JPEDAV (2009) 30:101–102
DOI: 10.1007/s11669-008-9445-2
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Fe-Ge-La (Iron-Germanium-Lanthanum)

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Recently, [2008Zhu] determined an isothermal section of this system at 500 °C, which depicts three ternary compounds.

Binary Systems

In the Fe-Ge phase diagram, the intermediate phases found stable at 500 °C by [2008Zhu] are: Fe_3Ge ($L1_2$, $AuCu_3$-type cubic), Fe_5Ge_3 ($B8_1$, NiAs-type hexagonal), Fe_6Ge_5 (Fe_6Ge_5-type monoclinic, space group $C2/m$), FeGe, and $FeGe_2$ ($C16$, $CuAl_2$-type tetragonal). The Fe-La phase diagram [1997Zha] shows no intermediate phases. In the Ge-La system [Masslski2], the following seven compounds were found by [2008Zhu] at 500 °C: La_3Ge (tetragonal), La_5Ge_3 ($D8_8$, Mn_5Si_3-type hexagonal), La_4Ge_3 ($D7_3$, Th_3P_4-type cubic), La_5Ge_4 (Ge_4Sm_5-type orthorhombic), LaGe ($B27$, FeB-type orthorhombic), La_2Ge_3 (orthorhombic, space group *Imam*), and $\beta LaGe_{2-x}$ (orthorhombic). The phase La_2Ge_3 is not seen in the phase diagram of [Massalski2], but is listed in [Pearson3] and found by [2008Zhu].

Ternary Phases

[2008Zhu] prepared a series of samples covering the composition range $LaFe_xGe_2$ (x = 0.6-1) and found that the compositions at the previously reported compounds $LaFe_{0.69}Ge_2$ and $LaFeGe_2$ consisted of two-phase mixtures of $LaFe_{0.6}Ge_2$ and $LaFe_2Ge_2$. The compound $LaFe_{0.6}Ge_2$ (denoted as τ_3 in Table 1 and Fig. 1 and as C by [2008Zhu]) has the $CeNiSi_2$-type orthorhombic structure [1990Fra]. $LaFe_2Ge_2$ (denoted τ_1 here and A by [2008Zhu]) has the Al_4Ba-type tetragonal structure. $LaFeGe_3$ (denoted τ_2 here and B by [2008Zhu]) has the $BaNiSn_3$-type tetragonal structure [1995Yam], see Table 1 for details.

Ternary Isothermal Section

With starting metals of 99.9% Fe, 99.999% Ge, and 99.9% La, [2008Zhu] arc-melted 126 alloy compositions under Ar atm. The alloys were given a final anneal at 500 °C for 10 days and quenched in liquid nitrogen. The phase equilibria were studied by optical microscopy, x-ray powder diffraction and differential thermal analysis at a heating rate of 10 °C/min. The isothermal section at 500 °C constructed by [2008Zhu] is shown in Fig. 1. The three ternary compounds τ_1, τ_2, and τ_3 are present. Whereas τ_1 and τ_2 are stoichiometric, $LaFe_{0.6}Ge_2$ (τ_3) shows a small homogeneity range of 16.7-18.0 at.% Fe (x = 0.60-0.66) [2008Zhu]. The equilibrium involving the ordered forms of bcc Fe ($B2$ and $D0_3$) was not investigated by [2008Zhu] and these phases are not shown separately from bcc in Fig. 1. In a study of a series of alloy samples of $La(Fe_{1-x}Ge_x)_{13}$ (x = 0-0.2) at 500 °C, [2008Zhu] did not find the compound with the $NaZn_{13}$-type of structure reported by several authors in the related $La(Fe_{1-x}Si_x)_{13}$ alloys. Also, [2008Zhu] found that two other reported compounds $La_3Fe_2Ge_4$ and $La_{15}FeGe_9$ to be two-phase mixtures at 500 °C. The structural details of $La_3Fe_2Ge_4$ [Pearson3] and $La_{15}FeGe_9$ [1996Gul] are listed tentatively at the end of Table 1.

Table 1 Fe-Ge-La crystal structure and lattice parameter data [2008Zhu, Pearson3]

Phase	Composition, at.%	Pearson symbol	Space group	Prototype	Lattice parameter, nm
$LaFe_2Ge_2$ (τ_1 or A)	40 Fe 40 Ge 20 La	*tI*10	*I*4/*mmm*	Al_4Ba	a = 0.4110 c = 1.0581
$LaFeGe_3$ (τ_2 or B)	20 Fe 60 Ge 20 La	*tI*10	*I*4*mm*	$BaNiSn_3$	a = 0.4368 c = 0.9985
$LaFe_{0.6-0.66}Ge_2$ (τ_3 or C)	16.7-18 Fe 55.6-54.6 Ge 27.8-27.3 La	*oC*16	*Cmcm*	$CeNiSi_2$	a = 0.4347 b = 1.683 c = 0.4210
$La_3Fe_2Ge_4$	22.2 Fe 44.4 Ge 33.3 La	*hP*3	*P*6/*mmm*	AlB_2	a = 0.4216 c = 0.4236
$La_{15}FeGe_9$	4 Fe 36 Ge 60 La	*hP*?	$P6_3/mcm$	Mn_5Si_3	a = 1.54810 c = 0.68768

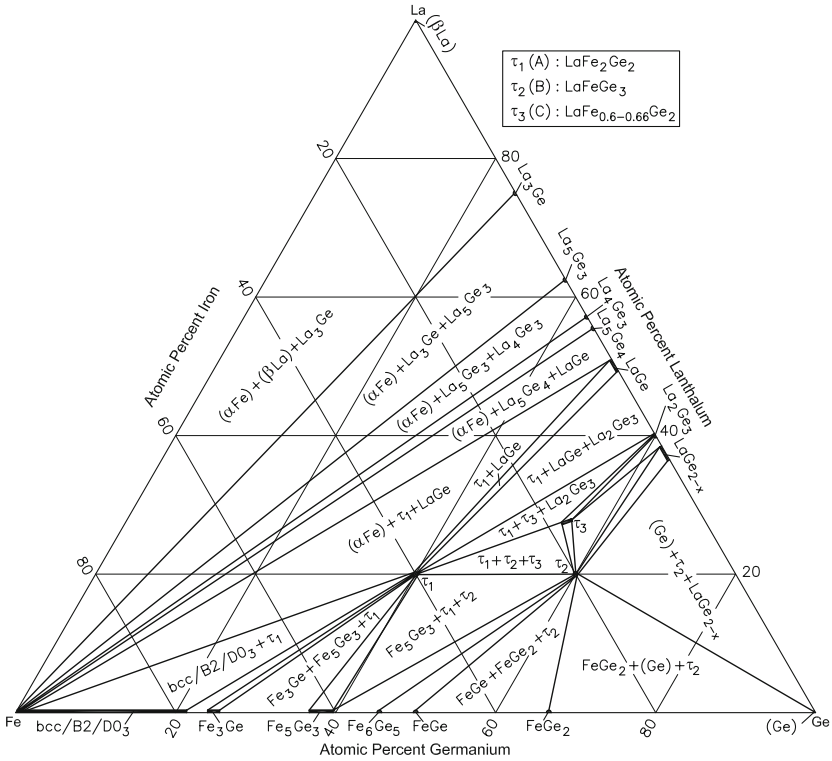

Fig. 1 Fe-Ge-La isothermal section at 500 °C [2008Zhu]. Narrow two-phase regions are omitted

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