Supplementary Information

Understanding the Effect of Reflow Profile on the Metallurgical Properties of Tin-Bismuth Solders

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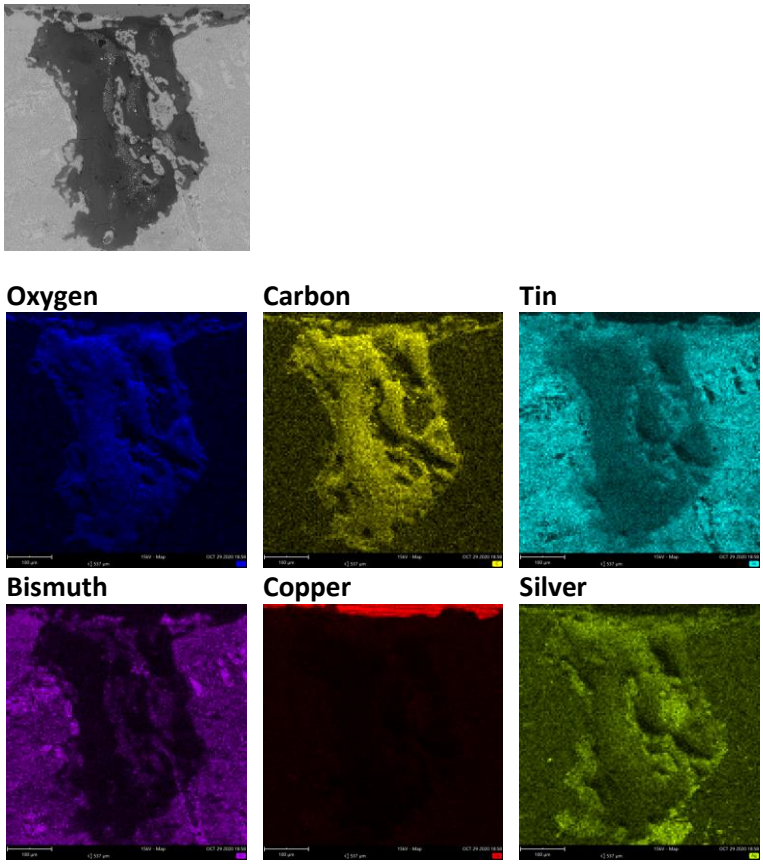


Figure S1: SEM/EDX (mapping) analysis of black residue

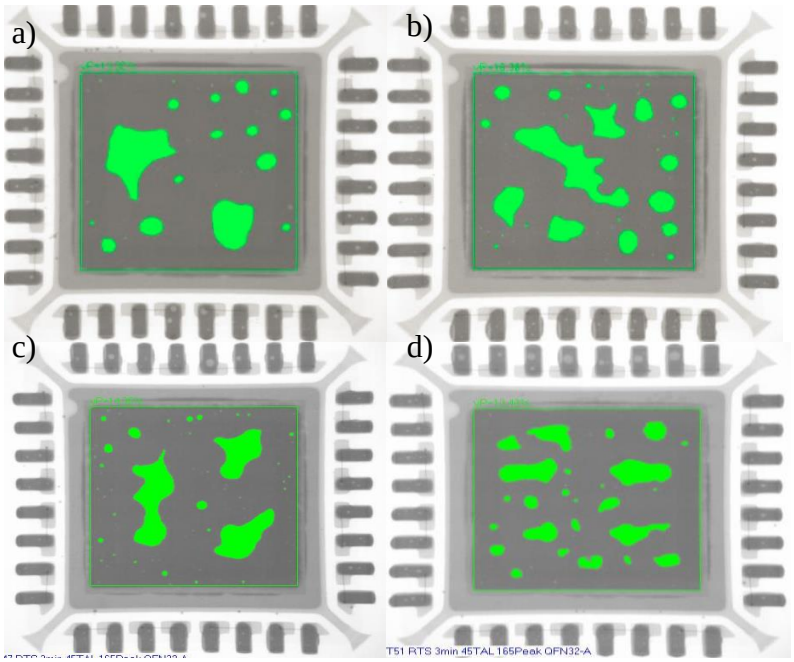
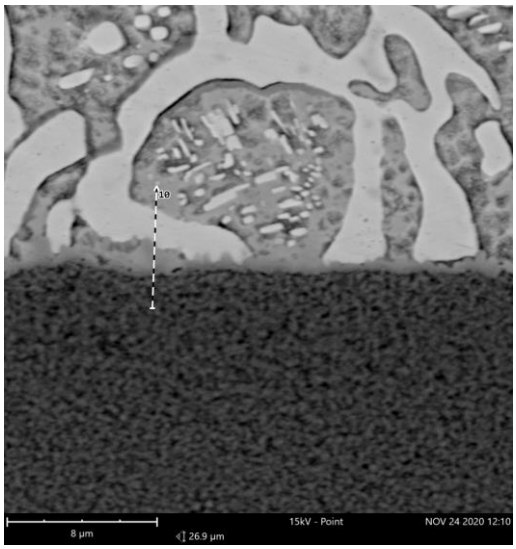


Figure S2 Representative 2D X-ray images for a QFN32 component reflowed with (**a**) 42Sn58Bi, (**b**) 42Sn57Bi1Ag, (**c**) LT 47 and (**d**) LT 51.



Element Symbol	Atomic Conc.	Weight Conc.
C	31.11	5.97
O	21.65	5.53
Cu	16.94	17.18
Sn	14.27	27.04
Bi	12.77	42.59

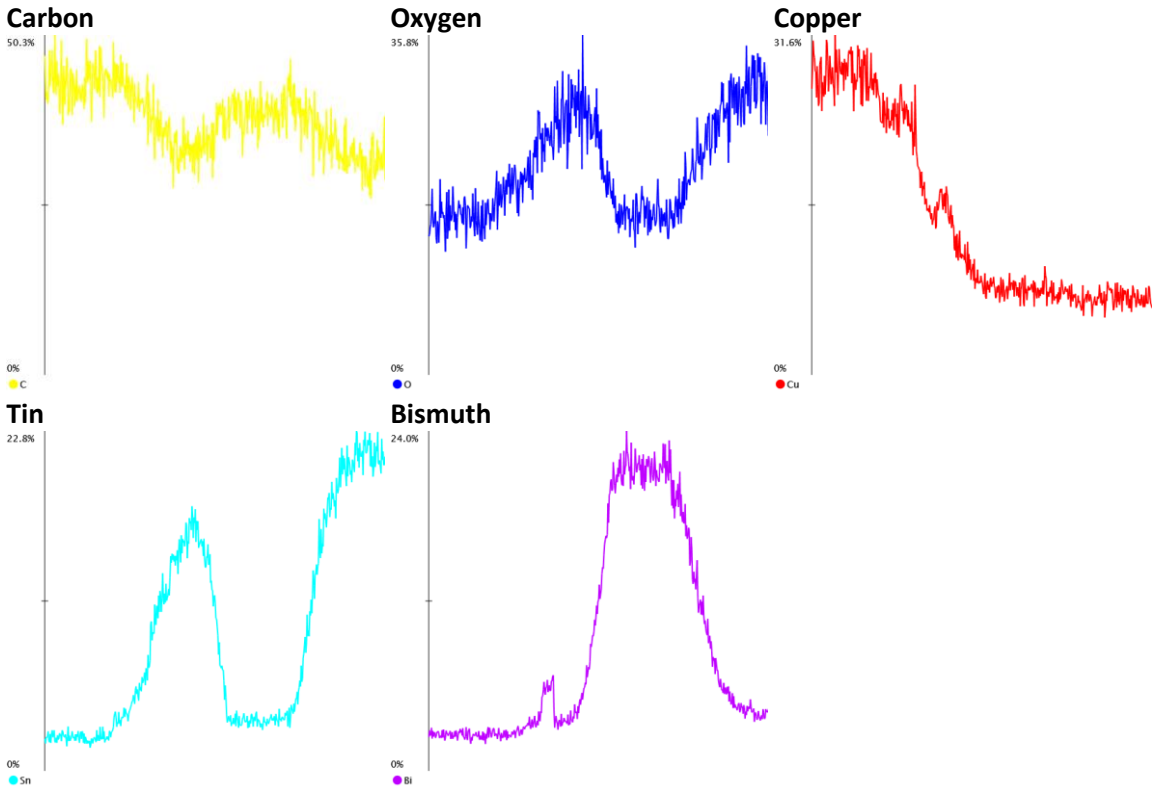
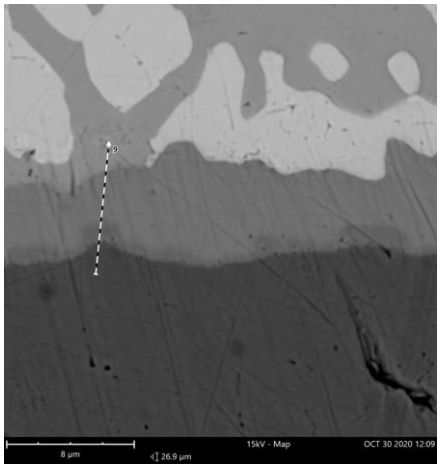


Figure S3: Intermetallic layer with the copper substrate of sample (42Sn58Bi solder alloy, reflow profile 1) before aging analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	33.19	8.02
Cu	24.80	31.70
O	18.79	6.05
Sn	17.39	41.53
Bi	1.98	8.34
Ag	0.54	1.17

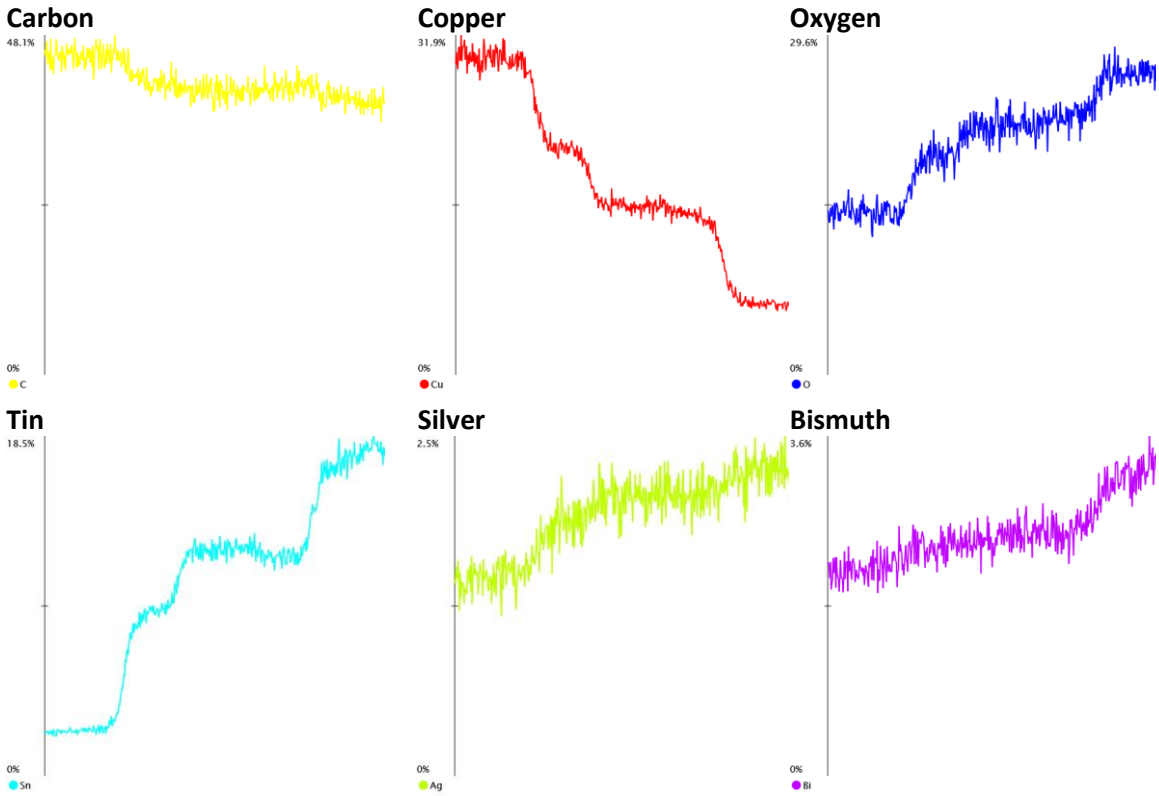
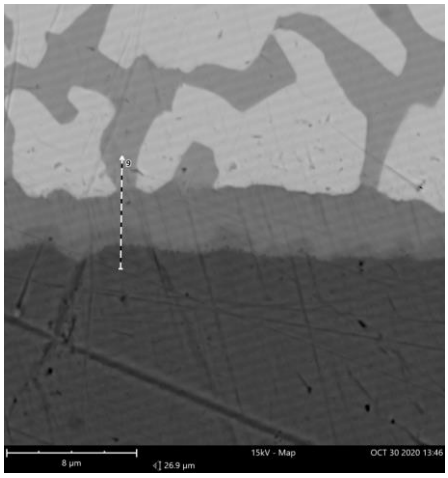


