1 Magnetic properties of 3d, 4d, and 5d elements, alloys and compounds

1.1 - 1.4 See Subvolume III/32A

1.5 Alloys and compounds of 3d elements with main group elements

1.5.1 - 1.5.3 See Subvolume III/32B

1.5.4 3d elements and C, Si, Ge, Sn or Pb

1.5.4.1 Introduction

Phase diagram and crystal structure

Phase diagrams of the binary systems have been revised in various aspects in the last decade [90m]. Solubility limits for 3d-elements and the intermediate phases are listed in Table 1.

In the Tables 2 – 11, the values of the lattice parameters given are those at room temperature unless otherwise mentioned. The Pearson symbol [91v] and/or the space group are reported for those structures to which no "Strukturbericht" symbols have been given.

Magnetic properties

Magnetic properties of alloys and compounds between 3d elements and 4B-group elements are being investigated continuously. Only the alloys and compounds for which new data are available have been listed in the Tables 2 – 11.

Arrangement of materials

The arrangement of the compounds and alloys is the same as in the former edition.

In the $D0_3$ (Fe_3Al) and $L2_1$ (Heusler alloy) types of crystal structure, the occupation of atomic sites by atoms can be described in terms of four interpenetrating fcc sublattices with origins at (0 0 0), (1/4 1/4 1/4), (1/2 1/2 1/2) and (3/4 3/4 3/4), which are designated in the current convention as A, B, C, and D sublattices, respectively, though not completely unified. In the following this designation is adopted. As for the $D0_3$ structure, the sublattices D, B and A + C consist of 4a, 4b and 8c sites, respectively, of the space group $Fm\overline{3}-O_h^5$. In the former edition LB III/19C (the figure on p.1 and the following), these A, B, C and D sublattices were designated as B, C, D and A, respectively.

Table 1. Solubility limits and intermediate phases in the binary systems of 3d elements with C, Si, Ge, Sn or Pb. See [90m] unless otherwise stated. The phase diagrams are also represented in [92b]. The crystallographic data are compiled in [91v]. Neither metastable nor impurity-stabilized phases are listed here except for the case of cementite, Fe_3C. If only phase names are listed, the composition ranges are shown in atomic percentages of the respective 4B group elements. The terminal phases at the 4B element side are not shown, sincee the 3d elements are almost insoluble. Crystal structures are given in parentheses by the "Strukturbericht" type symbol [58p, 90m, 91v, 92b]. If these are missing, the crystal system is indicated according to the following abbreviations. mono: monoclinic, ortho: orthorhombic, rhomb: rhombohedral, hex: hexagonal, tetr: tetragonal, cub: cubic. See also [90E1] for Co-Si and Co-Ge systems.

C	Ti	V	Cr	Mn
	(βTi) 0-0.6% (A2) HT (αTi) 0-1.6% (A3) Ti_2C (cub) TiC (B1)	(V) 0-4.3% (A2) αV_2C (ortho) βV_2C (L'3) β'V_2C (hex) HT V_4C_{3-x} (rhomb) VC (B1) V_6C_5 (mono) [g]) V_8C_7 (cub)	(Cr) 0-0.3% (A2) $Cr_{23}C_6$ ($D8_4$) Cr_7C_3 ($D10_1$) Cr_3C_2 ($D5_{10}$)	(δMn) 0-0.1% (A2) HT (γMn) 0-13% (A1) HT (βMn) 0-0.5% (A13) HT (αMn) 0-6.5% (A12) ε 13.5-24.5% (?) HT $Mn_{23}C_6$ ($D8_4$) Mn_3C ($D0_{11}$) HT Mn_5C_2 (mono) HT Mn_7C_3 ($D10_1$)
	Fe	Co	Ni	
	(δFe) 0-0.4% (A2) HT (γFe) 0-9.06% (A1) HT (αFe) 0-0.096% (A2) Fe_3C ($D0_{11}$) metastable	(αCo) 0-4.2% (A1) HT (εCo) 0% (A3)	(Ni) 0-2.7% (A1)	
Si	Ti	V	Cr	Mn
	(βTi) 0-3.5% (A2) HT (αTi) 0-0.5% (A3) Ti_3Si (tetr) Ti_5Si_3 ($D8_8$) Ti_5Si_4 (tetr) TiSi (B27) $TiSi_2$ (C54)	(V) 0-7% (A2) V_3Si (A15) V_5Si_3 ($D8_m$) V_6Si_5 (ortho) HT VSi_2 (C40)	(Cr) 0-9.5% (A2) Cr_3Si (A15) βCr_5Si_3 (?) HT αCr_5Si_3 ($D8_m$) CrSi (B20) $CrSi_2$ (C40)	(δMn) 0-2% (A2) HT (γMn) 0-2.8% (A1) HT (βMn) 0-16.7% (A13) HT (αMn) 0-6% (A12) R 12-15.75% (rhomb) ν 16.2-18.75 (ortho) βMn_3Si ($D0_3$) HT αMn_3Si (?) Mn_5Si_2 (tetr) Mn_5Si_3 ($D8_8$) MnSi (B20) $MnSi_{1.75-x}$ (tetr) [b])

