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TERMINAL SOLID SOLUBILITY OF Gd IN Fe

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The constitutional data on Fe-Gd system do not include precise values of the extent of solid solubility of Gd in Fe. On the basis of investigations on the changes in α–γ iron transition temperature (as a function of Gd contents) it has been established that Gd in concentrations up to 0.2 at % decreases the temperature of α–γ transition and its effect is therefore, as a stabilizer of γ iron. Higher concentration of Gd in iron however, act as "bcc" stabilizer by increasing the α–γ iron transformation temperature. The solid solubility of Gd in α-iron at the peritectoid temperature of 931°C is ~1.0 at %.

Key words: Solid solubility, Fe-Gd system, γ-Stabilizer of iron.

Introduction

There is a considerable amount of phase diagram data on the Fe-Gd system in the literature. The phase diagram of the Fe-Gd system due to Novy *et al* (1961), suggests the occurrence of seven intermetallic compounds. A later version of the equilibrium diagram however, suggests that only four intermetallic compounds exist in this system (Massalski 1986 and Zinkevich *et al* 2000). Various constitutional aspects of the Fe-Gd system have been discussed by the authors (Atiq *et al* 1994 and 1997) including the formation, structures and homogeneity ranges of various compounds. Regardless of the conflicting evidence on the constitution of this system, none of the researchers reported the extent of terminal solid solubility of Fe in Gd or vise versa. The only information available on this matter in the literature is that (α-Gd dissolves less than 0.6 at. % Fe and that the solubility of Gd in iron is very small (Massalski 1986).

The terminal solid solubility of Gd in Fe cannot be detected accurately by standard techniques such as energy depressive x-ray (EDX) or electron probe microanalysis (EPMA). This is due to the fact that the characteristic x-ray lines of Gd i.e., Gdα1 and GdLα2 lie very close to K_α and K_β lines of iron, which decreases the accuracy of the analysis based on x-rays (Dariel *et al* 1976).

The investigation reported here was based on the determination of the α-γ transition temperature as a function of Gd content.

Experimental

Alloy preparation. A series of Fe-Gd alloys as listed in Table 1, with gadolinium content varying from 0.02 to 11.0 at. % were prepared by smelting the constituents of purity >99.99% in an argon arc melting furnace with non-consumable tungsten electrode. The alloys were remelted several times to ensure homogeneity. In addition, all alloys were homogenized at 1050°C for one week in an inert atmosphere. The compositions of the alloys were determined by atomic absorption spectrophotometry.

Differential thermal analysis. Differential Thermal Analysis (DTA) was carried out on bulk homogenized samples using a Stanton Red croft STA 780 apparatus with DAPS-2 computer software. The average weight of the sample was about 50 mg. Samples were held in alumina crucibles and platinum metal was used as reference material. Titanium gettered argon was used to provide the inert atmosphere and the temperature of the α-γ iron transition was determined for the various alloys. The extrapolated on set temperatures as well as peak temperatures of the endotherms were determined. It is the on-set temperature which corresponds to the phase transition rather than peak temperature, the results therefore, are based on the on-set temperatures (Blazek 1973; Pope and Judd 1977). The procedure to determine the transition temperature on a given sample yielded values to within ± 0.1°C, but taking reproducibility of data from repeat samples into account resulted in the values being quoted to ± 0.5°C.

Results and Discussion

Table 1 and Fig 1 shows that gadolinium when dissolved in iron up to 0.20 at. % (alloys GF 0.02, GF 0.04, GF 0.05, GF 0.07, and GF 0.20) decreased the temperature of α-γ iron transformation. Higher gadolinium contents in the alloy raised the temperature of transformation (alloys GF-0.35, GF-0.48, GF-0.52, GF-0.64 and GF-0.81).

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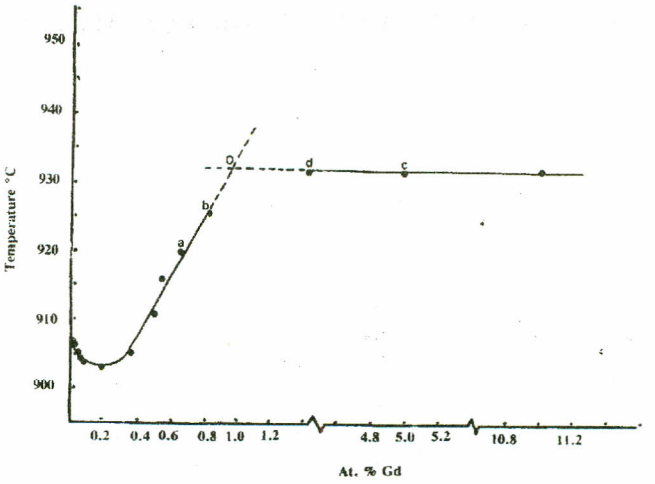

Fig 1. Changes in ∝-γ iron transition temperature as a function of Gd content.

