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Al-Er-Fe (Aluminum-Erbium-Iron)

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A partial isothermal section for this ternary system at 500 °C was determined by [2001Yan] and was reviewed by [2004Rag]. Recently, [2010Jem] determined an isothermal section for this ternary system at 800 °C covering the entire composition range, which depicts six ternary compounds.

Binary Systems

The Al-Er phase diagram [Massalski2] depicts the following intermediate compounds: $ErAl_3$ ($L1_2$, $AuCu_3$-type cubic), $ErAl_2$ ($C15$, $MgCu_2$-type cubic), ErAl (ErAl-type orthorhombic), Er_3Al_2 (Zr_3Al_2-type tetragonal), and Er_2Al ($C23$, Co_2Si-type orthorhombic). In the Fe-Al phase diagram, the γ solid solution based on face-centered cubic (fcc) Fe is restricted by a loop. The solid solution based on the body-centered cubic (bcc) Fe exists in both the disordered $A2$ and ordered $B2$ and $D0_3$ forms. Apart from the high temperature phase ε ($D8_2$, Cu_5Zn_8-type cubic), there are three intermediate phases in the system with restricted ranges of homogeneity: $FeAl_2$ (triclinic), Fe_2Al_5 (orthorhombic), and $FeAl_3$ or Fe_4Al_{13} (monoclinic). The Er-Fe phase diagram [Massalski2] shows four line compounds: $Fe_{17}Er_2$ ($Ni_{17}Th_2$-type hexagonal), $Fe_{23}Er_6$ ($D8_a$, $Mn_{23}Th_6$-type cubic), Fe_3Er (Be_3Nb-type rhombohedral), and Fe_2Er ($C15$, $MgCu_2$-type cubic).

Ternary Compounds

Five ternary compounds, all with a range of homogeneity, were identified in this system at 800 °C by [2010Jem]. The structural details as determined by [2010Jem] are listed in Table 1. $ErFe_{12-x}Al_x$ ($5 \le x \le 8$) (denoted here as τ_1) has the $ThMn_{12}$-type tetragonal structure. $Er_2Fe_{17-x}Al_x$ ($4.75 \le x \le 5.7$) (τ_2) has the Cu_7Tb-type hexagonal structure. $Er_2Fe_{17-x}Al_x$ ($5.7 \le x \le 9.5$) (τ_3) has the Th_2Zn_{17}-type rhombohedral structure. $ErFe_{3-x}Al_x$ ($0.5 \le x \le 1$) (τ_4) has the $DyFe_2Al$-type hexagonal structure. $ErFe_{1+x}Al_{1-x}$ ($-0.2 \le x \le 0.25$) (τ_5) is of $MgZn_2$-type hexagonal. In addition, a sixth compound of fixed composition $ErFe_2Al_{10}$ (τ_6) with orthorhombic symmetry was earlier reported by [1998Thi] (see Table 1).

Isothermal Section

With starting metals of 99.99% Al, 99.8% Er, and 99.9% Fe, [2010Jem] arc-melted under Ar atm 90 alloy samples.

Table 1 Al-Er-Fe crystal structure and lattice parameter data [2010Jem]

Phase	Composition, atomic %	Pearson symbol	Space group	Prototype	Lattice parameter, nm
$ErFe_{12-x}Al_x$ (τ_1) ($5 \le x \le 8$)	38.5-61.5 Al 53.8-30.8 Fe 7.7 Er	*tI*26	*I*4/*mmm*	$ThMn_{12}$	*a* = 0.8594- 0.8704 *c* = 0.4981-0.5037
$Er_2Fe_{17-x}Al_x$ (τ_2) ($4.75 \le x \le 5.7$)	25.0-30.0 Al 64.5-59.5 Fe 10.5 Er	*hP*8	*P*6/*mmm*	Cu_7Tb	*a* = 0.4956 (a) *c* = 0.4229
$Er_2Fe_{17-x}Al_x$ (τ_3) ($5.7 \le x \le 9.5$)	30.0-50.0 Al 59.5-39.5 Fe 10.5 Er	*hR*19	$R\bar{3}m$	$ThZn_{17}$	*a* = 0.8695 (b) *c* = 1.2692
$ErFe_{3-x}Al_x$ (τ_4) ($0.5 \le x \le 1$)	12.5-25 Al 62.5-50 Fe 25 Er	*hP*24	$P6_3/mmc$	$DyFe_2Al$	*a* = 0.5156 (c) *c* = 1.6522
$ErFe_{1+x}Al_{1-x}$ (τ_5) ($-0.2 \le x \le 0.25$)	40-25 Al 26.7-41.7 Fe 33.3 Er	*hP*12	$P6_3/mmc$	$MgZn_2$	*a* = 0.5332 (d) *c* = 0.8683
$ErFe_2Al_{10}$ (τ_6)	76.9 Al 15.4 Fe 7.7 Er	*oC*52	*Cmcm*	$YbFe_2Al_{10}$	*a* = 0.8948 *b* = 1.0136 *c* = 0.8988