Si	Fe	Co	Ni
	(γFe) 0-3.2 (A1) HT (αFe) 0-19.5% (A2) α_2 10-22% (B2) α_1 10-30% ($D0_3$) βFe_2Si (hex) HT ηFe_5Si_3 ($D8_8$) HT εFeSi (B20) $\zeta_\alpha FeSi_2$ (tetr) HT [f]) $\zeta_\beta FeSi_2$ (ortho) [f])	(αCo) 0-16.4% (A1) HT (εCo) 0-18.4% (A3) Co_3Si (tetr) HT βCo_2Si (?) HT αCo_2Si (C23) CoSi (B20) $CoSi_2$ (C1)	(Ni) 0-15.8% (A1) β_1Ni_4Si ($L1_2$) β_2Ni_3Si (mono) HT β_3Ni_3Si (mono) HT γ$Ni_{31}Si_{12}$ (hex) δNi_2Si (ortho) θNi_2Si (hex) HT [g]) ε'Ni_3Si_2 (?) HT εNi_3Si_2 (ortho) NiSi (B31) β$NiSi_2$ (?) HT α$NiSi_2$ (C1)

Ge	Ti	V	Cr	Mn
	(βTi) 0-? (A2) HT (αTi) 0-? (A3) Ti_5Ge_3 ($D8_8$) Ti_6Ge_5 (ortho) $TiGe_2$ (C54)	(V) 0-4.5% (A2) V_3Ge (A15) V_5Ge_3 ($D8_m$) $V_{11}Ge_8$ (ortho) $V_{17}Ge_{31}$ (tetr)	(Cr) 0-11% (A2) Cr_3Ge (A15) βCr_5Ge_3 ($D8_m$) HT αCr_5Ge_3 (hex?) $Cr_{11}Ge_8$ (ortho) CrGe (B20) $Cr_{11}Ge_{19}$ (tetr)	(δMn) 0-3.3% (A2) HT (γMn) 0-13% (A1) HT (βMn) 0-9% (A13) HT (αMn) 0-1.5% (A12) εMn_3Ge ($D0_{19}$) HT [c]) ε_1-Mn_3Ge ($D0_{22}$) [c]) ζ$Mn_{2.6}Ge$ with sub-phases ζ_1 and ζ_2 (hex) HT [87K2] κMn_5Ge_2 (ortho) [84O1] χMn_2Ge ($B8_2$) HT ηMn_5Ge_3 ($D8_8$) θ$Mn_{11}Ge_8$ (ortho) [84O2]

