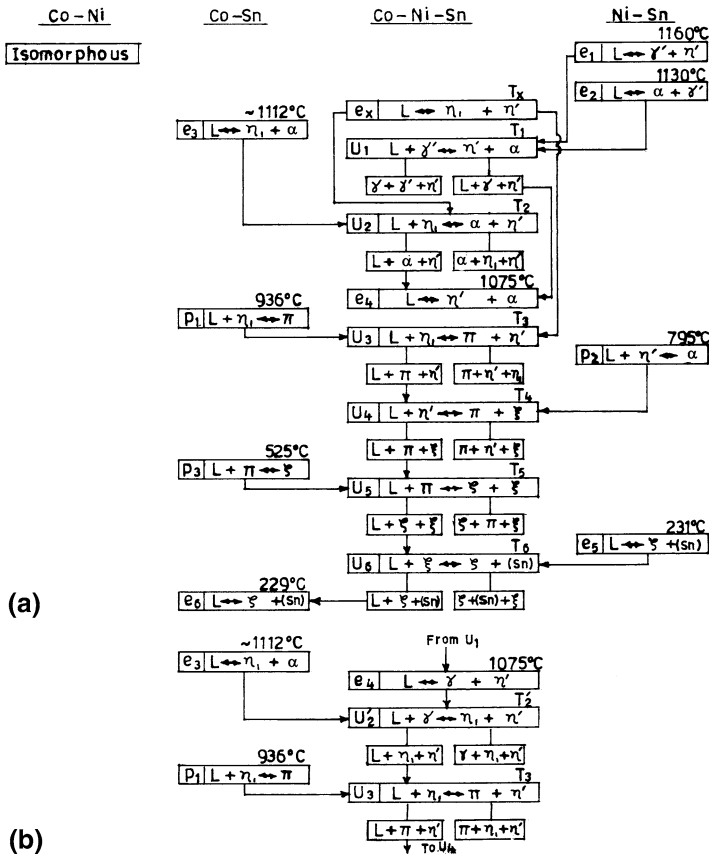

Fig. 6 (a) Probable reaction scheme for the Co-Ni-Sn system with Co_3Sn_2-Ni_3Sn_2 pseudobinary. (b) Change in the probable reaction scheme if Co_3Sn_2-Ni_3Sn_2 pseudobinary does not exist

U-type reaction U_2' (see Fig. 3b). On the higher Sn side of the Co_3Sn_2-Ni_3Sn_2 line, the possible reactions are indicated in Fig. 5 and 6(a). For either of the two possibilities mentioned above, the reactions at the higher Sn side of the Co-Ni-Sn system will remain the same as indicated in Fig. 5 and 6(a, b). The above suggested liquidus projection and reaction schemes for the Co-Ni-Sn system (Fig. 5 and 6a, b) requires experimental verification to know whether the Co_3Sn_2-Ni_3Sn_2 pseudobinary exists and to know which of the two reaction schemes is actually applicable for the Co-Ni-Sn system.

References

1973Pan: L.A. Panteleimonov and I.A. Babanskaya, Alloys of Ni_3Sn_2 with Fe and Co, *Vestn. Moskov. Univ. (Khim)*, 1973, **14**, p 486-487, in Russian (Phase Equilibria, #)

1983Nis: T. Nishizawa and K. Ishida, *Bull. Alloy Phase Diagrams*, 1983, **4**(4), p 387-390 (Evaluation)

1991Nas: P. Nash, *Phase Diagrams of Binary Nickel Alloys*, ASM International, Materials Park, OH, USA (Review)

# indicates presence of phase diagram.

Co-Ni-Sn evaluation contributed by **K.P. Gupta**, The Indian Institute of Metals, Metal House, Plot 13/4, Block AQ, Sector V, Calcutta, India. Literature searched through 1996. Dr. Gupta is the Alloy Phase Diagram Co-Category Program Editor for ternary nickel alloys.