HYTEK®

Lead Free Solder for High Reliability

Horten, October 23, 2025

Example of Lead Free for space projects

- EU LETTERS (Ongoing) https://letterssproject.eu/
- ESA Lead free task group (Ongoing)
- ESA Roadmap (2020)
- NASA/IPC NASA-DoD Lower Process Temperature Lead-Free Solder Project

HYTEK © 2025

Mismatch between materials

CTE X and Y ?

5 ppm/°C

SnPb app.
24 ppm/°C

17 ppm/°C

? ppm/°C

60 ppm/°C

HYTEK © 2025

Example of standards for high reliability

- ECSS-Q-ST-70-61C High reliability assembly for surface mount and through hole connections
- ESCC 23500 REQUIREMENTS FOR LEAD MATERIALS AND FINISHES FOR COMPONENTS FOR SPACE APPLICATION
- ECSS-Q-ST-70-12C Rev.1 Design rules for printed circuit boards
- ECSS-Q-ST.70-60C Rev. 1 Qualification and procurement of printed circuit boards
- IPC J-STD-001JS Space and Military Applications Electronic Hardware Addendum
- IPC J-STD-001J Requirements for Soldered Electrical and Electronic Assemblies

HYTEK © 2025

Example: Lead Free Low Melting Point (LMP) loddetin

- SnAg3Cu0,5(SAC305) (Senju patent)
- SnAg0,3Cu0,7 (LowSAC0307) (Alpha Metals patent)
- SnCu0,7Ni0,1 (SN100C) (Nihon patent)
- Sn42Bi57Ag1 (LMP type)
- SnAg3.8Cu0.7Ni0.12Sb1.5Bi (Innolot: Heraeus, Alpha and Loctite patent)
- Typically SAC adjusted with e.g. Bi, In, Zn, …….

HYTEK © 2025

Patent (e.g. Japan)

Worldwide applications

1999 • JP

Application JP25003199A events

1998-09-04	• Priority to JP10-251064
1998-09-04	• Priority to JP25106498
1999-09-03	• Application filed by 株式会社豊田中央研究所
1999-09-03	• Priority to JP25003199A
2000-05-23	• Publication of JP2000141079A
2008-08-20	• Application granted
2008-08-20	• Publication of JP4135268B2
2019-09-03	• Anticipated expiration
2019-10-02	• Application status is Expired - Lifetime

Sn-40Bi-XCu

引張強さ (MPa)

引張伸び (%)

Cu含有量 (重量%)

(a) 50μm In添加あり

(b) 50μm In添加なし

HYTEK © 2025

Typically materials for solder

- Tin (Sn)
- Lead (Pb)
- Silver (Ag)
- Copper (Cu)
- Bismuth (Bi)
- Indium (In)
- Gold (Au)

- Antimony (Sb)
- Germanium (Ge)
- Gallium (Ga)
- Silicium (Si)
- Zinc (Zn)

6.2.2 Composition ECSS-Q-ST-70-61C

ECSS-Q-ST-70-61_1510141

a. The solder alloy shall have a composition specified in Table 6-1.

NOTE 1 Complementary information can be found in EN-IEC 61190-1-3 for solder and EN-IEC 61190-1-2 for solder paste.

NOTE 2 The solder alloy used depends upon the application. See Annex H for guidelines for the choice of solder type.

HYTEK © 2025

Solder accepted by ESA ECSS-Q-ST-70-61C

ECSS-Q-ST-70-61_1510144

Table 6-1: Chemical composition of spacecraft solders

ESA designation	Sn min % - max %	Pb max %	In min % - max %	Sb max %	Ag min % - max %	Bi max %	Cu max %	Fe max %	Zn max %	Al max %	As max %	Cd max %	Other max %
PTH and SMD assembly applications													
63 Tin solder Sn63	62,5-63,5	remainder	-	0,05	-	0,10	0,05	0,02	0,001	0,001	0,03	0,002	0,08
62 Tin Silver loaded Sn62	61,5-62,5	remainder	-	0,05	1,8-2,2	0,10	0,05	0,02	0,001	0,001	0,03	0,002	0,08
60 Tin solder Sn60	59,5-61,5	remainder	-	0,05	-	0,10	0,05	0,02	0,001	0,001	0,03	0,002	0,08
Only PTH assembly applications													
96 Tin solder Sn96	remain	0,10	-	0,05	3,5-4,0	0,10	0,05	0,02	0,001	0,001	0,03	0,002	0,08

