Reply to "Formation of Transitional Ferrite Phase in an Iron-Chromium-Nickel Alloy"

(Received November 19, 1971)

Having read Dr. Singhal's short note⁽¹⁾ (This will be called hereafter Ref. 1) entitled "Formation of Transitional Ferrite Phase in an Iron-Chromium-Nickel Alloy", I reexamined Photo. 12 (b) and Photo. 4 (b) in our previous paper⁽²⁾ (Ref. 2). The following is a summary of my interpretations:

1. Interpretation of Photo. 12 (b) in Ref. 2

Numerical values concerning angular relationship among the gamma matrix, sigma, and ferrite phases have already been given in Table 1 of Ref. 1 and in Table 1

of Ref. 2. In addition to this, interplanar spacings obtained from the diffraction spots in Photo. 12 (b) of Ref. 2 and those calculated assuming that the precipitate is either sigma or ferrite are shown in Table 1.

From Table 1 it is to be noted that the maximum $|d/d|$ for sigma is 0.0653 whereas that for ferrite is 0.0511. From Table 1 of Ref. 1 it is seen that the maximum amount of disagreement between observation and calculation is 7° for the angle between $(\bar{4}1\bar{1})_\sigma$ and $(\bar{3}\bar{3}\bar{1})_\sigma$ whereas it is only 2° for the angle between

(1) L. K. Singhal : Trans. JIM, 13 (1972), 59.

(2) S. Nenno, M. Tagaya, K. Hosomi, and Z. Nishiyama : Trans. JIM, 4 (1963), 222.

Table 1 Interplanar spacings observed and calculated.

Calculated d values (Å)						Observed d values (Å)
$\langle hkl \rangle$	d_{cal}	$\Delta d/d^{**}$	$\langle hkl \rangle_{\alpha'}$	d_{cal}	$\Delta d/d^{**}$	d_{obs}
($\bar{1}40$)	2.129	-0.0653	(011)	2.034	-0.0216	1.99
($\bar{4}1\bar{1}$)	1.927	0.0586	($\bar{1}01$)	2.034	0.0029	2.04
($\bar{3}3\bar{1}$)	1.882	0.0255	($\bar{1}\bar{1}0$)	2.034	-0.0511	1.93
(271)	1.165	-0.0386	(121)	1.174	-0.0460	1.12

$$** \Delta d/d \equiv (d_{obs} - d_{cal})/d_{cal}$$

Table 2 Interplanar spacings observed and calculated.

Calculated d values (Å)						Observed d values (Å)
$(hkl)_\sigma$	d_{cal}	$\Delta d/d^*$	$(hkl)_{\alpha'}$	d_{cal}	$\Delta d/d^*$	d_{obs}
(330)	2.069	0.0681	(011)	2.034	0.0865	2.21
(411)	1.927	0.0747	(101)	2.034	0.0182	2.07
(141)	1.927	0.0794	(110)	2.034	0.0226	2.08

$$* \Delta d/d \equiv (d_{obs} - d_{cal})/d_{cal}$$

Table 3 Angles between the two planes of the precipitate phase and the gamma matrix.

Assumed phase	$(h_1k_1l_1)$	$(h_2k_2l_2)$	Calculated angle	Observed angle from Photo. 4(b)
Sigma	(141) $_\sigma$	(411) $_\sigma$	55°31'	56°
Ferrite	(110) $_{\alpha'}$	(101) $_{\alpha'}$	60° 0'	56°
Sigma	(411) $_\sigma$	(330) $_\sigma$	62°15'	61°
Ferrite	(101) $_{\alpha'}$	(011) $_{\alpha'}$	60° 0'	61°
Sigma	(330) $_\sigma$	(141) $_\sigma$	62°15'	63°
Ferrite	(011) $_{\alpha'}$	(110) $_{\alpha'}$	60° 0'	63°
Gamma	(111) $_r$	(111) $_r$	70°32'	68.5°
Gamma	(111) $_r$	(002) $_r$	54°44'	55°
Gamma	(002) $_r$	(111) $_r$	54°44'	57°

(011) $_{\alpha'}$ and (101) $_{\alpha'}$. Therefore, it seems that the precipitate is more appropriately interpreted to be ferrite

(3) L. K. Singhal and J. W. Martin : Acta Met., 16 (1968), 1441.

than sigma as Dr. Singhal pointed out.

2. Interpretation of Photo. 4 (b) in Ref. 2

From the diffraction spots in Photo. 4 (b), interplanar spacings were obtained. These observed values and the spacings calculated assuming that the precipitate is either sigma or ferrite are given in Table 2. Angles between crystallographic planes of the precipitate phase as well as those between planes of the matrix were measured. These values are shown in Table 3 together with the calculated values.

From Table 2, the maximum value of $|\Delta d/d|$ for sigma is found to be 0.0794 whereas that for ferrite is 0.0865.

From Table 3 it is to be noted that the maximum amount of disagreement between observation and calculation is 1° (15') for the angle between (411) $_\sigma$ and (330) $_\sigma$ whereas it is 4° for the angle between (110) $_{\alpha'}$ and (101) $_{\alpha'}$. Therefore in the case of Fig. 4 (b) in Ref. 2, the interpretation in terms of ferrite precipitate does not seem to be better than that in terms of sigma precipitate.

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As stated in item 1, it now appears that the occurrence of transitional ferrite in this particular alloy is quite likely. On the other hand there is little doubt about that sigma phase precipitates in this alloy when annealed at 700°C for more than 3~10 hours after 20 % cold rolling as shown in Photos. 7, 9, and 10 of Ref. 2. It is to be hoped to clarify what role the transitional ferrite might play in the process of precipitation of the sigma phase in this alloy, although there has been some discussion on this point in some austenitic stainless steels⁽³⁾. I am planning some experiments to confirm the occurrence of the transitional ferrite in AISI 310 type steel by means of X-ray diffraction as well as electron microscopy.

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