(a) at $x = 5.2$, (b) at $x = 9$, (c) at $x = 1$, and (d) at $x = 0$

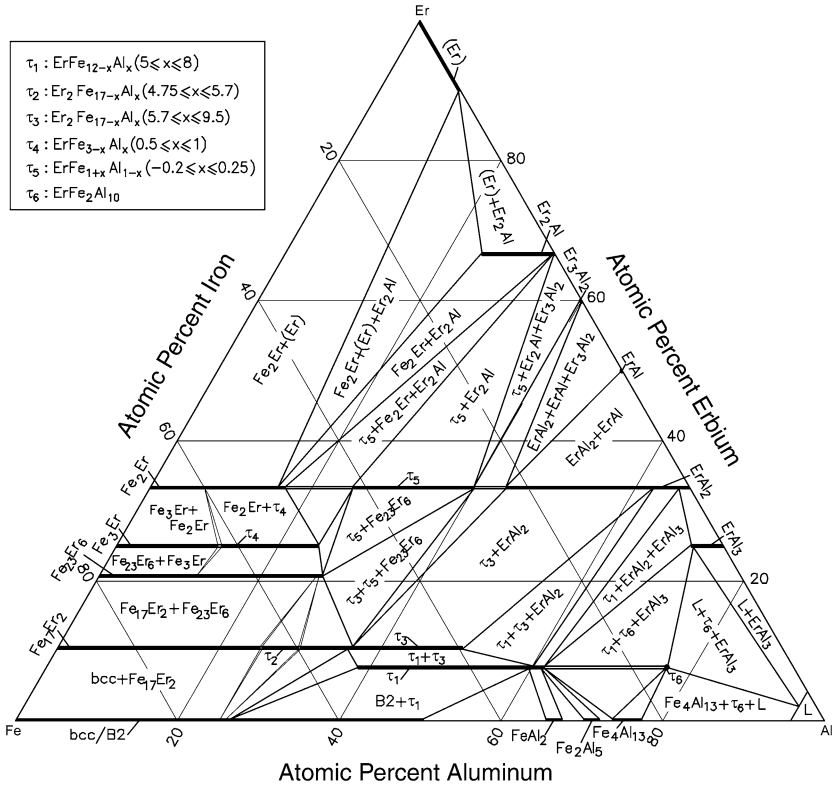

Fig. 1 Al-Er-Fe isothermal section at 800 °C [2010Jem]. Narrow two-phase regions are omitted

The samples were annealed at 800 °C for 1 week and quenched in water. The phase equilibria were studied with scanning electron microscopy, x-ray powder diffraction, and energy dispersive x-ray spectroscopy. The isothermal section at 800 °C constructed by [2010Jem] is shown in Fig. 1. All the six ternary compounds are present. In addition, ternary solid solutions are formed by several binary compounds at constant Er content. $Fe_{17}Er_2$ (Th_2Ni_{17}-type hexagonal) dissolves up to 25 at.% Al. $Fe_{23}Er_6$ ($Mn_{23}Th_6$-type cubic) dissolves up to 27.6 at.% Al. Fe_3Er dissolves up to 12.5 at.% Al. Fe_2Er dissolves up to 16.7 at.% Al. Er_2Al, $ErAl_2$, and $ErAl_3$ dissolve up to 9, 22.7, and 4 at.% Fe, respectively. (Er) was found to dissolve up to 10 at.% Al, in contrast to the much lower solubility reported earlier, see [Massalski2].

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