Copper – Indium – Ytterbium

Oksana Bodak†, Volodymyr Ivanchenko

Introduction

The Cu-In-Yb ternary system was investigated over the whole concentration range at 400°C. The isothermal section is presented in [1998Kal, 2005Kal]. The crystal structure characteristics of the compounds of the Cu-In-Yb system were determined by [1987Fel1, 1987Adr, 1987Fel2, 1989Sys, 1989Koj, 1990Koj, 1998Kal, 1999Sar, 2001Tsu, 2001Gio, 2003Luk, 2003Mor, 2005Kal]. The temperature dependence of the lattice constants for the $YbCu_4In$ compound was obtained by [1990Koj]. Thermodynamic, magnetic and electrical properties of these compounds (temperature and pressure dependencies of magnetic susceptibility and electrical resistivity) as well as electronic structure were studied by many authors using different methods and techniques (see Table 1). Particular attention was paid to the $YbCu_4In$ based compound. While being a Curie - Weiss paramagnet, $YbCu_4In$ undergoes a first-order valency isostructural phase transition at a temperature (T_v) of approximately 40 to 80 K at atmospheric pressure. Ytterbium ions in $YbCu_4In$ change their valency from +3 at 300 K to an average value of about +2.9 between 40 and 70 K. Below T_v, the ytterbium in this compound is in a mixed-valence state and the compound as a whole is sometimes called a light heavy-fermion system. Above T_v, the compound is known as a Curie - Weiss paramagnet of localized magnetic moments and, below T_v, a Pauli paramagnet in a nonmagnetic Fermi-liquid state. The exact temperature of the phase transition has been an issue for many years, and experiments using different samples of "$YbCu_4In$" have given different results. [1999Loe1, 1999Loe2] shows, that the temperature of the phase transition depends on the composition of the sample. Between the stoichiometric composition and the congruent melting composition, the valence transition temperature changes from 40 to 70 K. Electrical resistivity strongly increases at T_v. Specific heat measurements reveal a characteristic increase in C_p around T_v. The valence phase transition temperature of $YbCu_4In$ decreases with increasing pressure [1992Mat, 2002Uch, 2003Wad]. So, the $Yb_{0.4}Cu_2In_{0.6}$ compound exhibits characteristic properties associated with a heavy-fermion system [1987Fel1, 1987Fel2]. In [1987Fel2, 1989Koj, 1998Fis, 2000Yos], the dependence of T_v on composition and substitutions of Yb or In by other elements was studied in more detail. [2002Koy] proposed a schematic phase diagram for $YbCu_4In$ which corresponds to Doniach's phase diagram. The magnetic susceptibility of $YbCu_4In$ as a function of pressure was measured by [1999Sve2, 1999Sve3] at 78, 150 and 300 K. On the basis of an extrapolation of the experimental dependence, a *p-T* phase diagram was proposed for $YbCu_4In$. Also, the temperature-pressure phase diagram for $YbCu_4In$ was presented by [2003Mit]. The magnetic phase diagram for this compound was published by [2003Mus1, 2003Mus2]. There is good agreement between these results. Depending on the synthesis pressure the $YbCu_2In$ compound crystallizes in two different structural types, but in both cases it is almost non-magnetic and Yb ions are very close to the divalent state [2001Gio, 2001Tsu]. Table 1 lists a summary of the works performed on the study of phase equilibria, crystal structure and thermodynamics in this ternary system.
Some problems concerning electronic structure, theory of phase transformation in the $YbCu_4In$ compound have been resolved in [1999Sar, 1999Sve1, 2000Dze, 2000Yos, 2002Dze1, 2002Dze2, 2003Fre].

Binary Systems

The In-Yb binary system is accepted from [Mas2], Cu-In is from [2000Goe], based mainly on [1972Jai]. The Cu-Yb system is taken from the MSIT Evaluation Program [2002Rog].

Solid Phases

Crystallographic characteristics of the solid phases are presented in Table 2. In this system, five ternary compounds are stable at 400°C [2005Kal]. The crystal structures of two compounds, Yb_3CuIn_2 and Yb_4CuIn, are unknown. The compound τ_2, $YbCu_{4.8-4.0}In_{0.2-1.0}$ has a region of homogeneity between 3.3 and 16.7 at.% In. The τ_3', Yb_2Cu_2In (I) ternary compound with the tetragonal Mo_2B_2Fe structure has been prepared by [2001Tsu] using a high pressure technique. This compound synthesized under a pressure of 3.5 GPa has the same stoichiometry as the τ_3 phase obtained at ambient pressure with the W_2CoB_2 structural type [2001Gio].