Figure S4-1: Intermetallic layer with the copper substrate of sample **(42Sn58Bi solder alloy, reflow profile 1)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	27.27	30.87
C	26.38	5.65
Sn	21.31	45.07
O	19.22	5.48
Bi	2.77	10.33

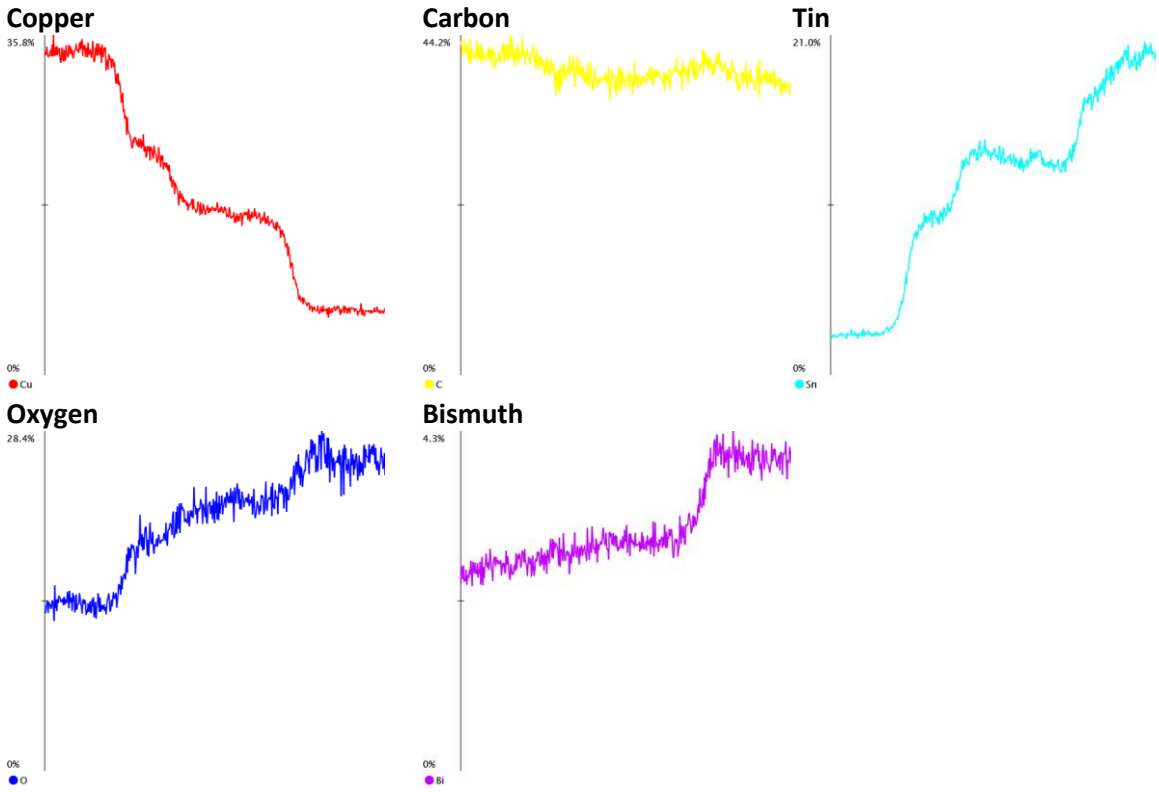
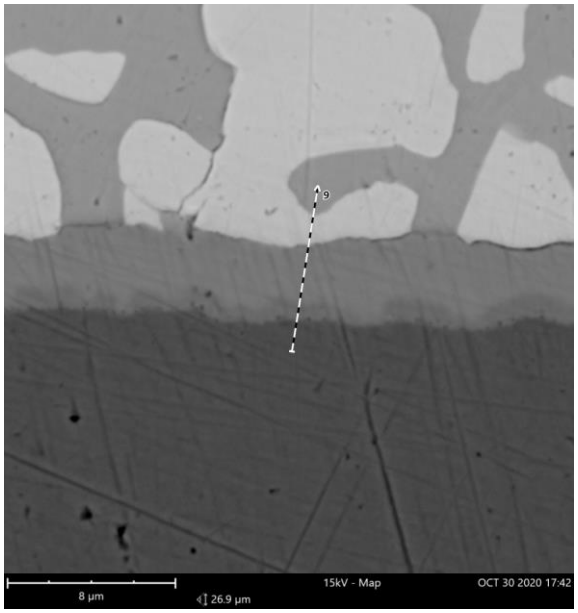


Figure S4-2: Intermetallic layer with the copper substrate of sample **(42Sn58Bi solder alloy, reflow profile 2)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	26.33	25.65
C	25.06	4.61
O	18.85	4.62
Sn	18.80	34.22
Bi	9.44	30.25

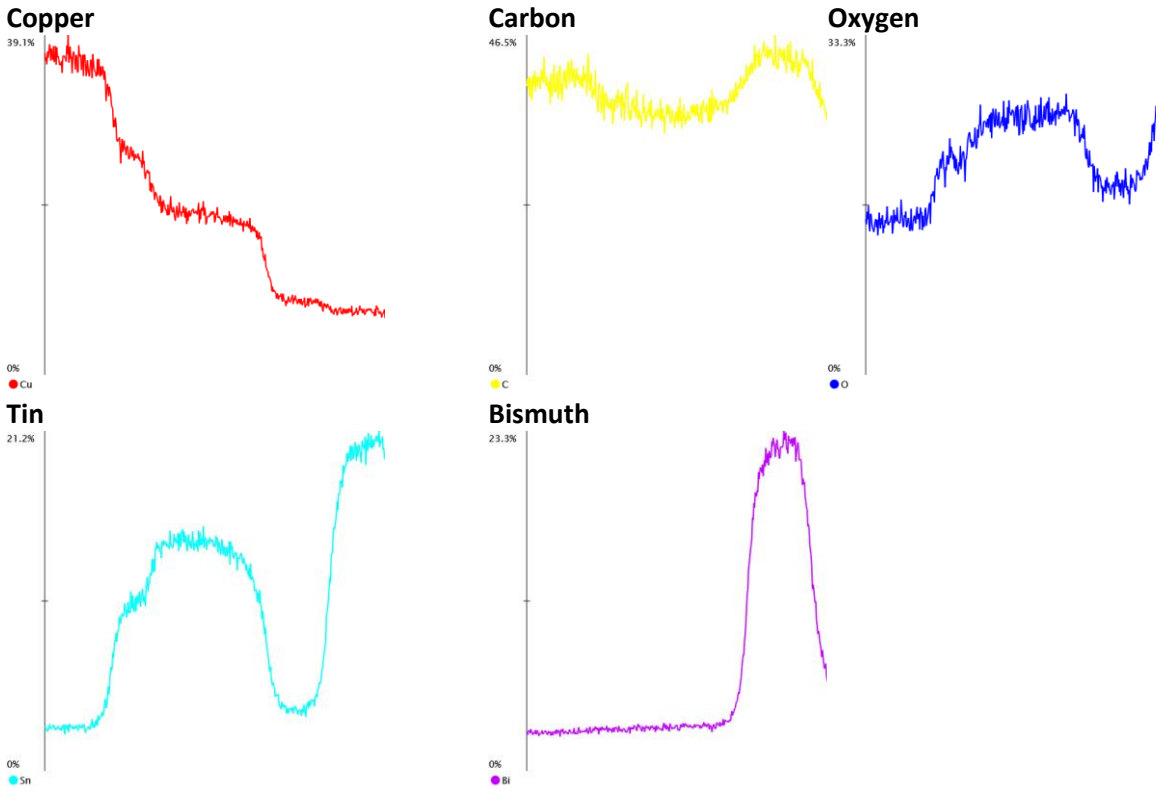
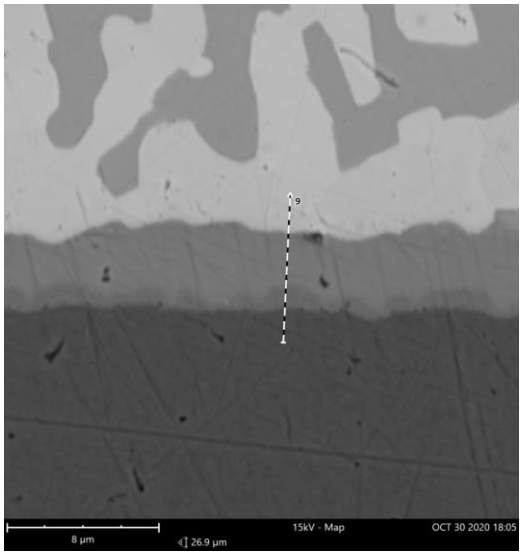


Figure S4-3: Intermetallic layer with the copper substrate of sample **(42Sn58Bi solder alloy, reflow profile 3)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	27.98	5.19
Cu	26.61	26.12
O	13.53	3.34
Sn	12.90	23.66
Bi	12.31	39.74

