01 Jan 1969

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R. H. Graham

Manfred Wuttig
Missouri University of Science and Technology

Recommended Citation

R. H. Graham and M. Wuttig, "Additional Magnetic Disaccommodations In Ternary Iron Base Alloys," *Scripta Metallurgica*, vol. 3, no. 1, pp. 9 - 13, Elsevier, Jan 1969.
The definitive version is available at https://doi.org/10.1016/0036-9748(69)90169-0

Scripta METALLURGICA Vol. 3, pp. 9-14, 1969 Pergamon Press, Inc.
Printed in the United States

ADDITIONAL MAGNETIC DISACCOMMODATIONS IN TERNARY IRON BASE ALLOYS

R. H. Graham and M. Wuttig
Department of Metallurgical Engineering
University of Missouri-Rolla

(Received July 31, 1968; Revised November 1, 1968)

Magnetic aftereffects and their anelastic counterparts due to the reorientation of interstitials (1-5) and interstitial clusters (6-9) are known to exist in bcc and fcc metals and alloys. Information on magnetic aftereffects due to the reorientation of interstitial-substitutional clusters in ternary iron base alloys is still scarce (3,8,10,11), however, although the anelastic analogies are known (12-21). It is the purpose of this note to report on magnetic aftereffects, the disaccommodation, in such ternary iron base alloys.

The alloys were prepared by induction melting starting with at least 99.9% purity materials, in nominally 99.7% alumina crucibles and in an argon atmosphere. The swaged ingots were recrystallized, decarburized and denitrided by annealing in wet and/or dry hydrogen. Using disaccommodation measurements (22) the residual carbon and nitrogen concentrations were determined to be less than 1 ppm at each. The specimens were then recarburized or renitrided in a methane/hydrogen or ammonia/hydrogen gas mixture. The compositions as determined by chemical analysis of all specimens investigated are listed in Table 1. Except for Fe-V-N and Fe-Ti-N the alloys were single phase as determined by initial permeability measurements (23). As the initial permeability decreased continuously during the nitriding process of Fe-V-N and Fe-Ti-N alloys, it is assumed that nitride precipitates were present in these specimens. A metallographic analysis confirmed the presence of precipitates.

The results of the disaccommodation measurements are shown in Figures 1 and 2. In these figures the difference of the inverse initial permeability measured isothermally at one and five minutes after demagnetization, Δr, is

TABLE 1

Specimen Analyses of Substitutional and Interstitial Contents

Alloy	Contents of Alloying Elements [wt%]	
	Substitutional	Interstitial
Fe-C	---	.005
Fe-Mn-C	.28	.005
Fe-Cr-C	.72	.007
Fe-V-C	.94	.007
Fe-Ti-C	.70	.007
Fe-N	---	.006
Fe-Mn-N	.28	.006
Fe-Cr-N	.72	.009
Fe-V-N	.45	.025
Fe-Ti-N	.16	.019

plotted versus temperature. Such a plot shows a maximum whenever the majority of the disaccommodation occurs in this time interval (22). The data show a maximum due to the reorientation of interstitials having iron neighbors only, which for the time interval chosen occurs at -22°C (C) and -33°C (N) in accord with published diffusion data (24). The line in Figure 1 represents the expected temperature dependence of Δr for a single relaxation with the relaxation time of the carbon interstitials given by $\tau = 2.9 \times 10^{-15} \times \exp(19.8\ \text{kcal/RT})$ sec (24) whereas the lines in Figure 2 represent the expected temperature dependence of Δr for two relaxations with the nitrogen relaxation times given by $\tau_1 = 1.1 \times 10^{-14} \times \exp(18.2\ \text{kcal/RT})$ sec (25) and $\tau_2 = 1.1 \times 10^{-14} \times \exp(Q_2/RT)$ sec. The values of Q_2 are listed in Table 2.

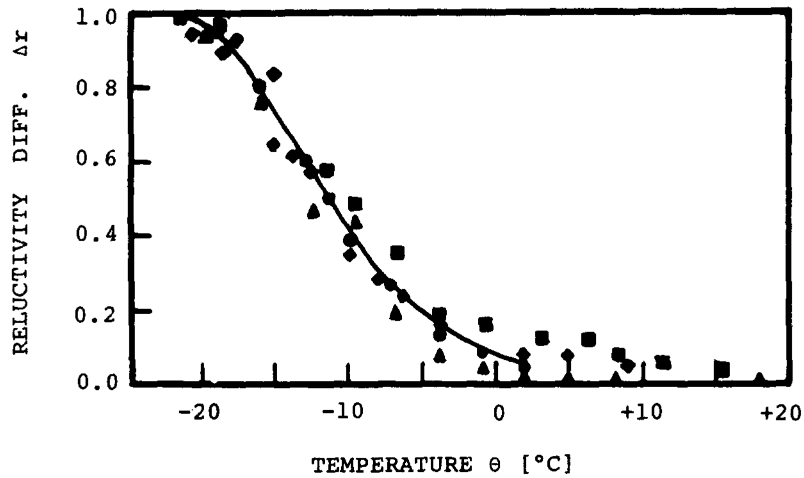
TABLE 2

Activation Energies Q_2 of Extra Disaccommodations Due to the Reorientation of Nitrogen Interstitials

