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Supplementary

Microstructure and Phase Transition of $Ag_{50.5}Cu_{33.3}Sn_{16.2-x}In_x$ Alloys through Experimental Study and Thermodynamic Calculation

Qingsong Tong, Maohua Rong * and Jiang Wang *

School of Materials Science and Engineering & Guangxi Key Laboratory of Information Materials, Guilin University of Electronic Technology, Guilin 541004, China; 13635644432@163.com

* Correspondence: rongmh124@guet.edu.cn (M.R.); waj124@guet.edu.cn (J.W.)

Table S1 Thermodynamic parameters of the Ag-Cu-Sn-In quaternary system

Phase	Thermodynamic parameters	Reference
liquid	${}^{0}L^{liq}_{Ag,Cu} = 16914.949 - 14.7721T + 1.54955TlnT;\ {}^{1}L^{liq}_{Ag,Cu} = -1963.300 + 0.8623T$	[28]
	${}^{0}L^{liq}_{Ag,In} = -26499.412 + 66.148718T - 8.6214682TlnT$	[29]
	${}^{1}L^{liq}_{Ag,In} = -38058.4 + 143.60133T - 17.657918TlnT$	[29]
	${}^{2}L^{liq}_{Ag,In} = -16572.628 + 121.0128T - 15.89588TlnT;\ {}^{3}L^{liq}_{Ag,In} = 5791.2978$	[29]
	${}^{0}L^{liq}_{Ag,Sn} = -3177.49 - 10.16124T + 0.380505TlnT$	[30]
	${}^{1}L^{liq}_{Ag,Sn} = -16782.28 + 2.06521T + 0.437477TlnT$	[30]
	${}^{2}L^{liq}_{Ag,Sn} = 3190.34 - 107.09456T + 13.954838TlnT$	[30]
	${}^{0}L^{liq}_{Cu,In} = -41564.8 + 238.616T - 29.827TlnT;\ {}^{1}L^{liq}_{Cu,In} = -76057.8 + 371.306T - 44.994TlnT$	[31]
	${}^{2}L^{liq}_{Cu,In} = -42076.5 + 192.395T - 23.281TlnT$	[31]
	${}^{0}L^{liq}_{Cu,Sn} = -9002.8 - 5.8381T;\ {}^{1}L^{liq}_{Cu,Sn} = -20100.4 + 3.63666T;\ {}^{2}L^{liq}_{Cu,Sn} = -10528.40$	[32]
	${}^{0}L^{liq}_{In,Sn} = -711 - 1.6934T;\ {}^{1}L^{liq}_{In,Sn} = -64 - 1.3592T$	[33]
	${}^{0}L^{liq}_{Ag,Cu,Sn} = -80000 + 27.98T;\ {}^{1}L^{liq}_{Ag,Cu,Sn} = -85233 + 29.44T;\ {}^{2}L^{liq}_{Ag,Cu,Sn} = -40000 + 26.56T$	[12]
	${}^{0}L^{liq}_{Ag,Cu,In} = -50066 + 24.15T;\ {}^{1}L^{liq}_{Ag,Cu,In} = -134807 + 94.27T;\ {}^{2}L^{liq}_{Ag,Cu,In} = 31076 - 167.55T$	[34]