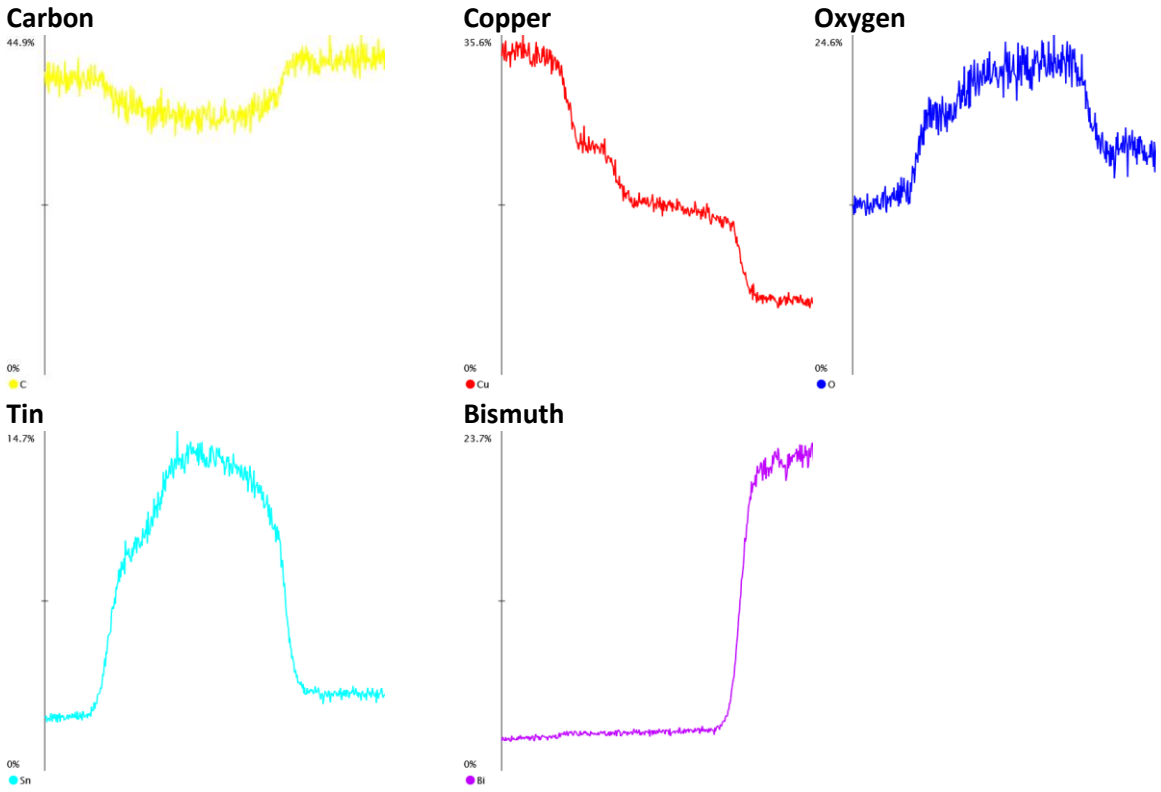
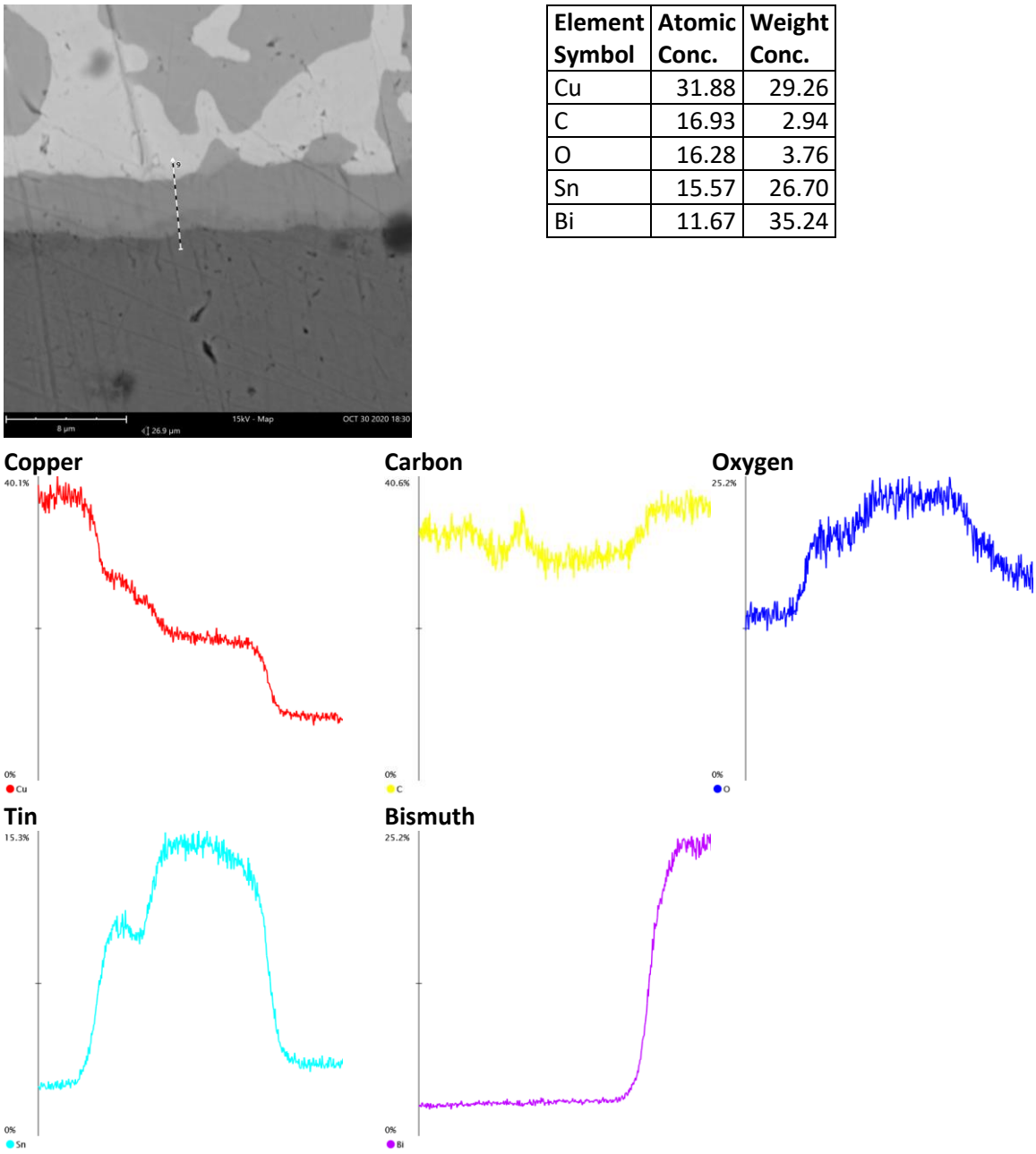
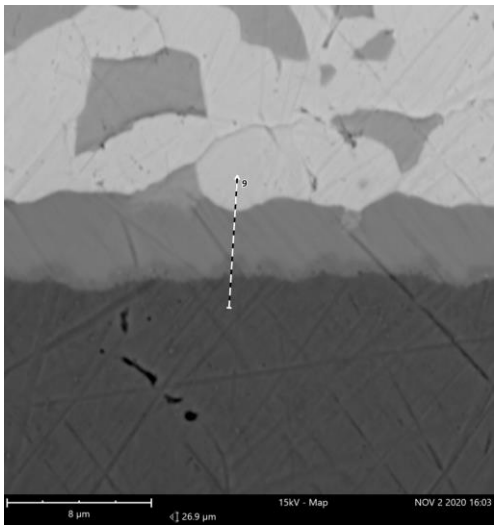


Figure S4-4: Intermetallic layer with the copper substrate of sample **(42Sn58Bi solder alloy, reflow profile 4)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	31.88	29.26
C	16.93	2.94
O	16.28	3.76
Sn	15.57	26.70
Bi	11.67	35.24

Figure S4-5: Intermetallic layer with the copper substrate of sample **(42Sn58Bi solder alloy, reflow profile 5)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	27.51	24.47
C	26.62	4.47
O	15.27	3.42
Bi	14.82	43.34
Sn	14.27	23.71

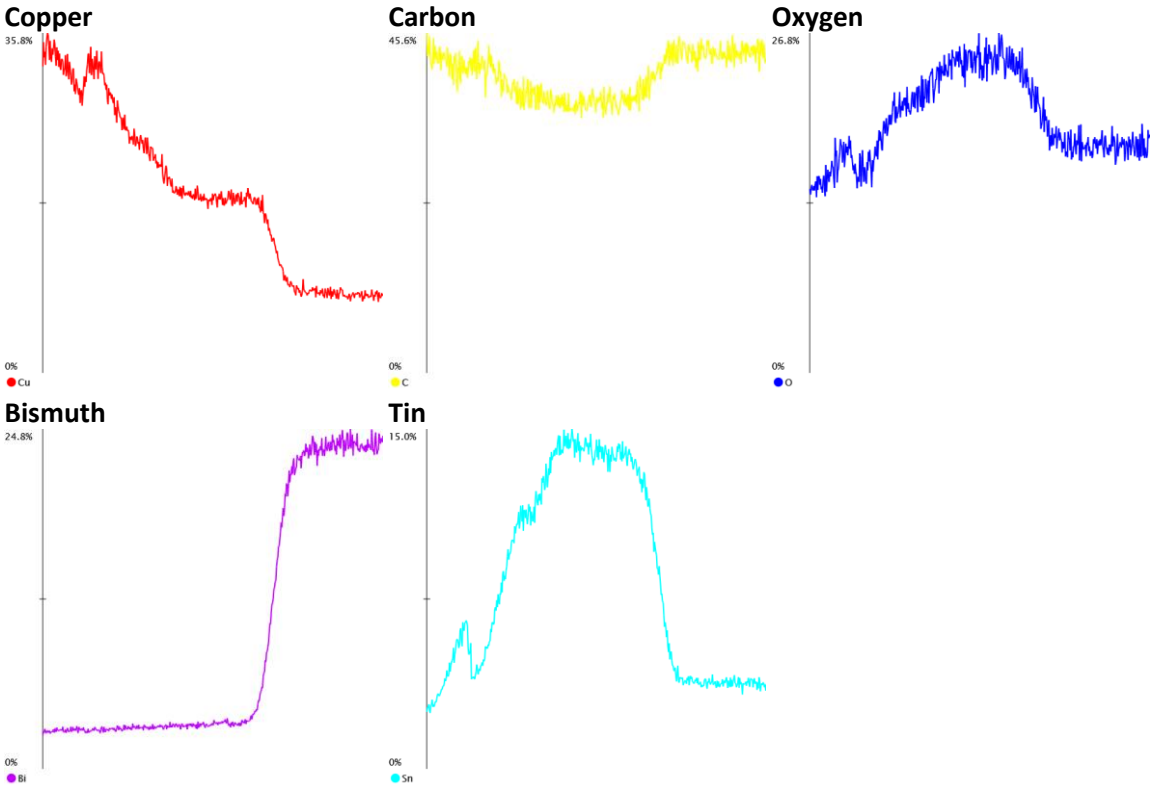
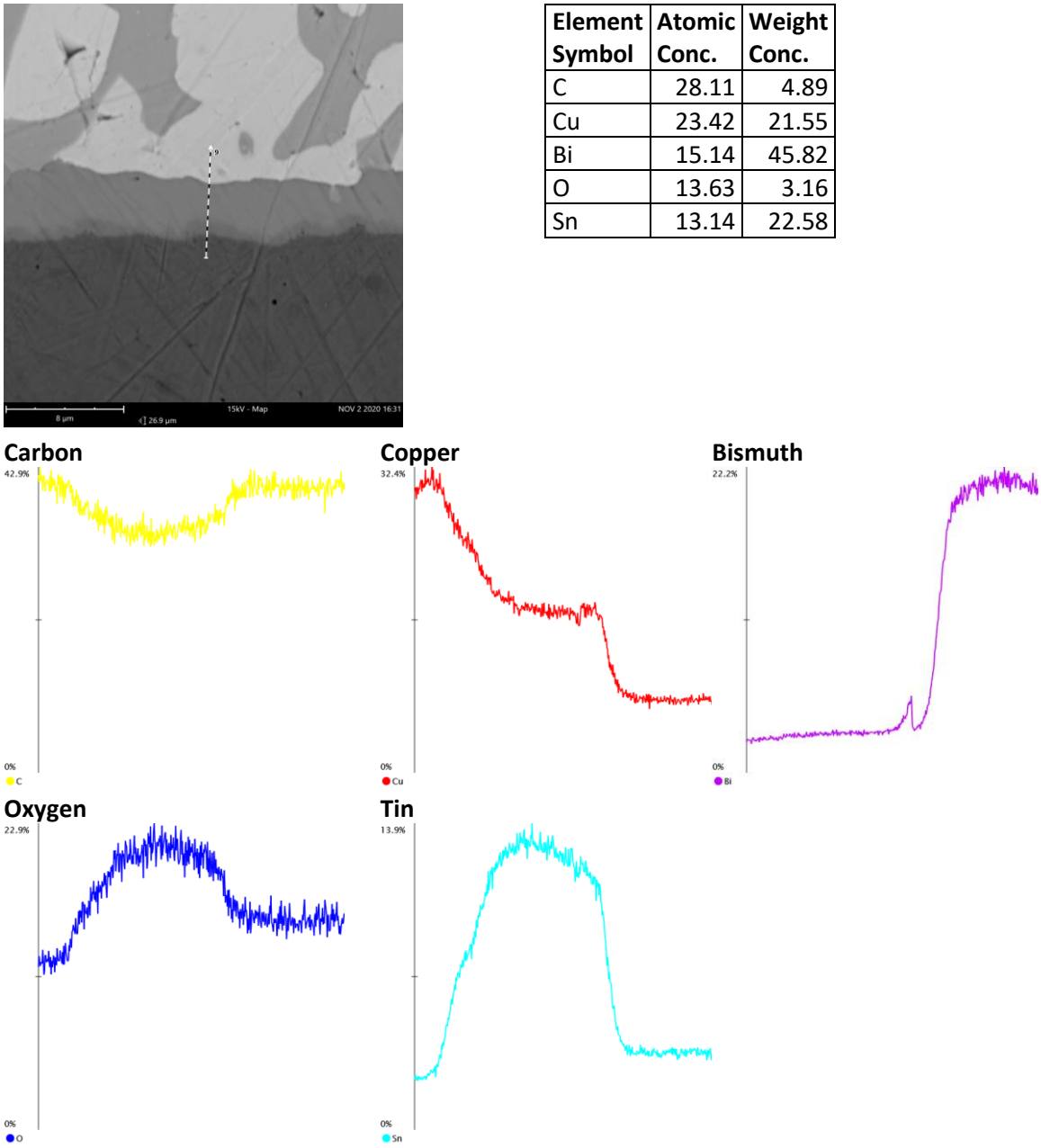
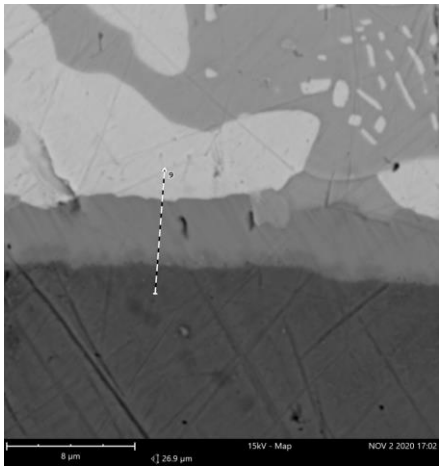