Quasibinary Systems

From the composition $Yb_{1.0}Cu_{4.2}In_{0.8}$ on the solidus surface, a ridge with constant ytterbium content extends to Yb_2Cu_9 ($YbCu_2$ in the original publication), reaching the compound at 930°C [1999Loe1, 1999Loe2]. But a quasibinary section was not presented.

Invariant Equilibria

[1999Loe1, 1999Loe2] showed that the congruent melting point of $Yb_{1.0}Cu_{4+x}In_{1-x}$ is 1005°C at a composition of $Yb_{1.0}Cu_{4.2}In_{0.8}$ (70Cu-13.3In-16.7Yb (at.%)). No other invariant equilibria in the ternary system have been established.

Liquidus Surface

Some liquidus isotherms in the vicinity of the Yb_2Cu_9 - $YbCu_4In$ section are presented in Fig. 1 in accordance with [1999Loe1, 1999Loe2].

Isothermal Sections

The isothermal section of the Cu-In-Yb system at 400°C is accepted from the review [2005Kal], which is an updated version of the section presented in [1998Kal] taking into account the later discovery of the τ_3 ternary compound [2001Gio]. The 400°C isothermal section is shown in Fig. 2 after modifications made to ensure agreement with the accepted binary diagrams and also to remove artificial homogeneity ranges of the binary and ternary phases, not reported in the literature. The Yb_2Cu_9 stoichiometry is accepted here according to the accepted Cu-Yb binary system, rather than the $YbCu_5$ stoichiometry given in [2005Kal].

Thermodynamics

Specific heat measurements through the valency transition in $YbCu_4In$ were made by [1987Fel1, 1996Hau, 1998Sar, 1999Sar]. [1998Sar] showed, that just above 40 K, C_p/T for $YbCu_4In$ rises from 1 $J{\cdot}mol^{-1}{\cdot}K^{-2}$ to 8 $J{\cdot}mol^{-1}{\cdot}K^{-2}$ in less than 1 K and than drops equally rapidly. The Sommerfeld coefficient of $YbCu_4In$ in the low-temperature valency structure is approximately 50 $mJ{\cdot}mol^{-1}{\cdot}K^{-2}$. The entropy change, ΔS, at the valency transition was measured as 10 $J{\cdot}mol^{-1}{\cdot}K^{-1}$. [1996Hau] reported an essentially linear increase in entropy from ~3 $J{\cdot}mol^{-1}{\cdot}K^{-1}$ at 40 K to ~11 $J{\cdot}mol^{-1}{\cdot}K^{-1}$ at 70 K. [1987Fel1] observed a two-peak structure (at ~40 K and ~60 K) in the specific heat leading to an integrated entropy of 13.3 $J{\cdot}mol^{-1}{\cdot}K^{-1}$ at 70 K. These three measurements yield similar entropy changes through the transition range.

Notes on Materials Properties and Applications

Temperature dependent electrical measurements for $YbCu_4In$ at high pressure (3.3 GPa) indicate that T_v decreases linearly with increasing pressure to 1 GPa [2002Uch]. Similar results were obtained in [1992Mat, 1998Sar, 2003Mit]. The substitution by ions larger than the Yb ion increases the valency transition temperature and *vice versa*, substitution by smaller ions than the Yb ion decreases T_v [1987Fel1, 1987Fel2]. The temperature of the phase transition depends also on the composition of the samples [1999Loe1, 1999Loe2, 1999Sar, 2000Yos, 2003Mor]. The temperature-pressure phase diagram for $YbCu_4In$ is shown in Fig. 3 [2003Mit] and it suggests a first-order-like transition between the two magnetic phases at the critical pressure of ~2.45 GPa. According to the calculated phase diagram for $YbCu_4In$ [2003Mus1] the largest critical field is observed for the {110} axis and the smallest field is observed for the {100} axis (Fig. 4). The change in the valency transition temperature in relation to the crystal composition of $YbCu_4In$ compound is presented in Fig. 5.
Details of property studies of Cu-In-Yb alloys are listed in Table 3.