	${}^{0}L^{liq}_{Ag,In,Sn} = 64697 - 8.82T;\ {}^{1}L^{liq}_{Ag,In,Sn} = 23474 - 22.792T;\ {}^{2}L^{liq}_{Ag,In,Sn} = 13374 - 27.171T$	[34]
	${}^{0}L^{liq}_{Cu,In,Sn} = 92284.1485 - 57.897T;\ {}^{1}L^{liq}_{Cu,In,Sn} = -17306.1096 + 20.828T;$	[34]
	${}^{2}L^{liq}_{Cu,In,Sn} = -1332.422 - 26.208T$	[34]
Fcc	${}^{0}L^{Fcc}_{Ag,Cu} = 32580.365 - 7.4547T;\ {}^{1}L^{Fcc}_{Ag,Cu} = -10144.596 + 5.5617T$	[28]
	${}^{0}L^{Fcc}_{Ag,In} = -17978.868 + 10.39293T;\ {}^{1}L^{Fcc}_{Ag,In} = -32794.133$	[29]
	${}^{0}L^{Fcc}_{Ag,Sn} = 745.45 + 11.498027T;\ {}^{1}L^{Fcc}_{Ag,Sn} = -36541.5$	[30]
	${}^{0}L^{Fcc}_{Cu,In} = -6475.9 + 21.830T;\ {}^{1}L^{Fcc}_{Cu,In} = -29935.2 - 5.672T;\ {}^{2}L^{Fcc}_{Cu,In} = 47350.2 - 40.210T$	[31]
	${}^{0}L^{Fcc}_{Cu,Sn} = -10672 - 1.4837T;\ {}^{1}L^{Fcc}_{Cu,Sn} = -15331.3 + 6.9539T$	[32]
	${}^{0}L^{Fcc}_{In,Sn} = 25000$	[33]
	${}^{0}L^{Fcc}_{Ag,Cu,In} = -273196 + 190T;\ {}^{1}L^{Fcc}_{Ag,Cu,In} = 85251.5$	[34]
	${}^{0}L^{Fcc}_{Ag,In,Sn} = 105437 - 27.156T;\ {}^{1}L^{Fcc}_{Ag,In,Sn} = 173115;\ {}^{2}L^{Fcc}_{Ag,In,Sn} = 121030$	[34]
	${}^{0}L^{Fcc}_{Cu,In,Sn} = -55000;\ {}^{1}L^{Fcc}_{Cu,In,Sn} = -55000;\ {}^{2}L^{Fcc}_{Cu,In,Sn} = -55000$	[34]
Bcc	${}^{0}L^{Bcc}_{Ag,In} = 2858.3 - 14.059T;\ {}^{1}L^{Bcc}_{Ag,In} = -80876.7 + 17.445T;\ {}^{2}L^{Bcc}_{Ag,In} = 31125.1$	[29]
	${}^{0}L^{Bcc}_{Cu,In} = -20532.763 + 12.724T;\ {}^{1}L^{Bcc}_{Cu,In} = -13379.27 - 12.358T$	[31]
	${}^{0}L^{Bcc}_{Cu,Sn} = -32656.8 + 25.0158T;\ {}^{1}L^{Bcc}_{Cu,Sn} = -13862.5 - 32.0218T$	[32]
	${}^{2}L^{Bcc}_{Cu,Sn} = -4175.47 + 5.0083T$	[32]
	${}^{0}L^{Bcc}_{Ag,Cu} = -12440.6 + 24.382T$	[34]
	${}^{0}L^{Bcc}_{In,Sn} = 25000$	[34]
	${}^{0}L^{Bcc}_{Ag,Cu,In} = 313800 - 266.2T;\ {}^{1}L^{Bcc}_{Ag,Cu,In} = 210500 - 276.05T;\ {}^{2}L^{Bcc}_{Ag,Cu,In} = 1200$	[34]