Figure S5-1: Intermetallic layer with the copper substrate of sample **(42Sn57Bi1Ag solder alloy, reflow profile 1)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	28.11	4.89
Cu	23.42	21.55
Bi	15.14	45.82
O	13.63	3.16
Sn	13.14	22.58

Figure S5-2: Intermetallic layer with the copper substrate of sample **(42Sn57Bi1Ag solder alloy, reflow profile 2)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	29.84	25.77
C	24.30	3.97
Sn	16.95	27.35
O	13.93	3.03
Bi	13.79	39.16

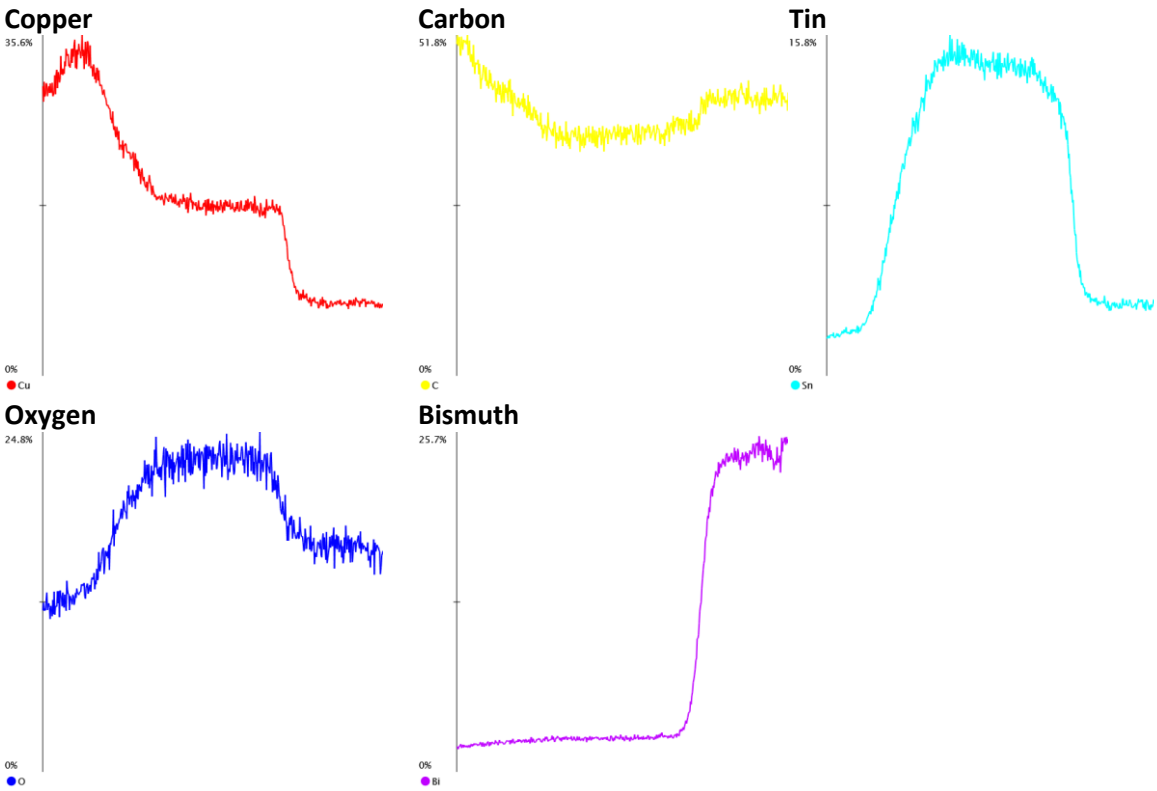
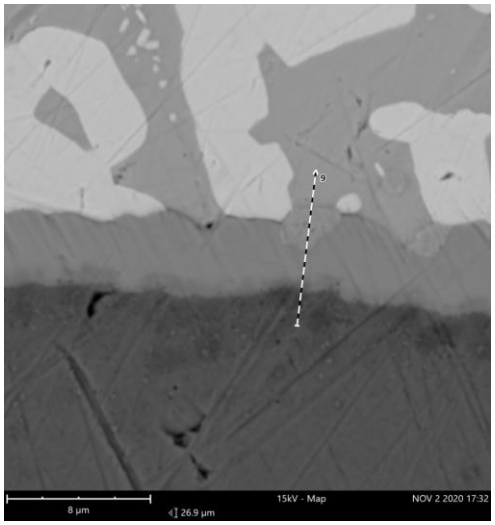


Figure S5-3: Intermetallic layer with the copper substrate of sample **(42Sn57Bi1Ag solder alloy, reflow profile 3)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	31.62	7.02
Sn	20.48	44.93
Cu	19.76	23.20
O	19.16	5.66
Ag	8.30	16.55
Bi	0.68	2.64

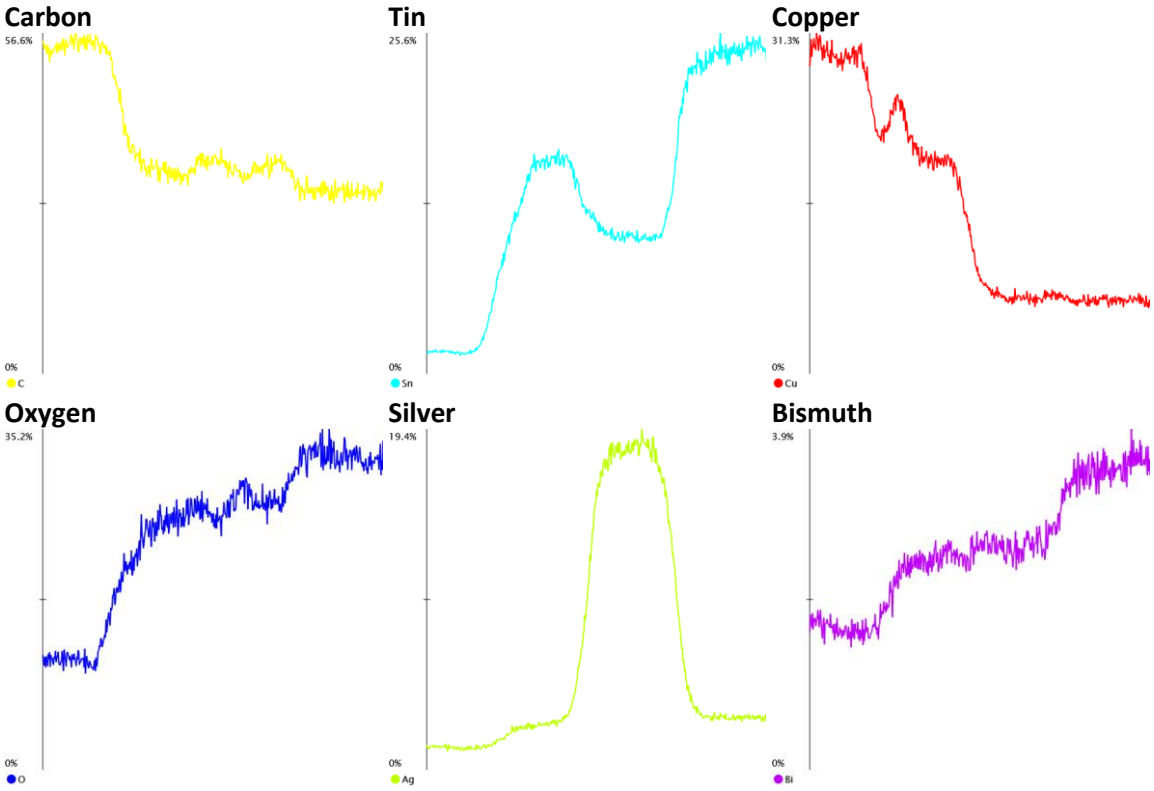
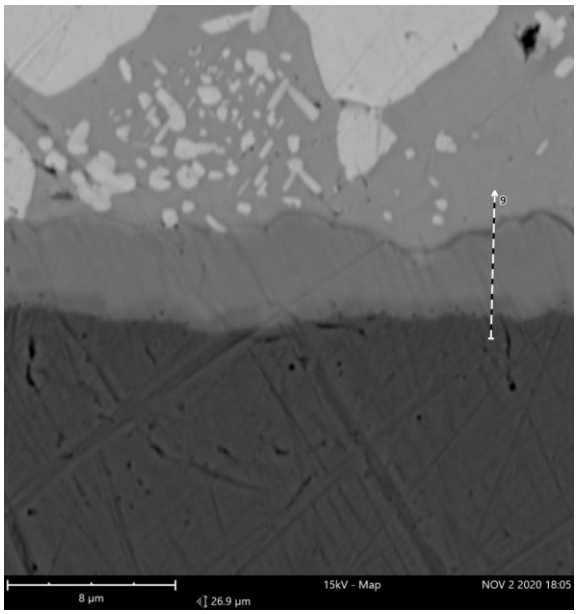