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Table 1: Investigations of the Cu-In-Yb Phase Relations, Structures and Thermodynamics

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[1987Adr]	X-ray powder diffraction Neutron diffraction	$YbCu_4In$
[1987Fel1]	X-ray diffraction study Neutron diffraction/IRR-2 nuclear reactor X-ray absorption/EXAFS-II Specific-heat measurements	4.2 - 300 K / $Yb_{0.4}In_{0.6}Cu_2$ 10 and 300 K / $Yb_{0.4}In_{0.6}Cu_2$ 6 - 300 K / $Yb_{0.4}In_{0.6}Cu_2$ 4.2 - 80 K / $Yb_{0.4}In_{0.6}Cu_2$
[1987Fel2]	X-ray powder diffraction	$Yb_xIn_{1-x}Cu_2$, x = 0.3, 0.4, 0.45, 0.5, 0.55
[1989Sys]	X-ray single crystal and powder diffraction/DRON-3.0 Laue method Weissenberg method	$YbCu_{5.1}In_{6.9}$
[1989Koj]	X-ray analysis Electron probe X-ray microanalysis	$Yb_xIn_{1-x}Cu_2$, x = 0.4 and 0.5
[1990Koj]	X-ray powder diffraction/ Rigaku RAD-IIC diffractometer TOF neutron powder diffraction/HRP diffractometer	4.2 - 300 K / $YbCu_4In$
[1992Gra]	Pressure dependence of the Cu-63 NQR	$YbCu_4In$
[1992Mat]	X-ray powder diffraction	$YbCu_4In$

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[1993Nak]	Magnetic susceptibility, electrical resistivity and low temperature specific heat	1.5 - 300 K, $YbCu_4In$
[1994Bau]	Transport and magnetic properties	$YbCu_4In$
[1994Kin]	Magnetic susceptibility, electrical resistivity and X-ray study of single crystal	$YbCu_4In$
[1994Oom]	X-ray diffraction at high pressure	Room temperature, $YbCu_4In$
[1995Alt]	Gd^{3+} - ESR and the static susceptibility	1.5 - 300 K, $YbCu_4In$
[1995Koj]	Electrical resistance as a function of temperature under various pressures	4.2 - 300 K, $YbCu_4In$
[1996Hau]	Pressure and field dependent study of magnetic susceptibility, electrical resistivity and low temperature specific heat	20 - 295 K, $YbCu_4In$
[1996Law]	Rietveld refinement of structure based on the neutron diffraction results	20 - 295 K, $YbCu_4In$
[1996Oku]	Valence-band photoemission spectra measurement	4.2 - 300 K, $YbCu_4In$
[1996Ter]	Volume thermal expansion measurements, effect of pressure and magnetic field on magnetic properties	4.2 - 300 K, $YbCu_4In$
[1997He]	Electrical resistivity, magnetic susceptibility and high field magnetization measurements	$YbIn_xCu_{5-x}$, $0.1 \le x \le 1.0$
[1997Imm]	High-field magnetoresistance under high pressure	4.2 - 300 K, $YbCu_4In$
[1997Law]	Inelastic neutron scattering	$YbCu_4In$
[1997Avi]	Magnetic anisotropy and the susceptibility of single crystals, using the torque and Faraday method	$YbCu_4In$
[1997Ret]	Electron-spin resonance measurements	$YbCu_4In$
[1998Fis]	X-ray powder diffraction/ Siemens D500 Thermoanalytical measurements/Netzsch STA 409 thermoanalyser DTA, SEM and EDX analyses/Zeiss DSM 940A scanning electron microscope, EDAX 9800	10 - 350 K / $YbCu_4In$
[1998Kal]	X-ray powder/ DRON-2.0, DRON-3.0, HZG-4a diffractometers and single crystal/SyntexP2 diffractometer phase analysis, Laue's method, Weissenberg method, Debye-Scherrer method, Microstructural analysis, Microhardness measurements	670 K / Cu-In-Yb in the whole concentration range
[1998Nak]	Cu-63 and In-115 Knight shifts	$YbCu_4In$
[1998Rei]	Temperature-dependent photoemission measurements	Single-crystalline $YbCu_4In$
[1998Sar]	Specific heat investigations/Standard semiadiabatic heat pulse technique. Pressure-dependent magnetic susceptibility	$YbCu_4In$
[1999Joy]	High resolution photoelectron spectroscopy	$YbCu_4In$