	$^{0}L^{Bcc}_{Cu,In,Sn} = 18052.7;\ ^{1}L^{Bcc}_{Cu,In,Sn} = -9000;\ ^{2}L^{Bcc}_{Cu,In,Sn} = 25000$	[34]
Hcp	$^{0}L^{Hcp}_{Ag,In} = -15502.468 + 9.129T;\ ^{1}L^{Hcp}_{Ag,In} = -60975.391 + 4.723T;\ ^{2}L^{Hcp}_{Ag,In} = 31769.287$	[29]
	$^{0}L^{Hcp}_{Ag,Sn} = 1046.1 + 10.23693T;\ ^{1}L^{Hcp}_{Ag,Sn} = -40505.5$	[30]
	$^{0}L^{Hcp}_{Ag,Cu} = 20573.1$	[34]
	$^{0}L^{Hcp}_{In,Sn} = 25700$	[34]
	$^{0}L^{Hcp}_{Ag,Cu,In} = -308146.1 + 334.359T$	[34]
	$^{0}L^{Hcp}_{Ag,In,Sn} = 9456 - 10.641T;\ ^{1}L^{Hcp}_{Ag,In,Sn} = 77280 + 1.308T;\ ^{2}L^{Hcp}_{Ag,In,Sn} = 76616 - 29.97T$	[34]
β-InSn	$^{0}L^{\beta-InSn}_{In,Sn} = 35.7 - 4.561T$	[33]
γ-InSn	$^{0}L^{\gamma-InSn}_{In,Sn} = -15715.5 + 19.3402T$	[33]
Bct	$^{0}L^{Bct}_{In,Sn} = -239 + 2.8509T$	[33]
Tetragonal	$^{0}L^{Tetragonal}_{In,Sn} = 718 - 1.495T;\ ^{1}L^{Tetragonal}_{In,Sn} = -2217$	[33]
$AgIn_2$	$^{0}G^{AgIn2}_{Ag:In} = -8059.1667 + 8.583T + 0.333\,^{0}G^{Fcc}_{Ag} + 0.667\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{0}G^{AgIn2}_{Cu:In} = 0.333\,^{0}G^{Fcc}_{Cu} + 0.667\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{1}G^{AgIn2}_{Ag,Cu:In} = -9466.667$	[29]
Ag_9In_4	$^{0}G^{Ag9In4}_{Ag:Ag:In:In} = -8200.208 - 0.48T + 0.692\,^{0}G^{Fcc}_{Ag} + 0.308\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{0}G^{Ag9In4}_{Ag:In:In:In} = 0.462\,^{0}G^{Fcc}_{Ag} + 0.538\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{0}G^{Ag9In4}_{Ag:Cu:In:In} = -3150.854 + 3.578T + 0.462\,^{0}G^{Fcc}_{Ag} + 0.231\,^{0}G^{Fcc}_{Cu} + 0.307\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{0}G^{Ag9In4}_{Ag:Ag,In:In:In} = -5300;\ ^{0}G^{Ag9In4}_{Ag:Ag,Cu:In:In} = -8174.992$	[29]
Ag_3Sn	$^{0}G^{Ag3Sn}_{Ag,Ag} = 4750 - 0.5T + {}^{0}G^{Fcc}_{Ag}$	[30]
	$^{0}G^{Ag3Sn}_{Ag,Sn} = -11085.3 + 110.01471T - 23.18TlnT - 0.00359T^{-2} + 4389.5T^{-1}$	[30]
γ-CuIn	$^{0}G^{\gamma-CuIn}_{Cu:Cu:In} = -2201.8 - 3.443T + 0.769\,^{0}G^{Fcc}_{Cu} + 0.231\,^{0}G^{Tetragonal}_{In}$	[31]
	$^{0}G^{\gamma-CuIn}_{Cu:In:In} = -7131.6 + 0.112T + 0.654\,^{0}G^{Fcc}_{Cu} + 0.346\,^{0}G^{Tetragonal}_{In}$	[31]
	$^{0}G^{\gamma-CuIn}_{Ag:Ag:In} = -1620.0692 - 6.5712T + 0.769\,^{0}G^{Fcc}_{Ag} + 0.231\,^{0}G^{Tetragonal}_{In}$	[34]
	$^{0}G^{\gamma-CuIn}_{Ag:In:In} = 200 + 0.654\,^{0}G^{Fcc}_{Ag} + 0.346\,^{0}G^{Tetragonal}_{In};\ ^{0}G^{\gamma-CuIn}_{Ag:Ag,In:In} = -8456.9907 + 9.1312T$	[34]
	$^{0}G^{\gamma-CuIn}_{Ag,Cu:Cu:In} = -24700 - 25T$	[34]
δ-Cu_7In_3	$^{0}G^{\delta-Cu_7In_3}_{Cu:In} = -7991.3 + 1.170T + 0.7\,^{0}G^{Fcc}_{Cu} + 0.3\,^{0}G^{Tetragonal}_{In}$	[31]
	$^{0}G^{\delta-Cu_7In_3}_{Ag:In} = 0.7\,^{0}G^{Fcc}_{Cu} + 0.3\,^{0}G^{Tetragonal}_{In}$	[29]
	$^{1}G^{\delta-Cu_7In_3}_{Ag,Cu:In} = 53045.9 - 93.729T$	[29]
η-LT	$^{0}G^{\eta-LT}_{Cu,In} = -8173.8 + 1.380T + 0.64\,^{0}G^{Fcc}_{Cu} + 0.36\,^{0}G^{Tetragonal}_{In}$	[31]

