JPEDAV (2009) 30:107–108
DOI: 10.1007/s11669-008-9457-y
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Fe-Si-U (Iron-Silicon-Uranium)

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The previous review of this system by [1992Rag] presented an isothermal section at ~795 °C near the U-corner. The update by [2003Rag] summarized the results of [1994Gon] on the ternary solid solutions that lie on the line of constant U content of 7.7 at.%. Recently, [2008Ber] determined an isothermal section at 900 °C for the entire composition range, which depicts eleven ternary phases.

Binary Systems

The Fe-Si phase diagram [Massalski2] shows that the fcc solid solution based on Fe is restricted by a γ loop. The intermediate phases are: α_2 (*B*2, CsCl-type cubic), α_1 ($D0_3$, BiF_3-type cubic), Fe_2Si (stable between 1212 and 1040 °C; hexagonal), Fe_5Si_3 ($D8_8$, Mn_5Si_3-type hexagonal), FeSi

Table 1 Fe-Si-U crystal structure and lattice parameter data [2008Ber]

Phase	Composition, at.%	Pearson symbol	Space group	Prototype	Lattice parameter, nm
U_2FeSi_3 (τ_1 or A)	16.7 Fe 50.0 Si 33.3 U	*hP*3	*P6/mmm*	AlB_2	*a* = 0.4011 *c* = 0.3864
UFe_2Si_2 (τ_2 or B)	40 Fe 40 Si 20 U	*tI*10	*I4/mmm*	$ThCr_2Si_2$	*a* = 0.3946 *c* = 0.9540
$U_3Fe_2Si_7$ (τ_3 or C)	16.7 Fe 58.3 Si 25 U	*oC*24	*Cmmm*	$La_3Co_2Sn_7$	*a* = 0.4013 *b* = 2.4324 *c* = 0.4023
U_2Fe_3Si (τ_4 or D)	50 Fe 16.7 Si 33.3 U	*hP*12	$P6_3/mmc$	$MgZn_2$	*a* = 0.5154 *c* = 0.7686
$UFe_{12-x}Si_x$ (*x* = 1-3) (τ_5 or E)	84.6-69.2 Fe 7.7-23.1 Si 7.7 U	*tI*26	*I4/mmm*	$ThMn_{12}$	*a* = 0.8350 (a) *c* = 0.4705
$U_2Fe_{17-x}Si_x$ (*x* = 3.2-4) (τ_6 or F)	72.6-68.4 Fe 16.8-21.1 Si 10.5 U	*hP*38	$P6_3/mmc$	Th_2Ni_{17}	*a* = 0.8330 (b) *c* = 0.8201
UFeSi (τ_7 or G)	33.3 Fe 33.3 Si 33.3 U	*oP*12	*Pnma*	TiNiSi	*a* = 0.7001 *b* = 0.4065 *c* = 0.6857
$U_{1.2}Fe_4Si_{9.7}$ (τ_8 or H)	26.8 Fe 65.1 Si 8.1 U	*hP*16	$P6_3/mmc$	$Er_{1.2}Fe_4Si_{9.7}$	*a* = 0.3960 *c* = 1.5075
$U_2Fe_3Si_5$ (τ_9 or I)	30 Fe 50 Si 20 U	…	*C*2/*c*	$Lu_2Co_3Si_5$	*a* = 1.0843 *b* = 1.1482 *c* = 0.5163 β = 119.38°
UFe_5Si_3 (τ_{10} or J)	55.5 Fe 33.3 Si 11.1 U	…	*P4/mmm*	UFe_5Si_3	*a* = 0.39296 *c* = 0.77235
$U_6Fe_{16}Si_7$ (τ_{11} or K)	55.2 Fe 24.1 Si 20.7 U	*cF*116	$Fm\bar{3}m$	$Mg_6Cu_{16}Si_7$	*a* = 1.17817