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[1999Law]	Neutron-scattering in the time-of-flight mode, magnetic susceptibility	30 K and 60 K, $YbCu_4In$
[1999Loe1]	Wavelength dispersive X-ray analysis, DTA	$YbCu_4In$
[1999Loe2]	Wavelength dispersive X-ray analysis, DTA	$YbCu_4In$
[1999Sar]	X-ray powder diffraction Specific heat measurements/thermal relaxation technique X-ray absorption study (Stanford Synchrotron Radiation Laboratory)	1.5 - 20 K, $YbCu_4In$
[1999Sok]	Magnitostriction measurements, using the three-terminal capacitance method up to magnetic field of 8 T	5 - 100 K, $YbCu_4In$
[1999Smi]	Electrical and thermal conductivity	4.2 - 300 K, $YbCu_4In$
[1999Sve2] [1999Sve3]	Magnetic susceptibility under helium pressure up to 2 kbar	78, 50 and 300 K, $YbCu_4In$
[2000Gar]	Infrared, visible and near-UV reflectivity measurements	$YbCu_4In$
[2000Hir]	X-ray single crystals and powder diffraction/flux method	$YbCu_4In$
[2000Moo]	Photoelectron spectroscopy	$YbCu_4In$
[2001Gio]	X-ray diffraction Metallographic examination SEM and EPMA analyses Specific heat measurements	Yb_2Cu_2In
[2001Koy]	Nuclear magnetic resonance	1.9 - 4.2 K, $YbCu_4In$
[2001Rei]	Temperature-dependent photoemission spectroscopy at photon energies of hν = 1486 eV (XPS)	$YbCu_4In$
[2001Sus]	High-resolution photoemission spectroscopy	4.2 - 100 K, $YbCu_4In$
[2001Tsu]	X-ray powder diffraction	Yb_2Cu_2In
[2002Jai]	Measuring of specific heat in the high magnetic field by means of the adiabatic calorimeter	$YbCu_4In$
[2003Hed]	Electrical resistivity under high pressures	Up to 33 mK, $YbCu_4In$
[2002Koy]	^{63}Cu NMR study, superconducting-quantum interference magnetometer	10 - 300 K, $YbCu_4In$
[2002Mur]	Inelastic neutron scattering	$YbCu_4In$
[2002Par]	Low-temperature X-ray diffractometry, total thermal conductivity, electrical resistivity	4 - 300 K, $YbIn_{0.905}Cu_{4.095}$ - $YbCu_4In$
[2002Sat]	Photoemission spectroscopy	10 - 300 K. $YbCu_4In$

Reference	Method/Experimental Technique	Temperature/Composition/Phase Range Studied
[2002Uch]	Temperature-dependent electrical resistivity measurements under hydrostatic pressure to p = 3.3 GPa	1.5 - 300 K, $YbCu_4In$
[2002Zha1] [2002Zha2]	Temperature dependence of magnetic susceptibility in the magnetic field of 0.2 T and high-field magnetization up to 41 T under various fixed pressures	2 - 320 K, $YbCu_4In$
[2003Luk]	X-ray single crystal diffraction Czochralski technique	Yb_2Cu_2In
[2003Mis]	Thermal conductivity	4.2 - 300 K, $YbCu_{4+x}In_{1-x}$, x = 0, 0.015, 0.095, 0.17
[2003Mit]	Electrical resistivity and ac-susceptibility at high pressures	1.5 - 100 K, $YbCu_4In$
[2003Mor]	X-ray single crystal diffraction Bridgman method Wavelength dispersive X-ray analysis/JCMA-733 II	$YbCu_4In$
[2003Mus1] [2003Mus2]	X-ray single crystal diffraction/Laue diffractometer, magnetic susceptibility and high field magnetization of single crystalline samples have been measured for different field orientations at ambient and high pressures	1.5 - 100 K, $YbCu_4In$
[2003Wad]	Electrical resistivity, static susceptibility, Cu-63 pure-quadrupole-resonance at high pressures	1.5 - 100 K, $YbCu_4In$
[2004Got]	High-field magnetization	Single crystalline $YbCu_4In$
[2004Mus1]	Pressure effect on magnetic susceptibility	Single crystalline $YbCu_4In$
[2004Mus2]	Magnetization and magnetostriction in pulsed magnetic fields up to 40 T	4.2 - 120 K, $YbCu_4In$
[2004Sat1] [2004Sat2] [2004Sat3]	High-resolution photoemission spectroscopy	1.5 - 220 K, $YbCu_4In$
[2004Yos]	High resolution low-energy excited photoemission spectroscopy	$YbCu_4In$
[2005Koy]	Cu-63 NQR measurements under pressure up to 2.5 GPa	1.5 - 250 K, $YbCu_4In$