Figure S5-4: Intermetallic layer with the copper substrate of sample **(42Sn57Bi1Ag solder alloy, reflow profile 4)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)

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Element Symbol	Atomic Conc.	Weight Conc.
Cu	28.97	31.08
Sn	27.48	55.09
O	21.57	5.83
C	20.91	4.24
Bi	1.07	3.76

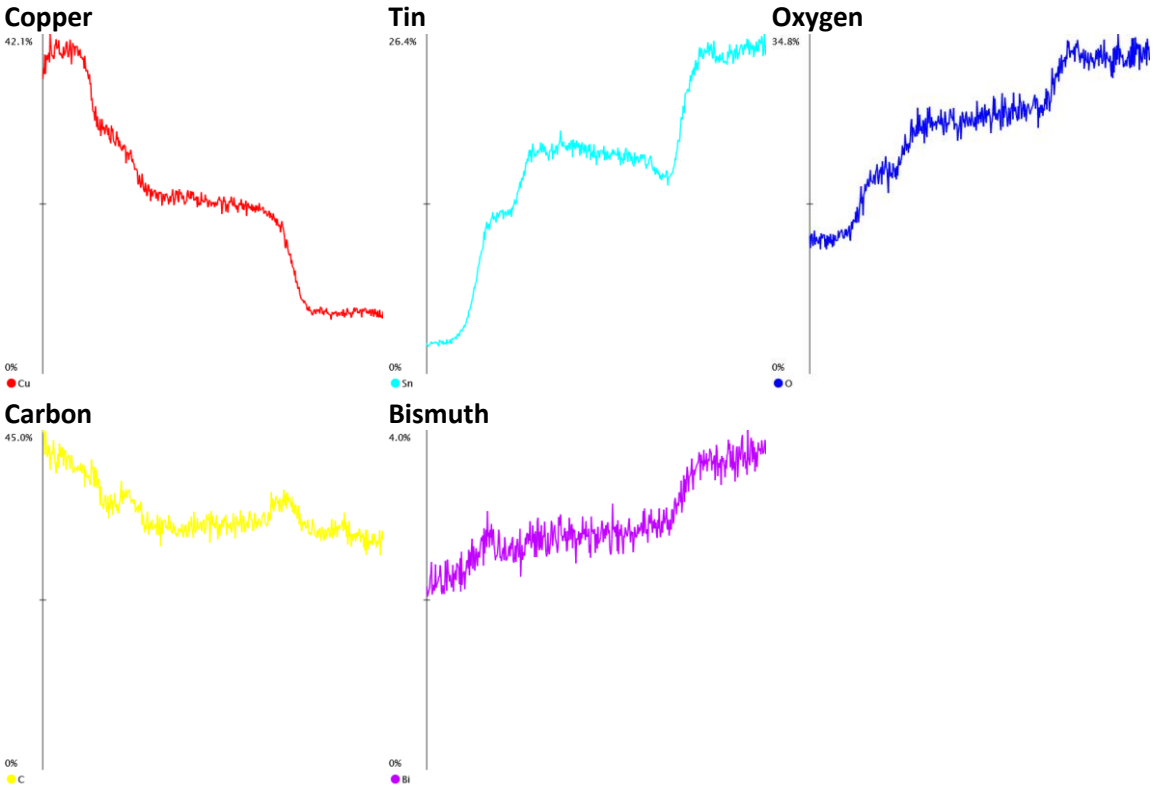
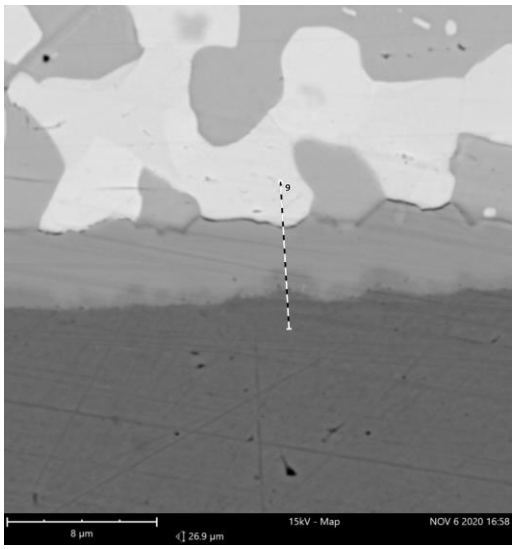


Figure S5-5: Intermetallic layer with the copper substrate of sample **(42Sn57Bi1Ag solder alloy, reflow profile 5)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)

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Element Symbol	Atomic Conc.	Weight Conc.
Cu	30.59	26.75
C	27.37	4.52
Bi	15.49	44.55
O	13.56	2.99
Sn	12.98	21.20

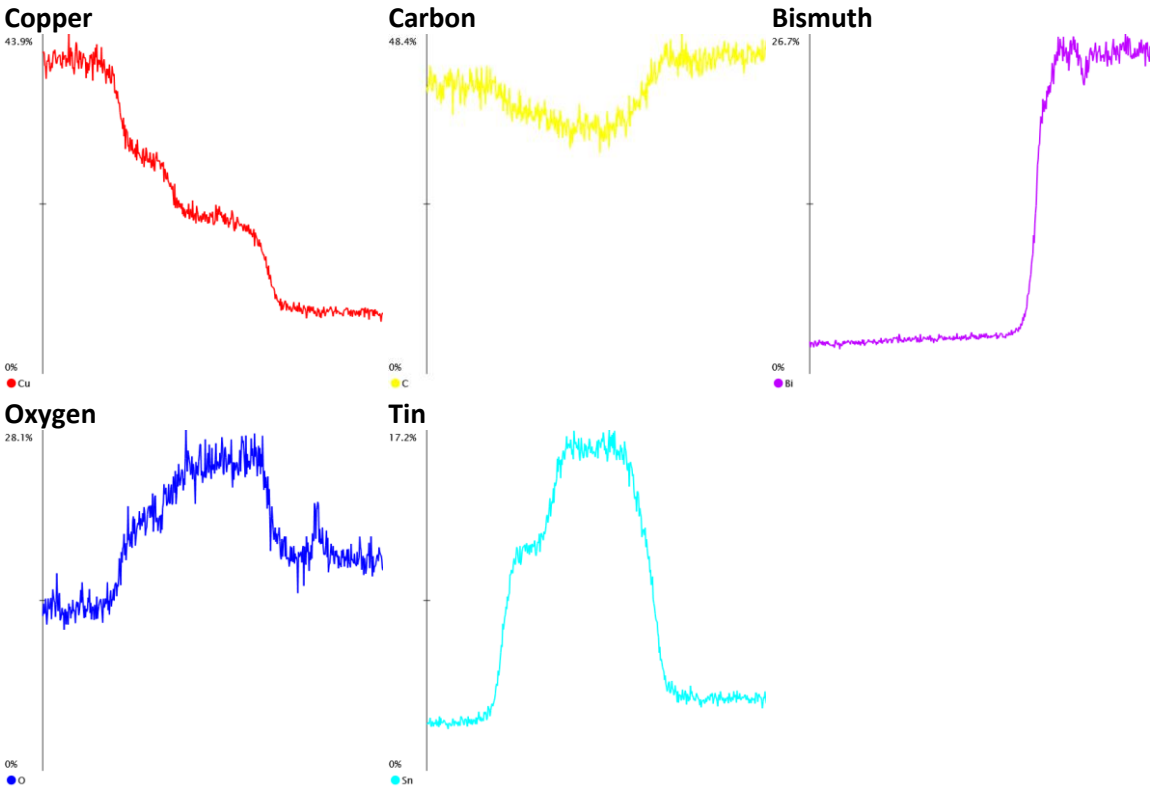
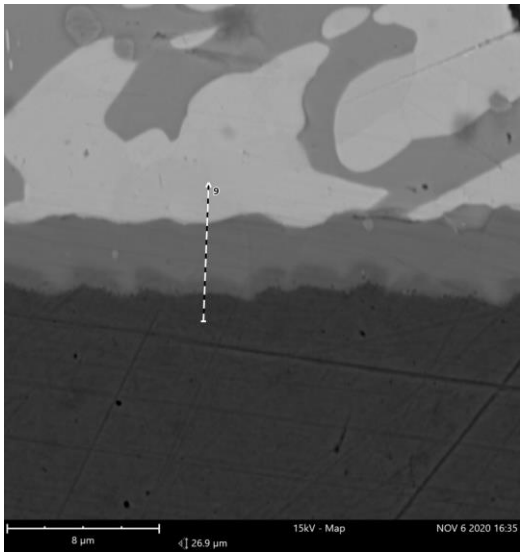


Figure S6-1: Intermetallic layer with the copper substrate of sample **(LT 47 solder alloy, reflow profile 1)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	31.27	25.64
C	22.88	3.55
Sn	16.40	25.12
Bi	15.91	42.90
O	13.53	2.79

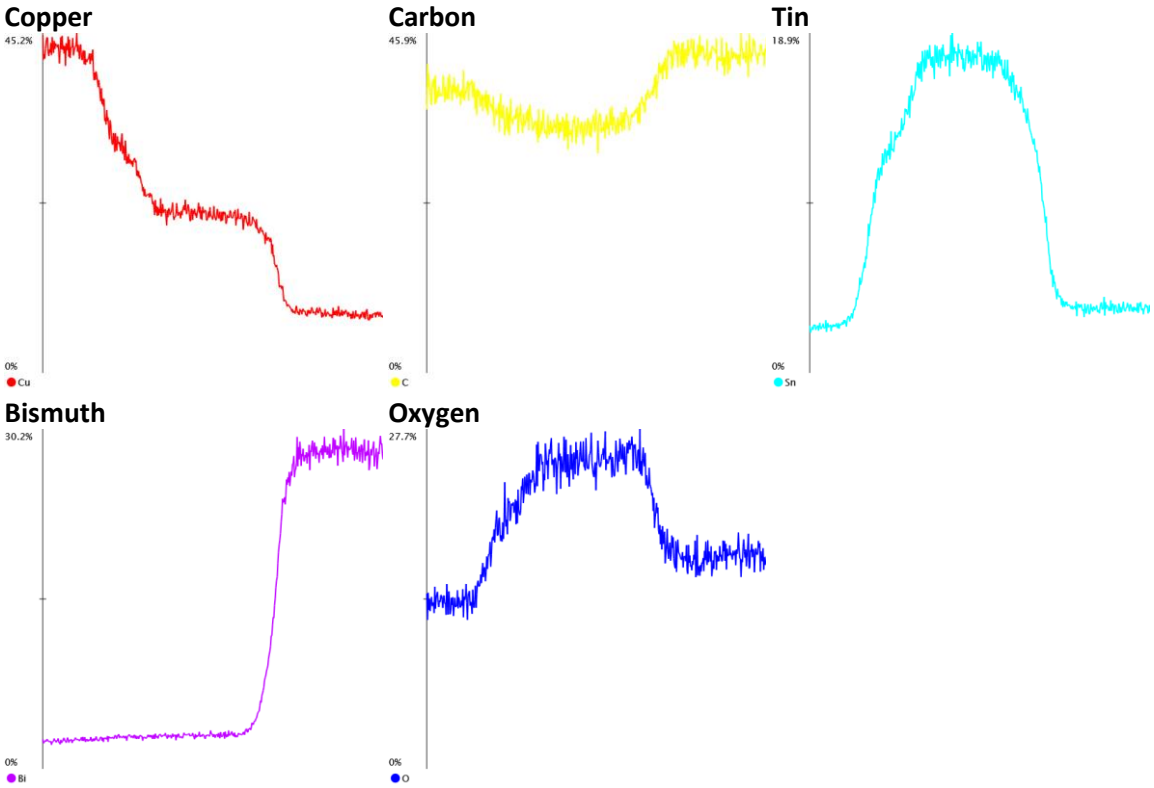
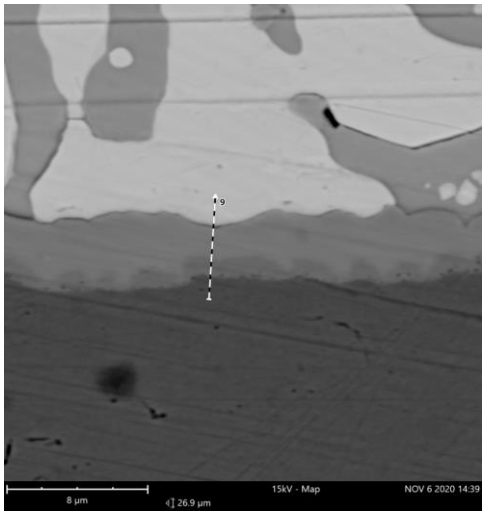