HYTEK © 2025

Example (CAVE Center for Advanced Vehicle Electronics)

2512 Chip Resistor Solder Joint Reliability

W/rr

95.5Sn-3.8Ag-0.7Cu

63Sn-37Pb

Occurrence CDF %

99
95
90
80
70
60
50
40
30
20
10
5
2
1

100
1000
10000
100000

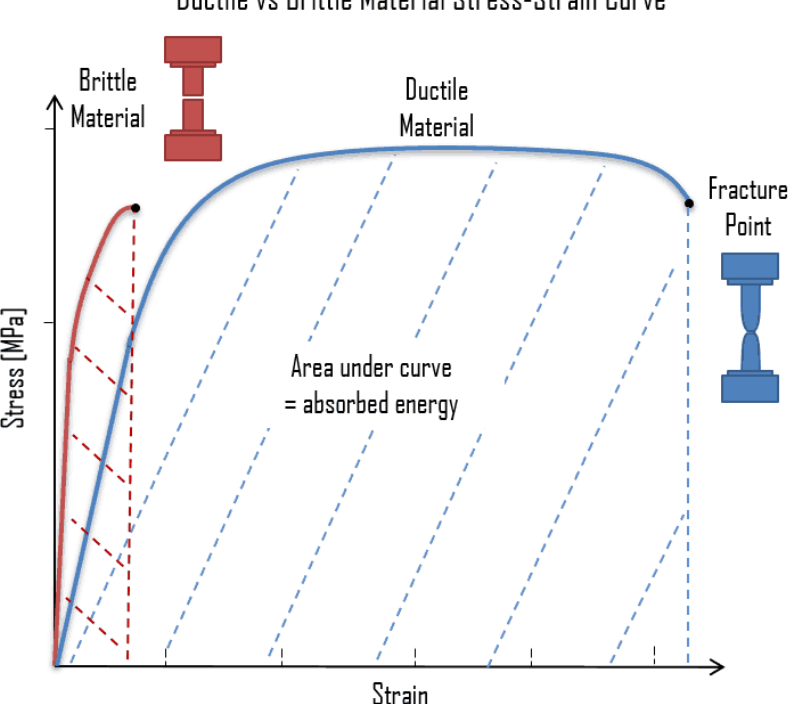
JCS

Cycles (-40 to 150 C)

HYTEK © 2025

Solder ductility

- Elongation is a measure of a material's plastic deformation and is a key indicator of its ductility.



HYTEK © 2025

Mechanical properties in solder

Example Almit

Chart 2. Mechanical Properties Test Results (n=3)