Table 2: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(γYb) 819 - 795	*cI*2 *Im*$\overline{3}$*m* W	*a* = 444	[Mas2] no appreciable solid solubility of Cu in (Yb), dissolves up to ~2 at.% In at 750°C
(βYb) 795 - (–3)	*cF*4 *Fm*$\overline{3}$*m* Cu	*a* = 548.5	[Mas2] dissolves up to ~3 at.% In at 750°C
(αYb) < –3	*hP*2 *P*6_3*/mm* Mg	*a* = 301.5 *c* = 482.3	[Mas2]
(Cu) < 1084.62	*cF*4 *Fm*$\overline{3}$*m* Cu	*a* = 361.46	pure Cu at 25°C [Mas2] melting point [1994Sub] dissolves up to 0.03 at.% Yb at 859°C dissolves 10.9 at.% at 574°C
(In)	*tI*2 *I*4*/mmm* In	*a* = 325.3 *c* = 494.7	pure In at 25°C [Mas2] no appreciable solid solubility of Cu and Yb in (In)
α, Cu_4In 710 - 574	*cI*2 *Im*$\overline{3}$*m* W	*a* = 301.40 *a* = 304.61	20.50 at.% In at 625°C [1994Sub] 18.64 at.% In at 672°C [1941And]
β, Cu_7In_3 < 631	*aP*40 *P*$\overline{1}$ Cu_7In_3	*a* = 107.1 *b* = 913.1 *c* = 672.6 α = 90.2° β = 90.4° γ = 106.82° *a* = 1000 *b* = 910 *c* = 672 α = 89.9° β = 82.6° γ = 106.9°	30.0 at.% In [1980Vro] 29.6 at.% In [1994Sub]
γ, Cu_9In_4 684 - 631	*cP*52 *P*$\overline{4}$3*m* $InMn_3$ or Al_4Cu_9	*a* = 925.03	29.6 at.% In at 650°C [1951Rey]
δ_1, Cu_2In 667 - 440	*hP*6 *P*6_3*/mmc* Ni_2In	*a* = 412.0 *c* = 526.3	[V-C2]
δ_2, $Cu_7In_4(h_2)$ 480 - 350	*oP*55 ?	*a* = 2137.5 *b* = 740.5 *c* = 521.8	[1972Jai] superstructure of the Ni_2In type

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
δ_3, Cu_7In_4(h$_1$) 450 - 298	*oP*88 ?	*a* = 3419.4 *b* = 739.5 *c* = 526.2	[1972Jai] superstructure of the Ni_2In type
δ_4, Cu_7In_4(r) < 389	-	-	[1972Jai]
δ_5, $Cu_{15}In_8$ < 350	-	-	[1972Jai]
YbCu < 628	*oP*8 *Pnma* FeB	*a* = 756.53 *b* = 425.53 *c* = 576.67	[2002Rog]
$YbCu_2$ < 757	*oI*12 *Imma* $CeCu_2$	*a* = 428.6.6 to 429.1 *b* = 689.4 to 689.9 *c* = 738.2 to 738.6	[2002Rog]
$YbCu_2$(HP)	*hP*12 $P6_3/mm$ $MgZn_2$	*a* = 526.0 ± 0.5 *c* = 856.7 ± 0.8	[2002Rog]
Yb_2Cu_7	-	-	[2002Rog]
Yb_2Cu_9 < 937	*mC*7448 *C*2* Yb_2Cu_9	*a* = 4896.1 *b* = 4899.4 *c* = 4564.3 β = 91.24°	Monoclinic superstructure derived from cubic $AuBe_5$ type via the introduction of anti-phase boundaries and copper-deficient shear planes [2002Rog]
$YbCu_{6.5}$ < 879	*hP*6 *P*6/*mmm* $CaCu_5$	*a* = 499.2 to 500 *c* = 412.6 to 413	[2002Rog], the composition Yb_2Cu_{13} was attributed to a structure described with same lattice parameter with a random substitution of 18% of Yb-sites by Cu-pairs
$YbCu_5$	*cF*24 *P6/mmm* $AuBe_5$	*a* = 696.9	prepared at 1.5 GPa, 1000°C, but also found in as-cast alloys prepared under ambient pressure [2002Rog]
Yb_6Cu_{23}(HP)	*cF*116 $Fm\bar{3}m$ Th_6Mn_{23}	*a* = 1203 ± 1	[2002Rog]
Yb_5In_2 < 810	*hR*132 $R\bar{3}c$ Yb_5In_2	*a* = 954.5 ± 0.1 *c* = 5427.2 ± 0.7	[Mas2] [V-C2] gives stoichiometry Yb_8In_3
Yb_2In < 820	*oP*12 *Pnma* Co_2Si	*a* = 707.2 ± 0.2 *b* = 534.0 ± 0.1 *c* = 986.6 ± 0.5	[V-C2], [Mas2]
YbIn < 1067	*cP*2 $Pm\bar{3}m$ CsCl	*a* = 380.76 ± 0.04	[V-C2], [Mas2]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
$YbIn_2$ < 890	*hP*6 $P6_3/mm$ $CaIn_2$	*a* = 489.08 ± 0.03 *c* = 764.06 ± 0.09	[V-C2], [Mas2]
$YbIn_3$ < 630	*cP*4 $Pm\overline{3}m$ $AuCu_3$	*a* = 461.5 ± 0.1	[V-C2], [Mas2]
* τ_1, $YbCu_{5.1}In_{6.9}$	*tI*26 *I*4/*mmm* $ThMn_{12}$	*a* = 921.9 *c* = 538.9	[1998Kal, 2005Kal]
* τ_2,$YbCu_{4.8–4.0}In_{0.2–1.0}$	*cF*24 $F\overline{4}3m$ $MgCu_4Sn$	*a* = 703.5 to 714.5	[1998Kal, 2005Kal]
* τ_3, Yb_2Cu_2In	*oI*10 *Immm* W_2CoB_2	*a* = 438.8 ± 0.5 *b* = 574.30 ± 0.06 *c* = 873.37 ± 0.09	[2001Gio]
* τ_3', Yb_2Cu_2In (I)	*tP*10 *P*4/*mbm* Mo_2B_2Fe	*a* = 747.3 *c* = 389.2	[2001Tsu], prepared under a pressure of 3.5 GPa at 600°C
* τ_4, Yb_3CuIn_2	-	-	[1998Kal, 2005Kal]
* τ_5, Yb_4CuIn	-	-	[1998Kal, 2005Kal]