(a) at *x* = 2; (b) at *x* = 3.2

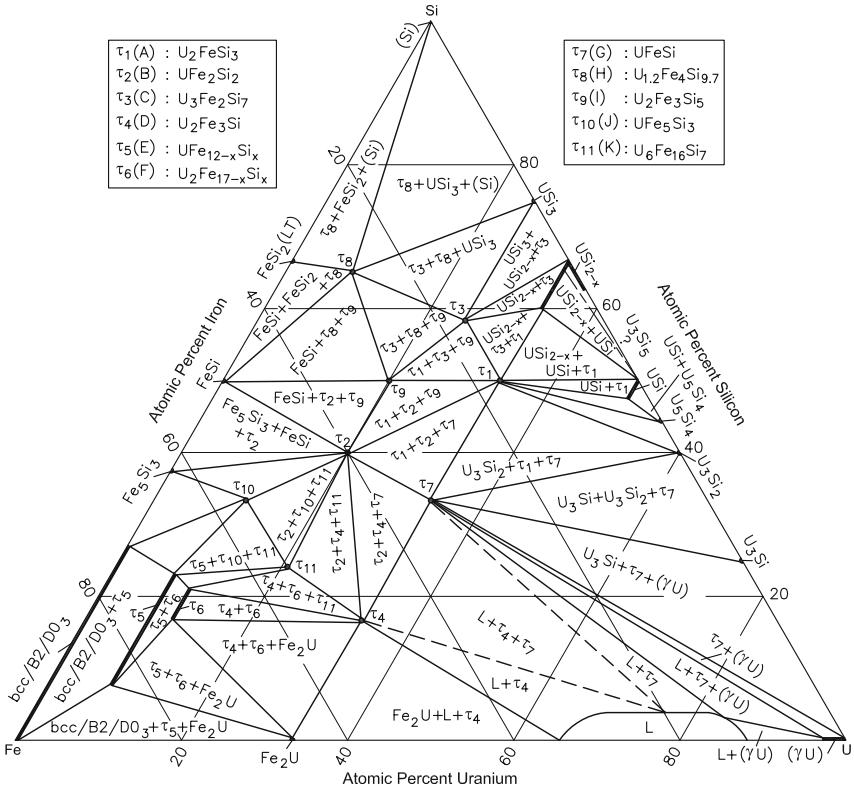

Fig. 1 Fe-Si-U isothermal section at 900 °C [2008Ber]. Narrow two-phase regions are omitted

(*B*20-type cubic), βFeSi$_2$ (tetragonal), and αFeSi$_2$ (orthorhombic). The Fe-U phase diagram [Massalski2] depicts two intermediate phases: Fe$_2$U (*C*15, MgCu$_2$-type cubic) and FeU$_6$ (MnU$_6$-type tetragonal). The Si-U phase diagram [Massalski2, 2008Ber] has a number of compounds: Si$_3$U (*L*1$_2$, AuCu$_3$-type cubic), Si$_2$U (ThSi$_2$-type tetragonal), Si$_{2-x}$U (GdSi$_2$-type orthorhombic at the Si-poor boundary and ThSi$_2$-type tetragonal at the Si-rich boundary), Si$_5$U$_3$ (AlB$_2$-type hexagonal and two orthorhombic distortions of AlB$_2$-type), SiU (SiU-type tetragonal), Si$_4$U$_5$ (hexagonal), Si$_2$U$_3$ (*D*5$_a$-type tetragonal), and SiU$_3$ (AuCu$_3$-type cubic at 900 °C and other forms at lower temperatures).

Ternary Phase Equilibria

At 900 °C, [2008Ber] confirmed the existence of 11 previously-reported ternary compounds: U$_2$FeSi$_3$ (τ_1 or A), UFe$_2$Si$_2$ (τ_2 or B), U$_3$Fe$_2$Si$_7$ (τ_3 or C), U$_2$Fe$_3$Si (τ_4 or D), UFe$_{12-x}$Si$_x$ (x = 1-3; τ_5 or E), U$_2$Fe$_{17-x}$Si$_x$ (x = 3.2-4; τ_6 or F), UFeSi (τ_7 or G), U$_{1.2}$Fe$_4$Si$_{9.7}$ (τ_8 or H), U$_2$Fe$_3$Si$_5$ (τ_9 or I), UFe$_5$Si$_3$ (τ_{10} or J), and U$_6$Fe$_{16}$Si$_7$ (τ_{11} or K). The notation τ_1, τ_2, τ_3, etc. are adopted here and correspond to A, B, C, etc. used by [2008Ber]. The structural details of these compounds determined by [2008Ber] are listed in Table 1.

Starting with high purity metals, [2008Ber] arc-melted alloys under Ar atm and annealed them at 900 °C for 15 days. The phase equilibria were studied with a scanning electron microscope equipped with an energy dispersive x-ray analyzer and with x-ray powder diffraction. The isothermal section constructed by [2008Ber] at 900 °C is shown in Fig. 1. All the 11 ternary compounds listed in Table 1 are present. The phase τ_5 (E) has a homogeneity range 7.7-23.1 at.% Si at constant U content of 7.7 at.%. The phase τ_6 (F) has a homogeneity range of 16.8-21.1 at.% Si at a constant U content of 10.5 at.%. The U-Si binary phases USi and USi$_2$ dissolve 2.5 and 6.7 at.% Fe respectively. The liquid phase present along the Fe-U side dissolves a few percent of Si.

References

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