Figure S6-2: Intermetallic layer with the copper substrate of sample **(LT 47 solder alloy, reflow profile 2)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	34.18	25.69
Bi	18.69	46.20
C	17.26	2.45
Sn	16.47	23.12
O	13.41	2.54

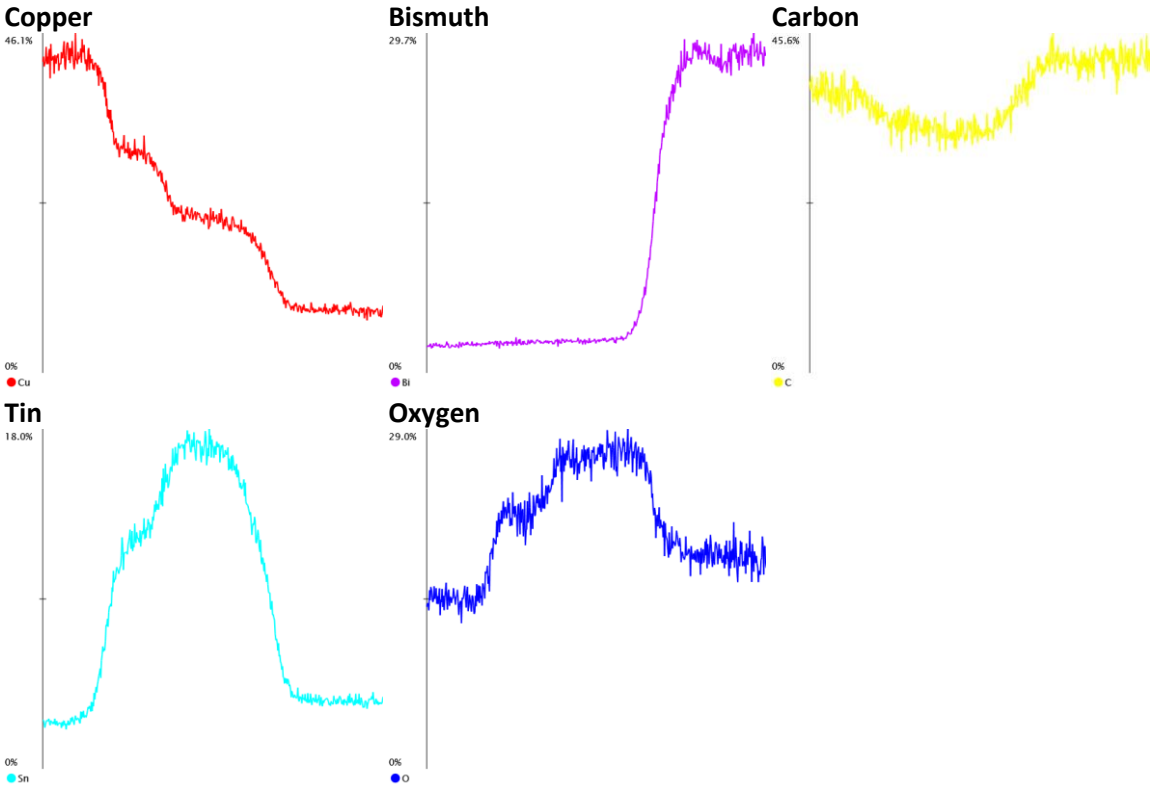
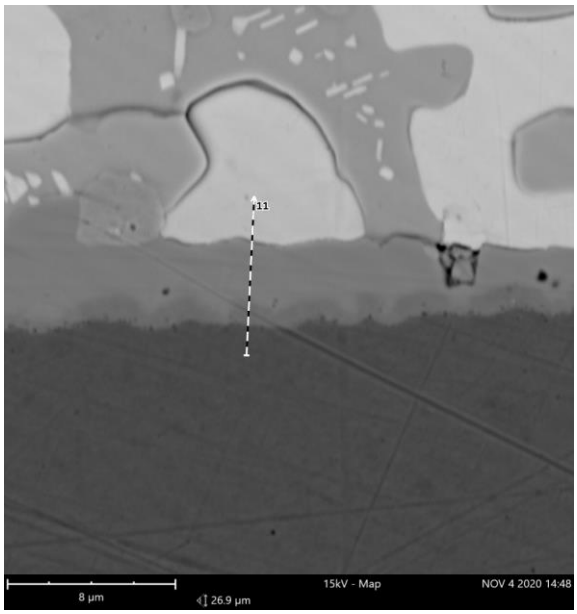


Figure S6-3: Intermetallic layer with the copper substrate of sample **(LT 47 solder alloy, reflow profile 3)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	29.25	25.01
C	20.00	3.23
Sn	16.44	26.26
Bi	14.56	40.94
O	12.33	2.65

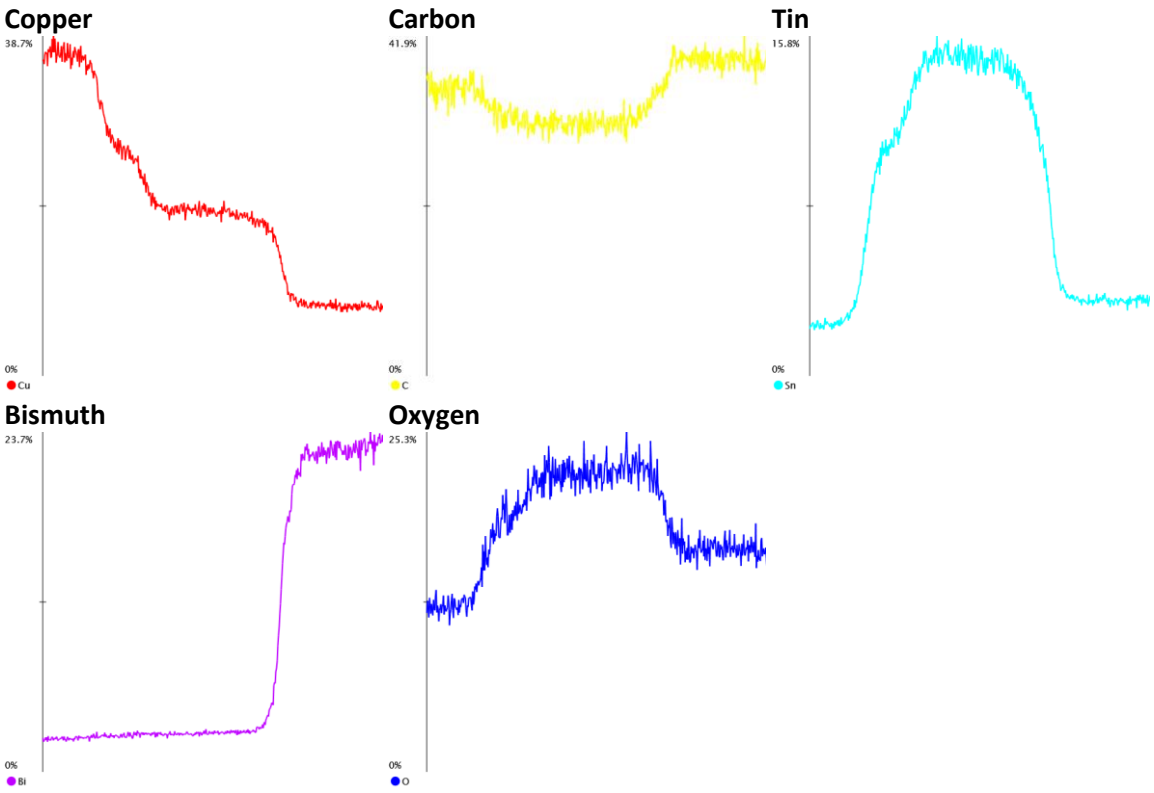
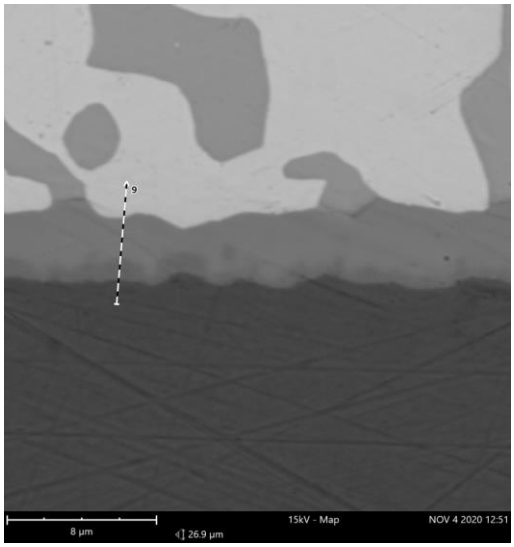


Figure S6-4: Intermetallic layer with the copper substrate of sample **(LT 47 solder alloy, reflow profile 4)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	30.30	26.27
C	25.51	4.18
Sn	16.33	26.46
Bi	14.05	40.07
O	13.81	3.02