Table 3: Investigations of the Cu-In-Yb Materials Properties

Reference	Method/Experimental Technique	Type of Property
[1987Fel1]	Magnetic and electrical investigations Mössbauer spectroscopy	Magnetic susceptibility and electrical resistivity For ^{170}Yb isotope
[1987Fel2]	Magnetic study/RAR vibrating sample magnetometer	Susceptibility
[1989Koj]	Magnetic measurements	Magnetic susceptibility
[1992Mat]	Magnetic and electrical investigations	Magnetic susceptibility, electrical resistivity as a function of pressure and temperature
[1992Gra]	^{63}Cu NQR	$YbCu_4In$
[1997Avi]	Torque and Faraday methods	Magnetic anisotropy and susceptibility
[1998Sar]	Calorimetry, pressure-dependent magnetic measurements	Specific heat, complete elastic moduli, magnetic susceptibility, Gruneisen parameter
[1999Law]	Neutron scattering experiments	Magnetic susceptibility
[1999Sar]	Magnetic study/ superconducting - quantum - interference - device magnetometer Electrical measurements	Magnetic susceptibility, Magnetization measurements Resistivity
[1999Smi]	Measurement of transport properties	Electrical and thermal conductivity

Reference	Method/Experimental Technique	Type of Property
[1999Sok]	Three-terminal capacitance method	Magnetostriction
[2000Hir]	^{63}Cu NQR NMR measurements /conventional phase coherent pulsed spectrometer	$YbCu_4In$ Magnetic susceptibility
[2000Yos]	Magnetic study	Magnetic susceptibility
[2001Tsu]	Magnetic measurements / superconducting - quantum - interference - device magnetometer	Magnetic susceptibility
[2001Gio]	Magnetic and electrical investigations	Magnetic susceptibility, electrical resistivity
[2002Par]	Measurements of transport properties	Total thermal conductivity and electrical resistivity
[2002Uch]	Electrical measurements	Electrical resistivity
[2002Koy]	^{63}Cu NMR Magnetic study	Magnetic susceptibility
[2003Luk]	Magnetic and resistivity measurements	Magnetic susceptibility and electrical resistivity
[2003Mit]	Magnetic and resistivity measurements	Electrical resistivity, ac susceptibility at high pressures
[2003Mis]	Measurements of transport properties	Thermal conductivity and electrical resistivity
[2003Mor]	Electrical investigations	Electrical resistivity
[2003Mus1] [2003Mus2]	Magnetic measurements, superconducting-quantum-interference-device magnetometer	Susceptibility and high-field magnetization at ambient and high pressures
[2003Wad]	Measurements of magnetic properties in the pulsed magnetic field	Magnetization and magnetostriction at high pressures