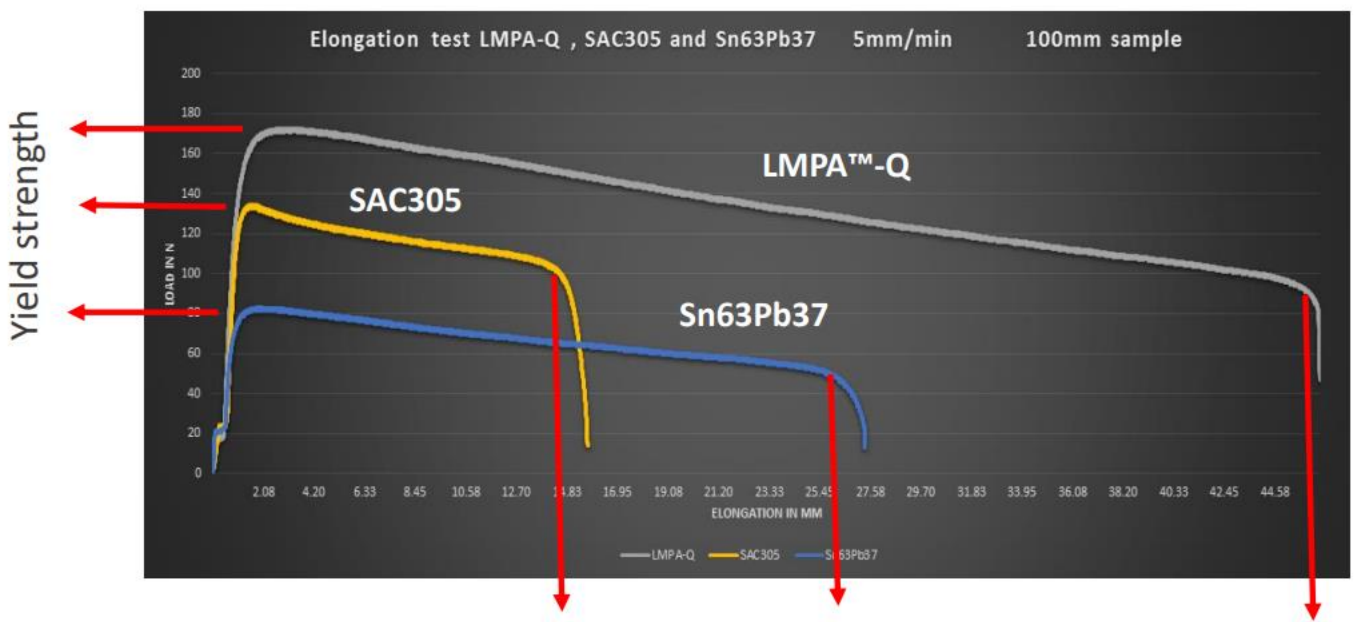
		Sn-3.9Ag-0.6Cu	Sn-3.5Ag-0.7Cu	Sn-3.0Ag-0.5Cu	63Sn-37Pb
Liquidus Temp C		218	218	220	183
Solidus Temp C		217	217	217	183
Tensile Strength (MPa)		43.7	44.0	41.1	34.7
Yield Point (MPa)		31.3	35.0	34.2	28.4
Elongation (%)		40.6	43.4	41.0	91.2
Coefficient of Work Hardening		0.083	0.056	0.040	0.032
Young's Modulus (GPa)		52	51	50	40
Poisson's Ratio		0.35	0.36	0.36	0.37
Specific Gravity		7.4	7.4	7.4	8.4
Specific Heat (J/g K)		0.22	0.22	0.23	0.18
Thermal Conductivity (%) 25C		61.1	62.1	63.2	52.8
Thermal Conductivity (%) 60C		0.085	0.086	---	0.086
Thermal Conductivity (%) 100C		0.174	0.173	0.173	0.173
CTE (10^{-6}/K)	20-60C	21.4	21.5	---	21.6
	20-100C	21.8	21.7	21.6	21.6

HYTEK © 2025

Example elongation test (Interflux)

Elongation test

Solder Alloy	Start Length	Length at failure	Elongation at failure
LMPA-Q	**100mm**	**146.45mm**	**46.45%**
SAC305	100mm	115.70mm	15.70%
Sn63Pb37	100mm	127.39mm	27.39%



Elongation at break

Interflux LMPA™-Q (Example)

alloy	metal content	melting T°	powder size	packaging
LMPA™- Q	printing: 89%	139°C-176°C	Type 3 / Type 4	jars: 500g