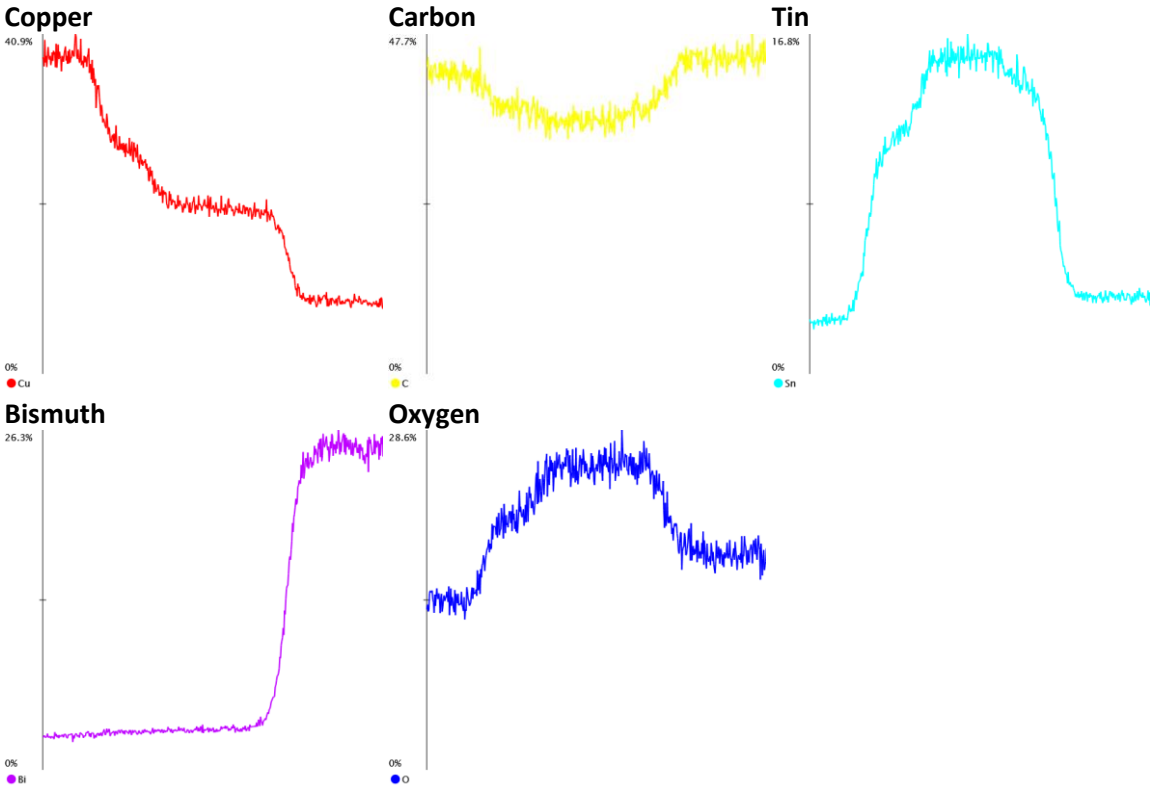
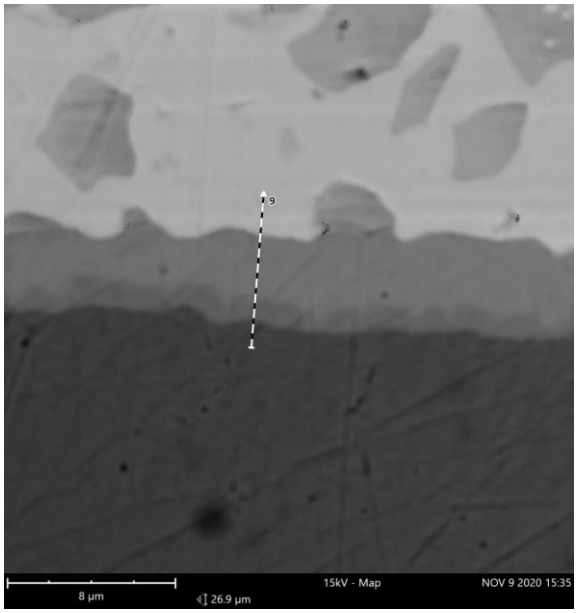


Figure S6-5: Intermetallic layer with the copper substrate of sample **(LT 47 solder alloy, reflow profile 5)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	25.79	23.44
C	25.26	4.34
O	17.98	4.11
Sn	15.19	25.78
Bi	13.91	41.58

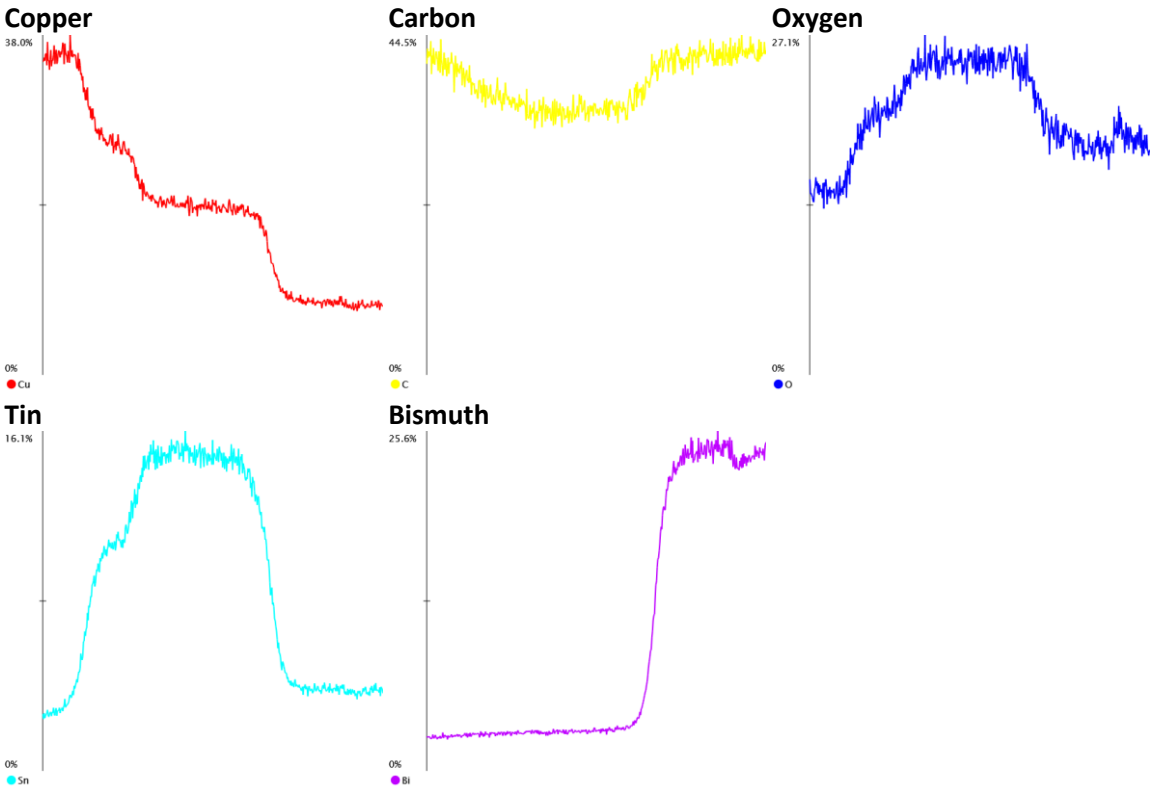
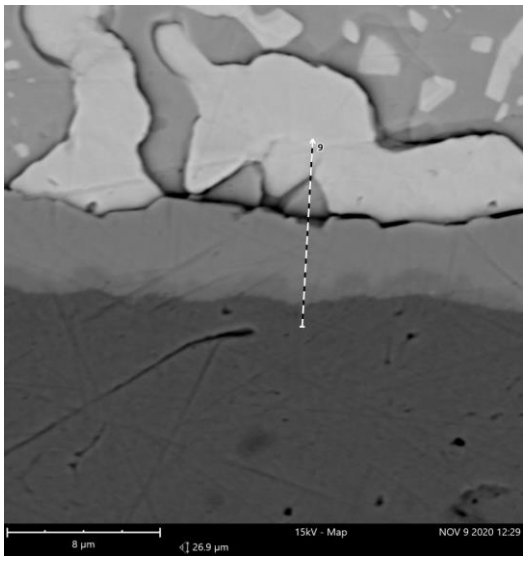


Figure S7-1: Intermetallic layer with the copper substrate of sample **(LT 51 solder alloy, reflow profile 1)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	26.68	4.77
Sn	22.43	39.65
Cu	20.80	19.68
O	20.08	4.78
Bi	10.00	31.12

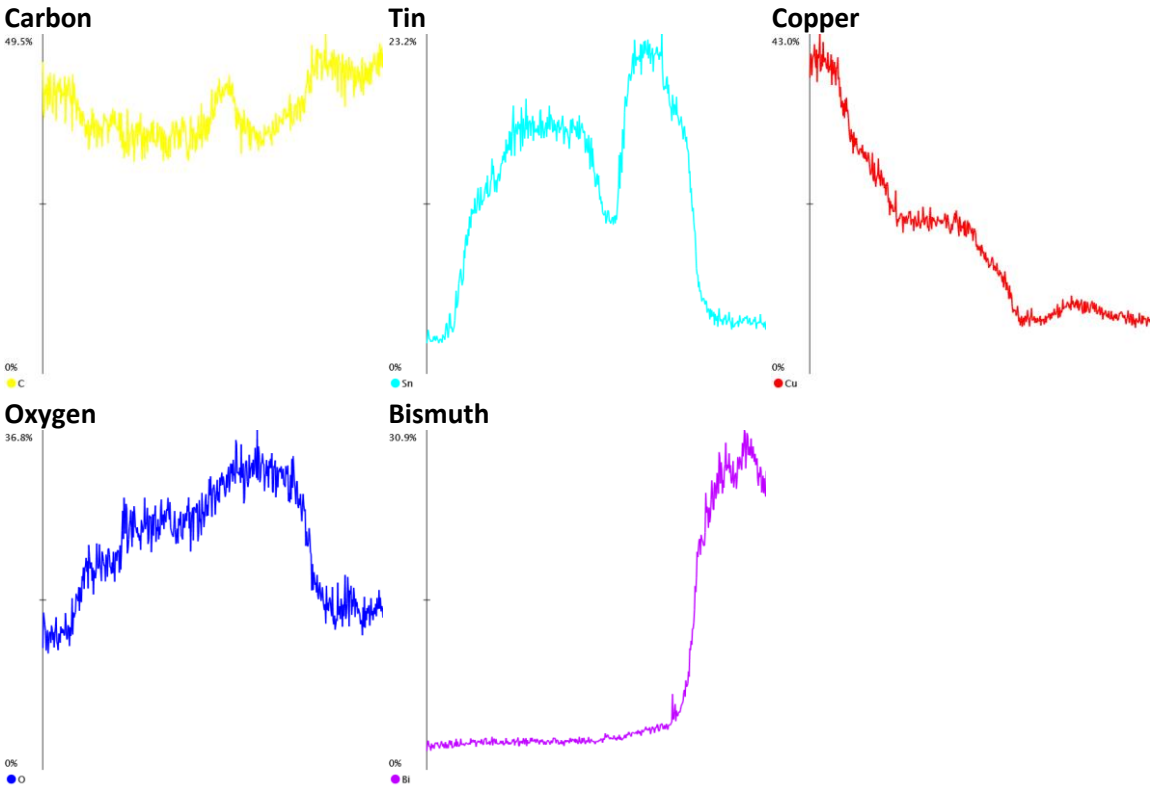
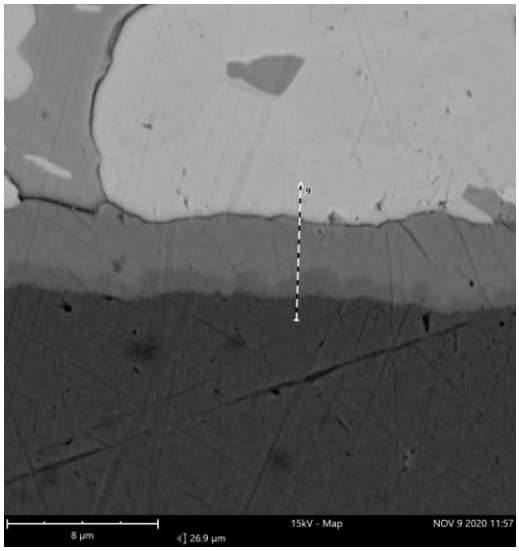


Figure S7-2: Intermetallic layer with the copper substrate of sample **(LT 51 solder alloy, reflow profile 2)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	27.46	23.12
C	27.44	4.37
Bi	16.18	44.82
Sn	15.84	24.92
O	13.09	2.78