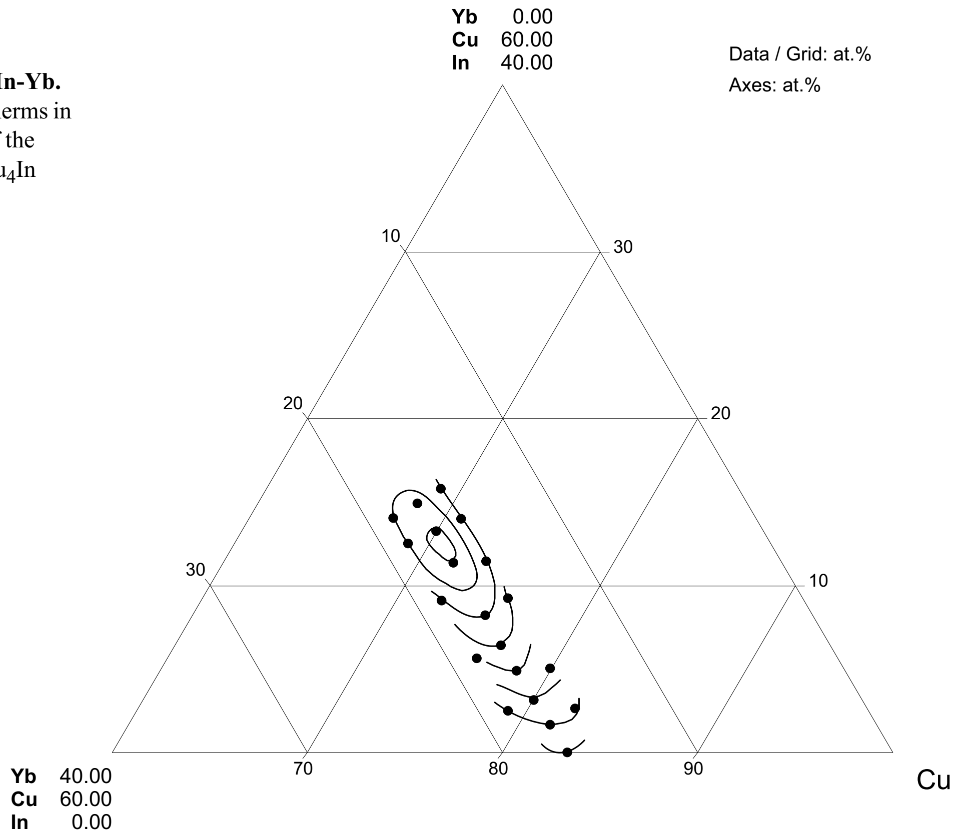

Fig. 1: Cu-In-Yb. Liquidus isotherms in the vicinity of the Yb_2Cu_9-$YbCu_4In$ section

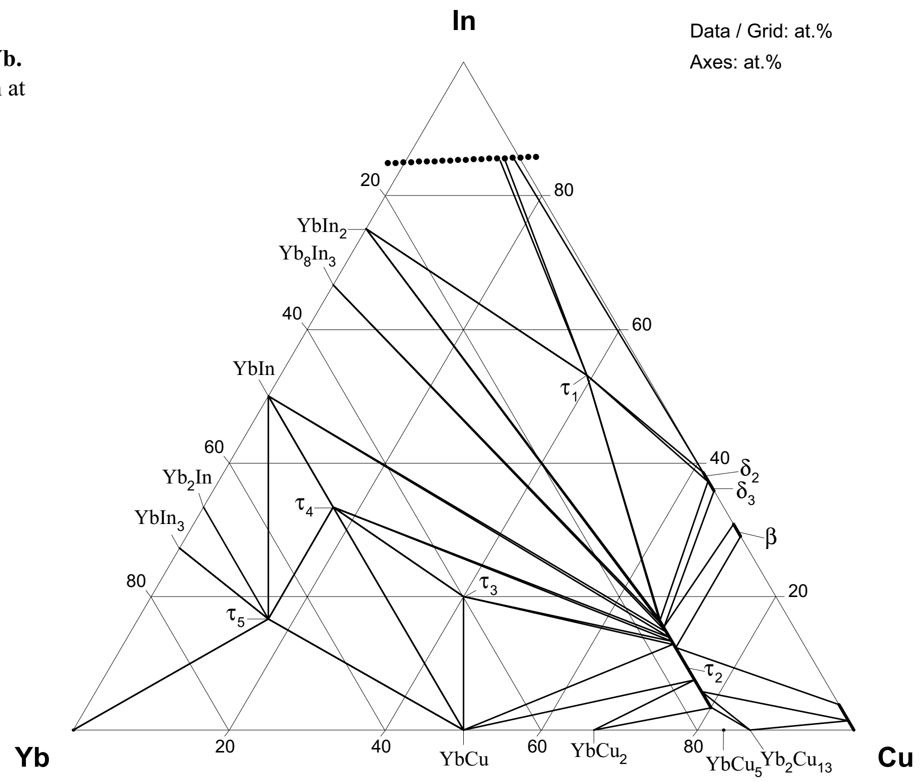

Fig. 2: Cu-In-Yb. Isothermal section at 400°C

Fig. 3: Cu-In-Yb. The temperature -pressure phase diagram for $YbCu_4In$.
T_V - temperature of valence transition,
T_M - temperature of magnetic transition