$Cu_{11}In_9$	$^0G_{Cu:In}^{Cu_{11}In_9} = -7525.6 + 1.703T + 0.55\,^0G_{Ag}^{Fcc} + 0.45\,^0G_{In}^{Tetragonal}$	[31]
	$^0G_{Ag:In}^{Cu_{11}In_9} = 0.55\,^0G_{Ag}^{Fcc} + 0.45\,^0G_{In}^{Tetragonal}$	[29]
	$^0G_{Ag,Cu:In}^{Cu_{11}In_9} = 10800 - 12T$	[34]
Cu_3Sn	$^0G_{Cu:Sn}^{Cu_3Sn} = -8194.2 - 0.2043T + 0.75\,^0G_{Cu}^{Fcc} + 0.25\,^0G_{Sn}^{Bct}$	[32]
	$^0G_{Cu:In}^{Cu_3Sn} = -7200 - 4T + 0.75\,^0G_{Cu}^{Fcc} + 0.25\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Cu:In,Sn}^{Cu_3Sn} = -5800 + 3T$	[34]
$Cu_{10}Sn_3$	$^0G_{Cu:Sn}^{Cu_{10}Sn_3} = -6655.1 - 1.485T + 0.769\,^0G_{Cu}^{Fcc} + 0.231\,^0G_{Sn}^{Bct}$	[32]
$Cu_{41}Sn_{11}$	$^0G_{Cu:Sn}^{Cu_{41}Sn_{11}} = -6323.5 - 1.2808T + 0.788\,^0G_{Cu}^{Fcc} + 0.212\,^0G_{Sn}^{Bct}$	[32]
	$^0G_{Cu:In}^{Cu_{41}Sn_{11}} = -5350 + 1.5T + 0.788\,^0G_{Cu}^{Fcc} + 0.212\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Cu:In,Sn}^{Cu_{41}Sn_{11}} = -13000 + 14.77T$	[34]
Cu_6Sn_5-l	$^0G_{Cu,Sn}^{Cu_6Sn_5-l} = -7129.7 + 0.4059T + 0.545\,^0G_{Cu}^{Fcc} + 0.455\,^0G_{Sn}^{Bct}$	[32]
Cu_6Sn_5-h	$^0G_{Cu:Cu:In}^{Cu_6Sn_5-h} = -6301.5 - 0.940T + 0.667\,^0G_{Cu}^{Fcc} + 0.333\,^0G_{In}^{Tetragonal}$	[31]
	$^0G_{Cu:Cu:Sn}^{Cu_6Sn_5-h} = 3200 + 2T + 0.667\,^0G_{Cu}^{Fcc} + 0.333\,^0G_{Sn}^{Bct}$	[32]
	$^0G_{Cu:In:In}^{Cu_6Sn_5-h} = -156.7 - 7.030T + 0.545\,^0G_{Cu}^{Fcc} + 0.455\,^0G_{In}^{Tetragonal}$	[32]
	$^0G_{Cu:In:Sn}^{Cu_6Sn_5-h} = -2492 + +4T + 0.545\,^0G_{Cu}^{Fcc} + 0.122\,^0G_{In}^{Tetragonal} + 0.333\,^0G_{Sn}^{Bct}$	[34]
	$^0G_{Cu:Sn:In}^{Cu_6Sn_5-h} = 16000 + 0.545\,^0G_{Cu}^{Fcc} + 0.122\,^0G_{Sn}^{Bct} + 0.333\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Cu:Sn:Sn}^{Cu_6Sn_5-h} = -6869.5 - 0.1589T + 0.545\,^0G_{Cu}^{Fcc} + 0.455\,^0G_{Sn}^{Bct}$	[32]
	$^0G_{Cu:Cu,In:In}^{Cu_6Sn_5-h} = -14526.5 + 18.020T$	[31]
	$^0G_{Cu:Cu,In:Sn}^{Cu_6Sn_5-h} = -14526.546 + 18.020T;\ ^0G_{Cu:Cu,Sn:In}^{Cu_6Sn_5-h} = -37093.16 + 18.520T$	[34]
	$^0G_{Cu:Cu,Sn:Sn}^{Cu_6Sn_5-h} = -8300;\ ^0G_{Cu:In,Sn:In}^{Cu_6Sn_5-h} = -8300;\ ^0G_{Cu:In,Sn:Sn}^{Cu_6Sn_5-h} = -8300$	[34]
	$^0G_{Cu:Cu:In,Sn}^{Cu_6Sn_5-h} = -19650.8 - 0.4T;\ ^0G_{Cu:In:In,Sn}^{Cu_6Sn_5-h} = -44570.8 + 39.6T$	[34]
	$^0G_{Cu:Sn:In,Sn}^{Cu_6Sn_5-h} = -30000 + T$	[34]
	$^0G_{Ag:Cu:In}^{Cu_6Sn_5-h} = 200 + 0.545\,^0G_{Ag}^{Fcc} + 0.122\,^0G_{Cu}^{Fcc} + 0.333\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Ag:In:In}^{Cu_6Sn_5-h} = 200 + 0.545\,^0G_{Ag}^{Fcc} + 0.455\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Cu:Cu,In:In}^{Cu_6Sn_5-h} = -14526.5 + 18.020T$	[31]
	$^0G_{Cu:Ag,Cu:In}^{Cu_6Sn_5-h} = -1000;\ ^0G_{Ag,Cu:Cu:In}^{Cu_6Sn_5-h} = -2000;\ ^0G_{Ag,Cu:In:In}^{Cu_6Sn_5-h} = 2000$	[34]
τ_1-$Cu_{11}In_2Sn$	$^0G_{Cu:In}^{Cu_{11}In_2Sn} = -5250 + 0.77\,^0G_{Cu}^{Fcc} + 0.23\,^0G_{In}^{Tetragonal}$	[34]
	$^0G_{Cu:Sn}^{Cu_{11}In_2Sn} = -7000 + T + 0.77\,^0G_{Cu}^{Fcc} + 0.23\,^0G_{Sn}^{Bct}$	[34]
	$^0G_{Cu:In,Sn}^{Cu_{11}In_2Sn} = -4800$	[34]
τ_2-Cu_2In_3Sn	$^0G_{Cu:In:Sn}^{Cu_2In_3Sn} = -9235 + 5T + 0.333\,^0G_{Cu}^{Fcc} + 0.5\,^0G_{In}^{Tetragonal} + 0.167\,^0G_{Sn}^{Bct}$	[34]