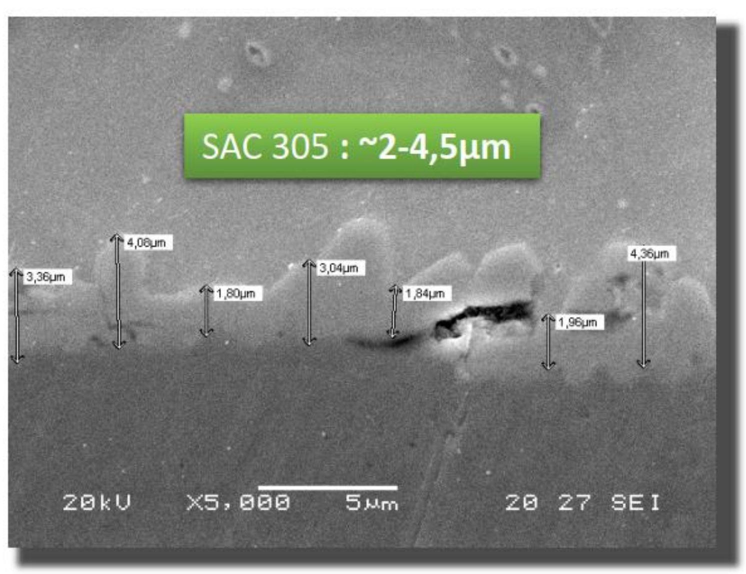
Sikkerheddatablad Interflux

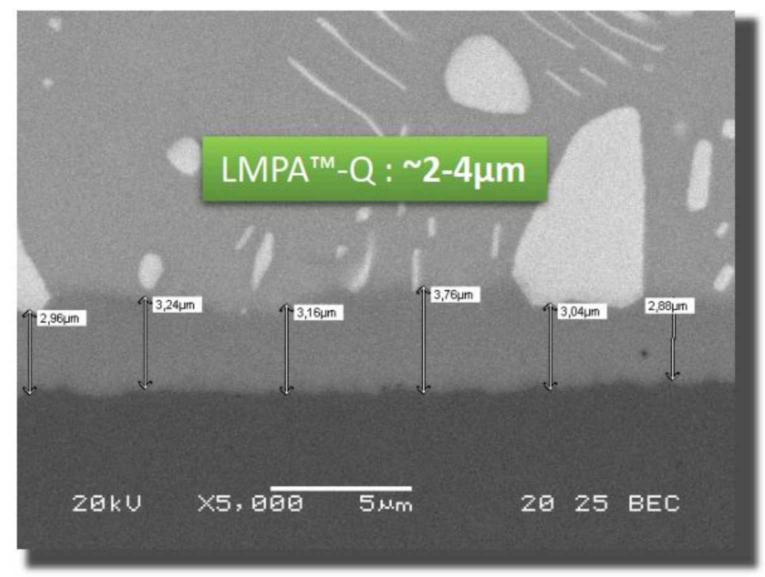
Legering	Tin % wt	Bismuth % wt	Dopants % wt
LMPA™-Q	Rest	39 - 59	<1