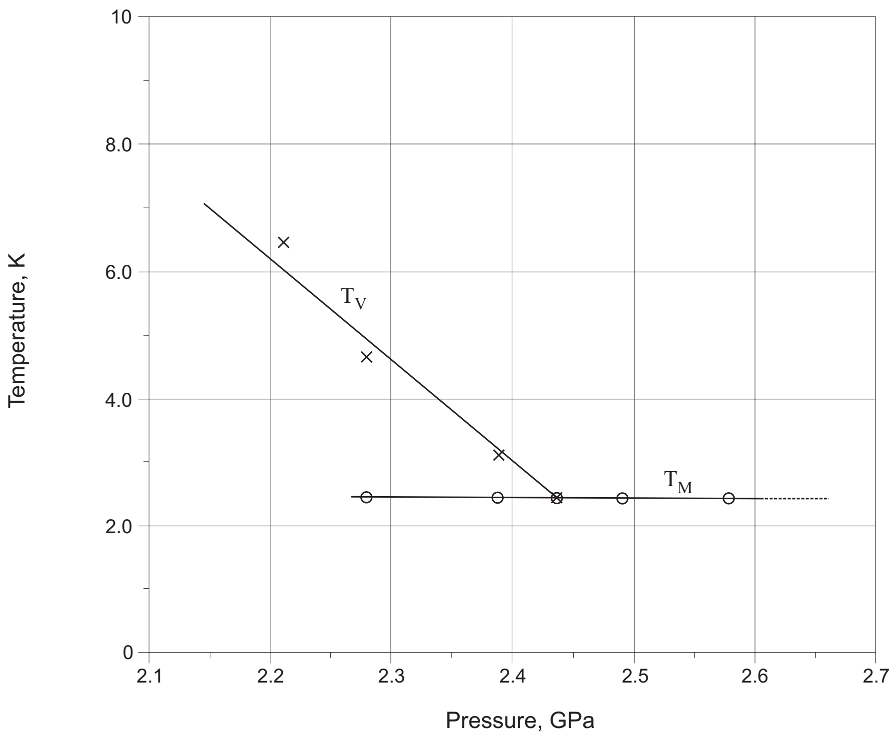

Fig. 4: Cu-In-Yb. The calculated magnetic phase diagram for $YbCu_4In$

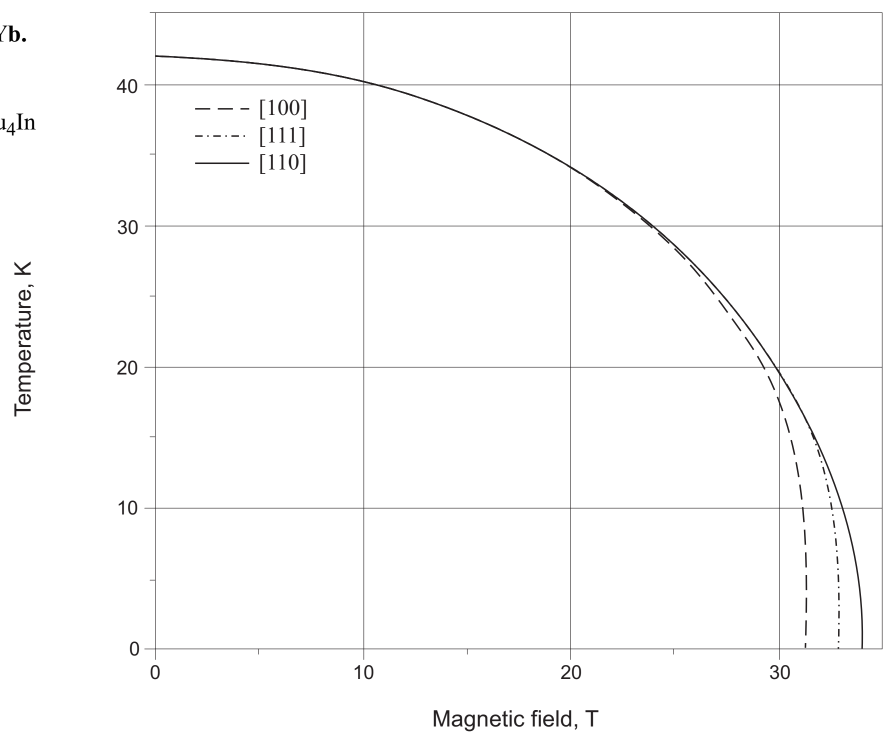

Fig. 5: Cu-In-Yb. Dependence of the valence transition temperature on the crystal composition of $YbCu_4In$