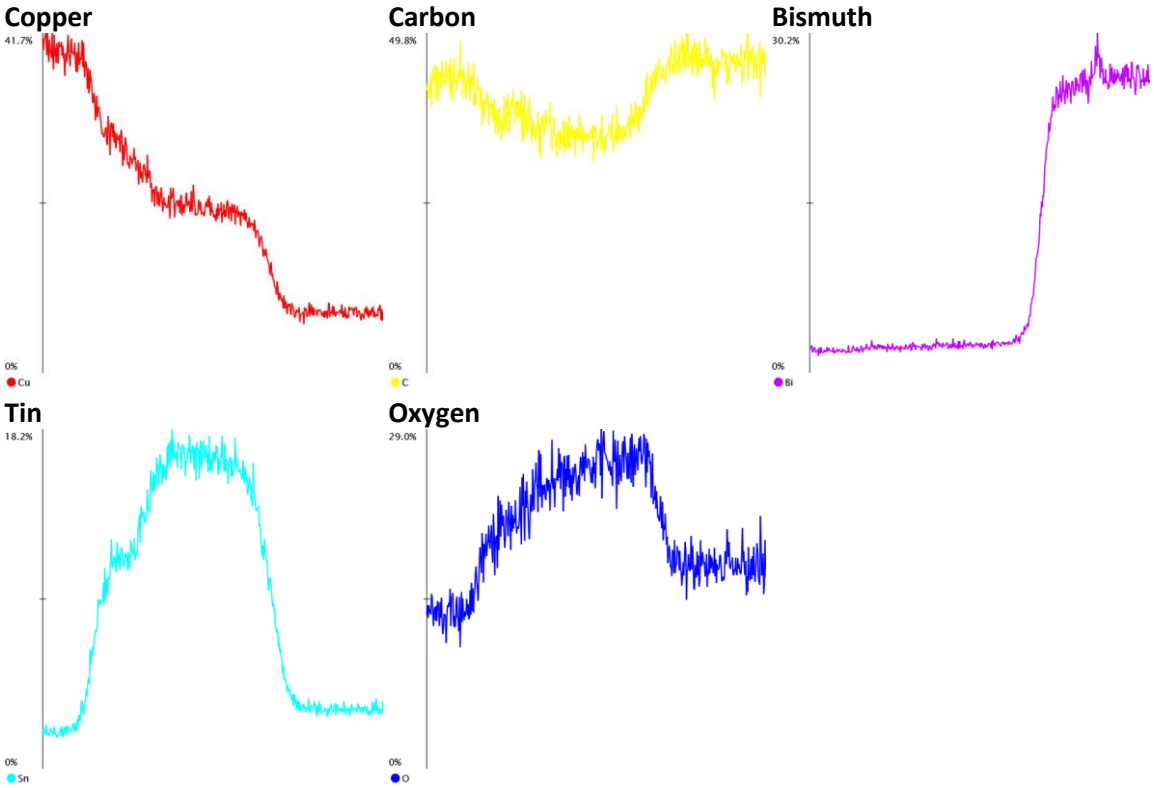
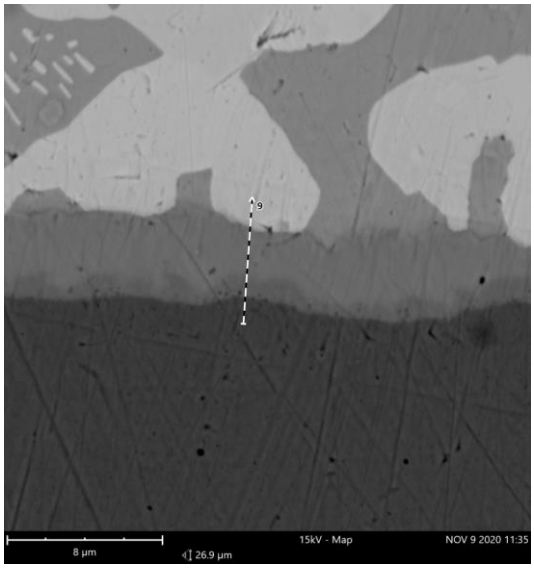


Figure S7-3: Intermetallic layer with the copper substrate of sample **(LT 51 solder alloy, reflow profile 3)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
Cu	30.18	26.73
C	26.25	4.39
Sn	16.42	27.17
O	13.89	3.10
Bi	13.26	38.62

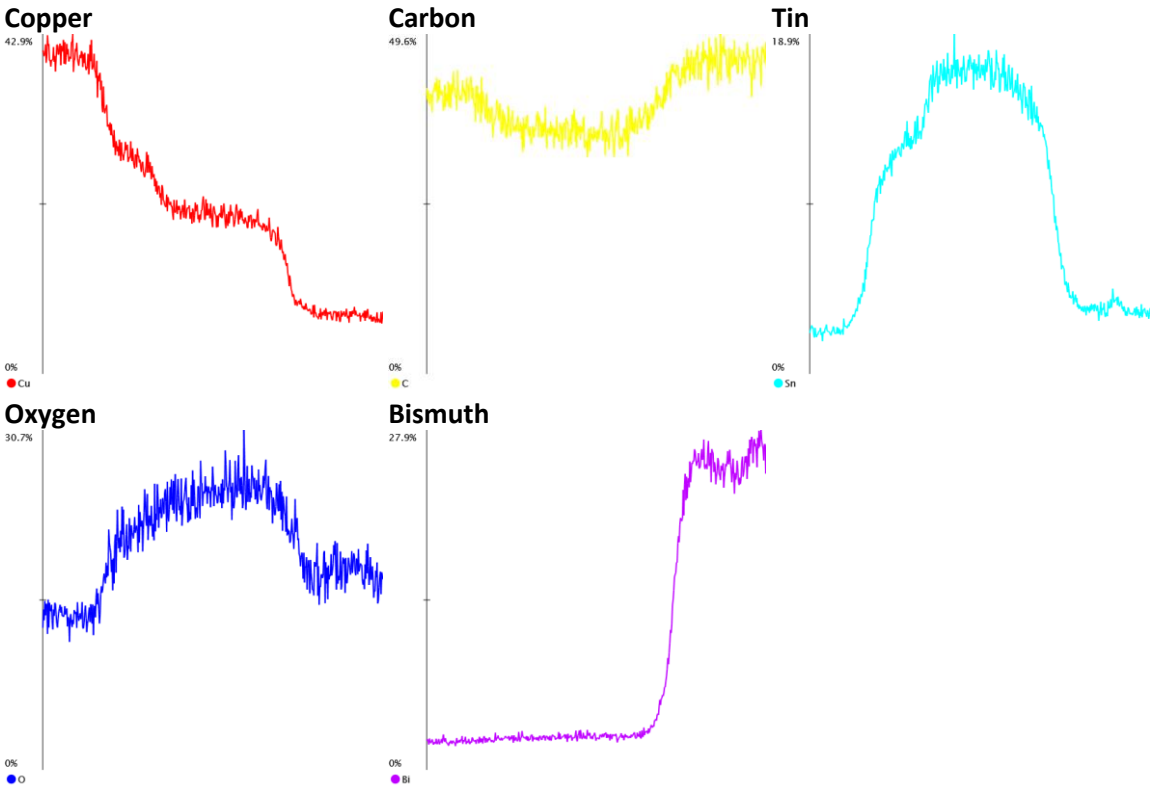
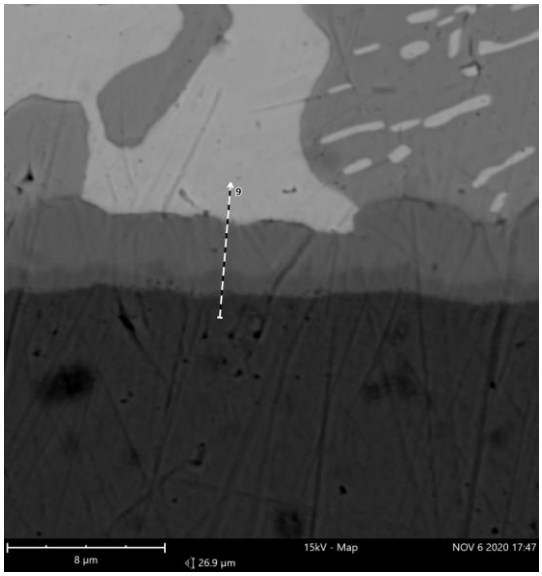


Figure S7-4: Intermetallic layer with the copper substrate of sample **(LT 51 solder alloy, reflow profile 4)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)



Element Symbol	Atomic Conc.	Weight Conc.
C	30.40	5.26
Cu	28.03	25.68
Bi	14.51	43.71
O	14.15	3.26
Sn	12.91	22.08

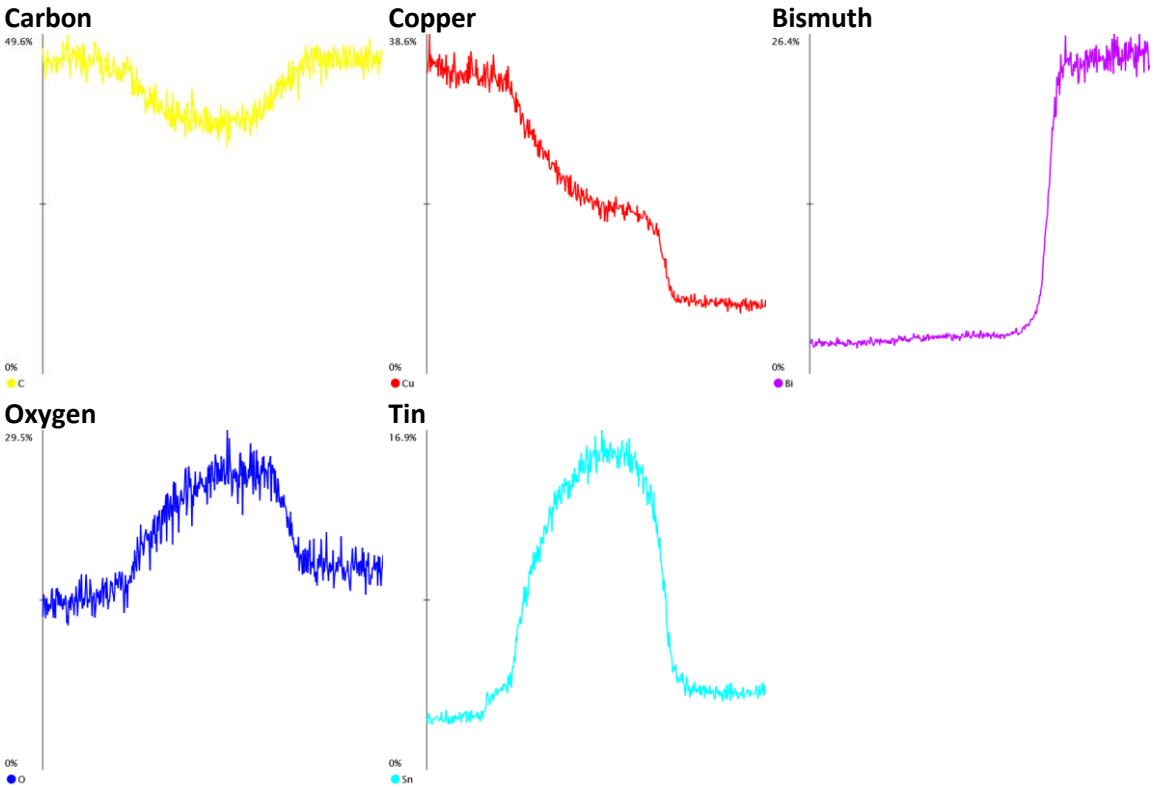


Figure S7-5: Intermetallic layer with the copper substrate of sample **(LT 51 solder alloy, reflow profile 5)** after aging (1000 cycles) analyzed by SEM/EDX (line scan)