HYTEK © 2025

Example of documentation of IMC growth

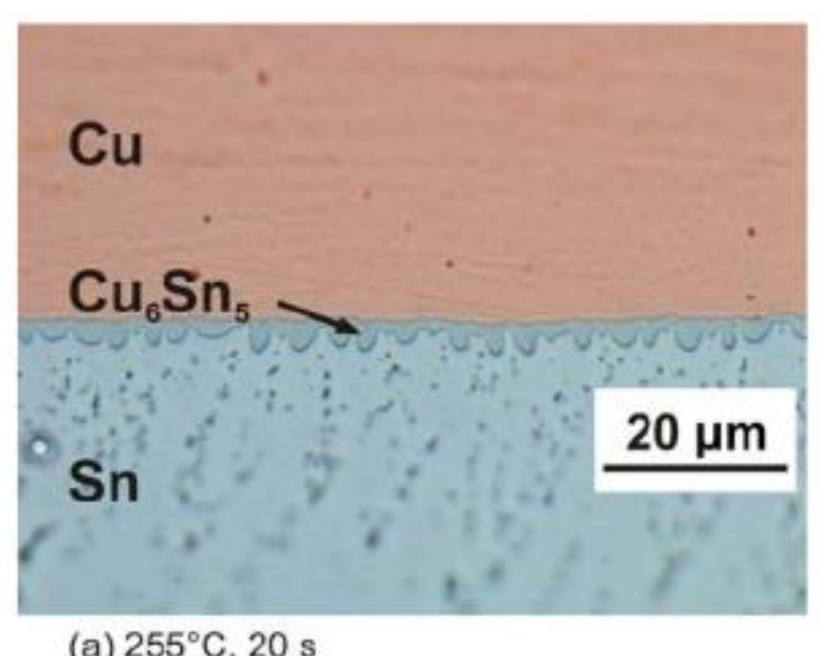
Ageing: 1000H@85°C



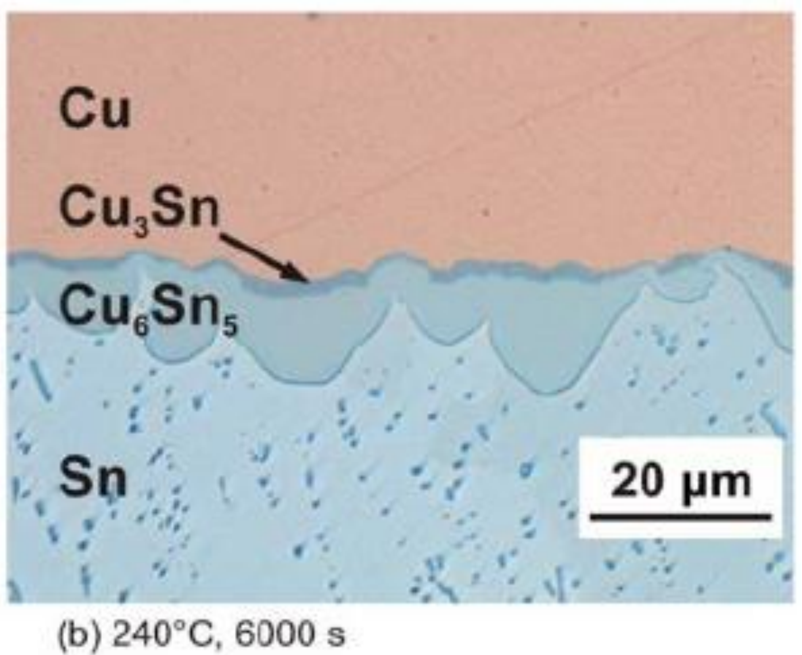


HYTEK © 2025

IMC layers



(a) 255°C, 20 s



(b) 240°C, 6000 s

HYTEK © 2025

100 hours at 120°C

Before aging

(a)
Before Aging
Cu
Cu_3Sn
Cu_6Sn_5
SAC305
5 μm

After aging

(b)
After Aging
Cu
Cu_3Sn
Cu_6Sn_5
Ag_3Sn (light gray)
SAC305
5 μm

HYTEK © 2025

Alpha Metals (Example)

Alloys:	SnBiAg (42%Sn57.6%Bi/0.4%Ag)
Powder Size:	Type 3 (25-45 µm per IPC J-STD-005)
Residues:	Approximately 5% by weight
Packaging Sizes:	500 gram jars, 6” & 12” cartridges
Lead Free:	Complies with RoHS Directive 2002/95/EC.

HYTEK © 2025

Alpha Metals (Example)

ALLOY	TEMPERATURE (°C)		LIQUIDUS FRACTION (%)			
	SOLIDUS	LIQUIDUS	139°C	140°C	142°C	144°C
Sn55.0Bi	138	144	10	39	96	100
Sn50.0Bi	138	155	6	26	90	96
Sn45.0Bi	138	168	9	50	75	78
Sn40.0Bi	138	178	16	66	75	77
Sn35.0Bi	138	186	12	61	70	77

ALLOY	SOLIDUS TEMPERATURE (°C)	LIQUIDUS TEMPERATURE (°C)
Sn57.6Bi0.4Ag	137	142
Sn57.0Bi1Ag	137	142
Sn38.0Bi1Ag	137	176
Sn58.0Bi1Ag1In	133	137
Sn58.0Bi1Ag3In	125	133*

HYTEK © 2025

Qualitek DSP 863 (Sn42/Bi58) (Example)

	Sn42/Bi58
Melting Point, °C	138 E
Hardness, Brinell	22HB
Coefficient of Thermal Expansion	13.8
Tensile Strength, psi	8766
Density, g/cc	8.72
Electrical Resistivity (μohm-cm)	34.5
Electrical Conductivity, %IACS	4.5