Alloy	Q_2 [kcal/mole]
Fe-Mn-N	19.3
Fe-Cr-N	19.6
Fe-V-N	21.0
Fe-Ti-N	21.0

As can be seen from Figures 1 and 2, "extra" disaccommodations at a temperature higher than the normally present one are prominent in Fe-S-N alloys but not in the Fe-S-C alloys investigated. Aside from the results for the

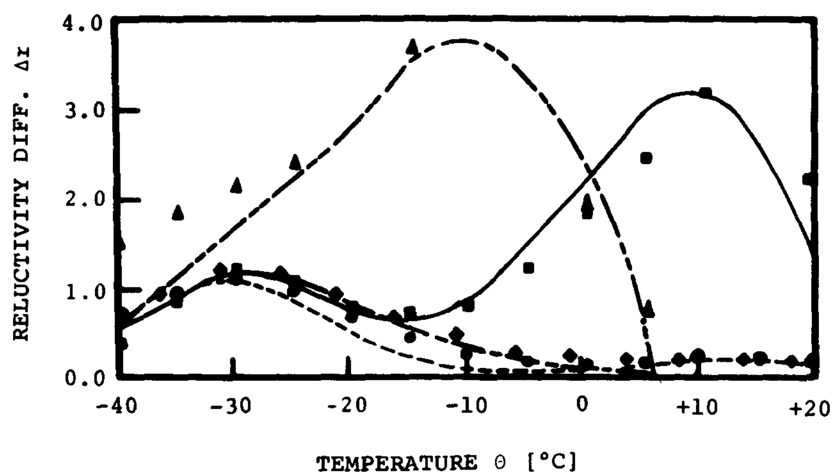
FIG. 1



Temperature Dependence of the Reluctivity Difference Δr for Fe-*S*-C Alloys (*S*-substitutional element)

Fe-C : ooo,——
Fe-Mn-C: ◆◆◆
Fe-Cr-C: ▲▲▲
Fe-V-C : ■■■

FIG. 2



Temperature Dependence of the Reluctivity Difference Δr for Fe-*S*-N Alloys

Fe-Mn-N: —.—.—. ◆◆◆
Fe-Cr-N: —..—..—.. ▲▲▲
Fe-V-N : ———— ■■■
Fe-Ti-N: .... ●●●

Fe-Ti-N alloys this result corresponds to the known anelastic behavior (12-14, 16,19-21,27-29). In commenting on the Fe-*S*-C alloys (13) it has been noted that the height of the Snoek peaks was less than had to be expected from the

chemical carbon analysis and it was suggested that carbide formation might account for this apparent discrepancy. This suggestion could not be confirmed in the present work as the initial permeability measurements indicated single phase alloys. On the other hand, the initial permeability measurements indicated the presence of nitrides in Fe-V-N and Fe-Ti-N alloys. Thus, the question must be asked whether the extra disaccommodations are due to [1st] the reorientation of substitutional-interstitial pairs (19,26) (only the interstitial is mobile) [2nd] of higher order clusters (27) or [3rd] whether they might be due to interstitials located at the interface between a precipitate and the matrix (29). While direct experimental evidence to support any one of the three models for any one of the alloys is not available, the presence of precipitates in Fe-V-N and Fe-Ti-N would not be in contradiction with mechanism #3. As no large scale precipitation was detected in the Fe-Mn-N and Fe-Cr-N alloys it appears that mechanism #1 or #2 applies to these alloys. At substitutional contents larger than about 1 at% further extra relaxations have been observed which were attributed to clusters of substitutional pairs and one interstitial (17,20,27).

The question remains why extra disaccommodations and mechanical relaxations are observed in the Fe-S-N alloys but not in the Fe-S-C alloys investigated in this study. At present, it can only be speculated that this might be due to the different electronic distortion of the 3d electron configuration of the iron and the substitutional ions caused by C and N respectively (30).

This work was supported by the National Science Foundation Grant GK-2678.

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