	Fe	Co	Ni
	(γFe) 0-3.4% (A1) HT (αFe) 0-17.5% (A2) α_2 10-22% (B2) α_1 15.2-22% ($D0_3$) εFe_3Ge ($D0_{19}$) HT ε'Fe_3Ge ($L1_2$) HT β 33.5-41% ($B8_1$) η 40.8-43.5% ($B8_2$) HT Fe_6Ge_5 (mono) FeGe (mono) HT (B35) HT (B20) $FeGe_2$ (C16)	(αCo) 0-17.5% (A1) HT (εCo) 0-18% (A3) Co_3Ge (A15?) HT Co_5Ge_2 (hex) HT αCo_5Ge_3 (ortho) βCo_5Ge_3 ($B8_2$) CoGe (mono) Co_5Ge_7 (tetr) $CoGe_2$ (ortho) [g])	(Ni) 0-12% (A1) βNi_3Ge ($L1_2$) γNi_3Ge (?) HT δNi_5Ge_2 (hex) HT Ni_2Ge (C23) εNi_5Ge_3 ($B8_1$) HT ε'Ni_5Ge_3 (mono) $Ni_{19}Ge_{12}$ (mono) HT Ni_3Ge_2 ($B8_1$) HT NiGe (B31)

Sn	Ti	V	Cr	Mn
	(βTi) 0-17.5% (A2) HT (αTi) 0-12.5% (A3) Ti_3Sn ($D0_{19}$) Ti_2Sn ($B8_2$) Ti_5Sn_3 ($D8_8$) βTi_6Sn_5 (hex) HT αTi_6Sn_5 (ortho)	(V) 0-16% (A2) "V_3Sn" 20-21% (A15) V_2Sn_3 (C_b=Mg_2Cu) [a])	(Cr) 0-2% (A2)	(δMn) 0-10% (A2) HT (γMn) 0-7% (A1) HT (βMn) 0-11% (A13) HT (αMn) 0-1% (A12) Mn_3Sn ($D0_{19}$) [d]) Mn_2Sn ($B8_2$) [e]) $MnSn_2$ (C16)

Fe	Co	Ni
(γFe) 0-0.8% (A1) HT (αFe) 0-9.2% (A2) Fe_5Sn_3 ($B8_2$) HT Fe_3Sn_2 (rhomb) HT FeSn (B35) $FeSn_2$ (C16)	(αCo) 0-2% (A1) HT (εCo) 0-0.2% (A3) βCo_3Sn_2 ($B8_1$) HT αCo_3Sn_2 (ortho) CoSn (B35) $CoSn_2$ (C16)	(Ni) 0-10.6% (A1) Ni_3Sn (hex) HT Ni_3Sn ($D0_{19}$) Ni_3Sn_2 (hex) HT Ni_3Sn_2 ($B8_1$) Ni_3Sn_4 (mono)

Pb	Ti	V	Cr	Mn
	(βTi) 0-16% (A2) HT (αTi) 0-4.2% (A3) Ti_4Pb ($D0_{19}$) Ti_2Pb (?)	insoluble	insoluble	insoluble

Fe	Co	Ni
insoluble	insoluble	insoluble

[a]) See also [94W2] for the composition.
[b]) Also designated as $MnSi_{2-x}$ or $MnSi_{\approx 1.7}$.
[c]) See [88Y2] for the transition temperature.
[d]) Composition range is more Mn-rich than Mn_3Sn.
[e]) Also designated as Mn_7Sn_4.
[f]) Sometimes designated as α or $\beta FeSi_2$, instead of ζ_α or $\zeta_\beta FeSi_2$.
[g]) See also [91C1] for space groups.

1.5.4.2 Ti and V alloys and compounds

Though progress is seen in thermal, structural, or electrical investigation and in high-pressure synthesis of new compounds, rather few relevant magnetic data are available. The former includes the identification of the symmetry of an ordered structure in a cubic, B1 (NaCl) type compound $TiC_{0.59}$ with carbon vacancy to be of the space group $R\bar{3}m$ [92T1], as well as new data on the lattice constants of $TiSn_2$, which are referred to in a work on resistivity measurements and listed in Table 2.