Table 1

Peak and on-set temperature of the endotherms (°C) corresponding to ∝-γ iron transformation, alongwith the nominal composition of alloys.

S.No.	Alloy designation	Alloy composition (at.%)		Endotherm temperature (°C)	
		Fe	Gd	Peak	On-set
1	Pure Iron	100.00	0.00	912.5	908.0
2	GF-0.02	99.98	0.02	912.0	907.5
3	GF-0.04	99.96	0.04	909.5	905.0
4	GF-0.05	99.95	0.05	909.0	905.0
5	GF-0.07	99.93	0.07	908.0	904.5
6	GF-0.20	99.80	0.20	907.0	904.0
7	GF-0.35	99.65	0.35	910.0	905.5
8	GF-0.48	99.52	0.48	915.5	911.0
9	GF-0.52	99.48	0.52	922.0	916.0
10	GF-0.64	99.36	0.64	926.0	919.5
11	GF-0.81	99.19	0.81	932.5	925.0
12	GF-1.4	98.60	1.40	945.0	931.0
13	GF-5.0	95.00	5.00	945.0	931.0
14	FF-11.0	89.00	11.0	945.0	931.0

The initial fall followed by a rise in the transition temperature is an unusual feature but is found in a few other systems, most noticeably the Fe-Cr system. Most rare earth elements, e.g., Fe-Sm (Buschow 1971) and Fe-Y (Dommagala *et al* 1961), tend to increase the ∝-γ transition temperature (Dariel *et al* 1997) as found in this present work above 0.6 at. % Gd. Thus Gd, like most other rare earths with some exceptions such as Er, acts as a bcc∝ stabilizer.

Alloys GF-1.4, GF-5.0, and GF-11.0 showed that above a certain amount of Gd in Fe, no further increase in the temperature of ∝-γ iron transformation takes place (Fig 1 and Table 1). It follows that 931°C corresponds to the peritectoid temperature, in good agreement with the reported value of 932°C (Massalski 1986).

Since the temperature of the transformation increase in alloys up to 0.81 at. % Gd and no change occurs in alloys containing 1.4 at. % or excess Gd, it is concluded that the iron solid solution becomes saturated in Gd between 0.81 to 1.4 at. % Gd. The curve in this figure was extrapolated along the points "a,b" and "c,d" to intersect at point "O", which corresponds to ~1 at. % Gd composition. It is concluded that the solid solubility of Gd in ∝-iron is about ~1 at. %.

Conclusion

1. The solid solubility of Gd in ∝-iron at 931°C is ~1%.
2. Gd initially decreases the ∝-γ iron transition temperature i.e., acts as γ stabilizer (up to 0.20 at.% Gd). However, at higher Gd contents the Gd, in common with most rare earths, acts as ∝-stabilizer.
3. The peritectoid temperature is 931°C.

References

Atiq S, Rawlings R D, West D R F 1994 The defects in the lattices of Fe_2 RE compounds. *Pak J Sci Ind Res* **37** (3) 77.

Atiq S, Rawlings R D, West D R F 1997 The defects in the lattices of $(Fe_{1x}\ Co_x)_{17}\ RE_2$ compounds. *Materials Sciences and Technology* **13** 375.

Blazek A 1973 *Thermal Analysis*. Van Nostrand Reinhold Co. Ltd. London.

Buschow K H J 1971 *Philips Research Report* **26** 49.

Dariel M P, Holthuis J T, Pickus M R 1976 *Journal of the less common metals*. **45** 91.

Dommagala R P, Raussch J J, Levinson D W 1961 *Am Soc* **53** 137.

Massalski T B 1986 Binary Alloy Phase Diagrams. *Amer Soc Met* 1063.

Novy V F, Vickery R C, Klebber E V 1961 *Transaction of the Metallurgical Society of AIME* **221** 580.

Pope M I, Judd M D 1977 *Differential Thermal Analysis*. Heydon and sons Ltd.

Zinkevich M, Mattern N, Seifert M J 2000 Reassessment of the Fe-Gd System. *J Phase Equilib* **4** 385.