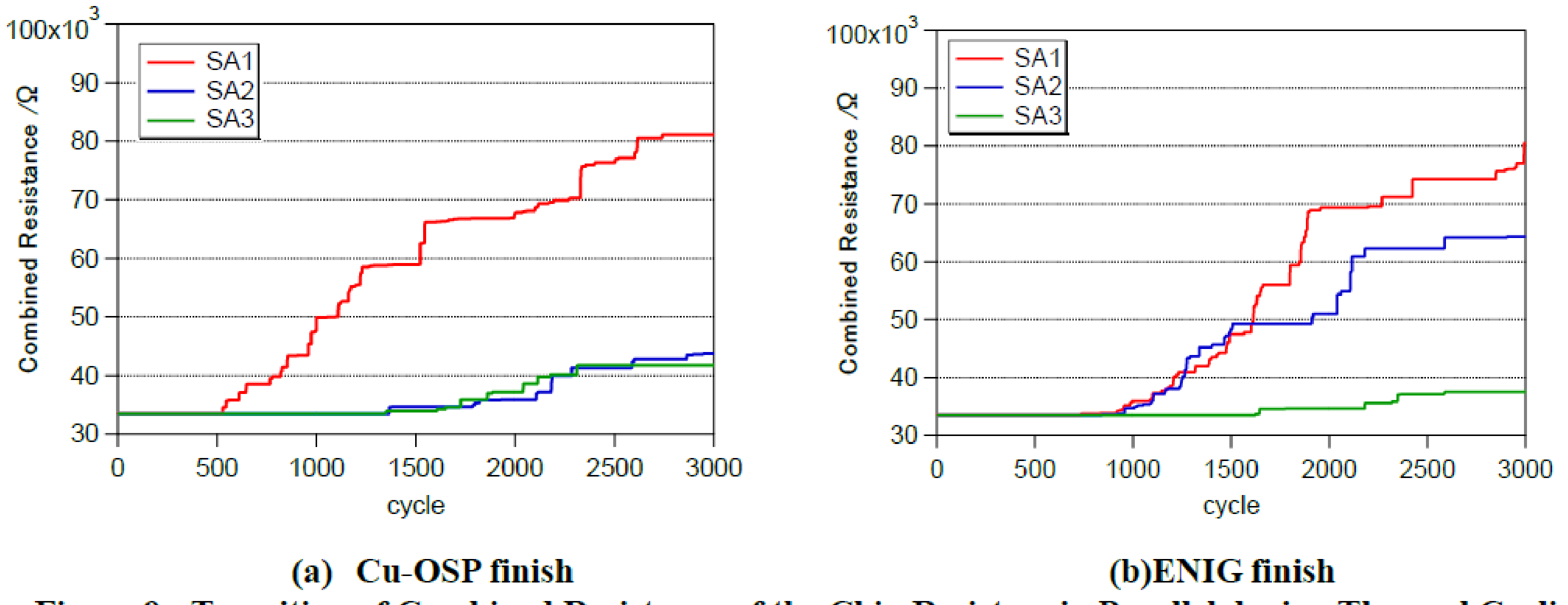
HYTEK © 2025

Indium (Example)

Indalloy® #	Composition	Liquidus/Solidus Temperature (˚C)	Solidus Temperature (˚C)
1E	52In/48Sn	118 Eutectic	
1	50In/50Sn	125	118
290	97In/3Ag	143 Eutectic	
2	80In/15Pb/5Ag	154	149
4	100In	157 Melting point	
204	70In/30Pb	175	165
205	60In/40Pb	181	173
227	77.2Sn/20In/2.8Ag	187	
7	50In/50Pb	210	184
3	90In/10Ag	237	143
164	92.5Pb/5In/2.5Ag	310	300

HYTEK © 2025

Improving Thermal Cycle and Mechanical Drop Impact Resistance of a Lead-free Tin-Silver-Bismuth-Indium Solder Alloy with Minor Doping of Copper Additive (KOKI)



(a) Cu-OSP finish **(b)ENIG finish**

Figure 9 - Transition of Combined Resistance of the Chip Resistors in Parallel during Thermal Cycling

HYTEK © 2025

Development of a Lead-Free Alloy for High-Reliability, High-Temperature Applications (Henkel)

Electrical Failures On RC Components

Number Of Electrical Failures

9
8
7
6
5
4
3
2
1
0

0 Cycles
250 Cycles
500 Cycles
750 Cycles
1000 Cycles
1250 Cycles
1500 Cycles
1750 Cycles
2000 Cycles

SAC -40/150°C
InnoLot -40/150°C

First failures on SAC at 750 cycles.
First failures on InnoLot at 1500 Cycles

HYTEK © 2025

AIM REL22 (Example)

PHYSICAL PROPERTIES

Parameter	Results	
	REL22	SAC305
Melting Properties	210-212°C with a range of 2 degree undercooling	217-220°C with a range of 20 degrees undercooling
Wetting Time	0.8/sec	0.9/sec
Wetting Force	4.4/mN	4.4/mN
Hardness	29/HV10	14/HV10
Tensile Strength (aged 150°C for 24 hours)	86 MPa	34 MPa
Microstructure Analysis (aged) **150° for 24 hours**	SU3500 20.0kV x2.00k BSE-COMP 20.0μm	SU3500 20.0kV x2.00k BSE-COMP 20.0μm

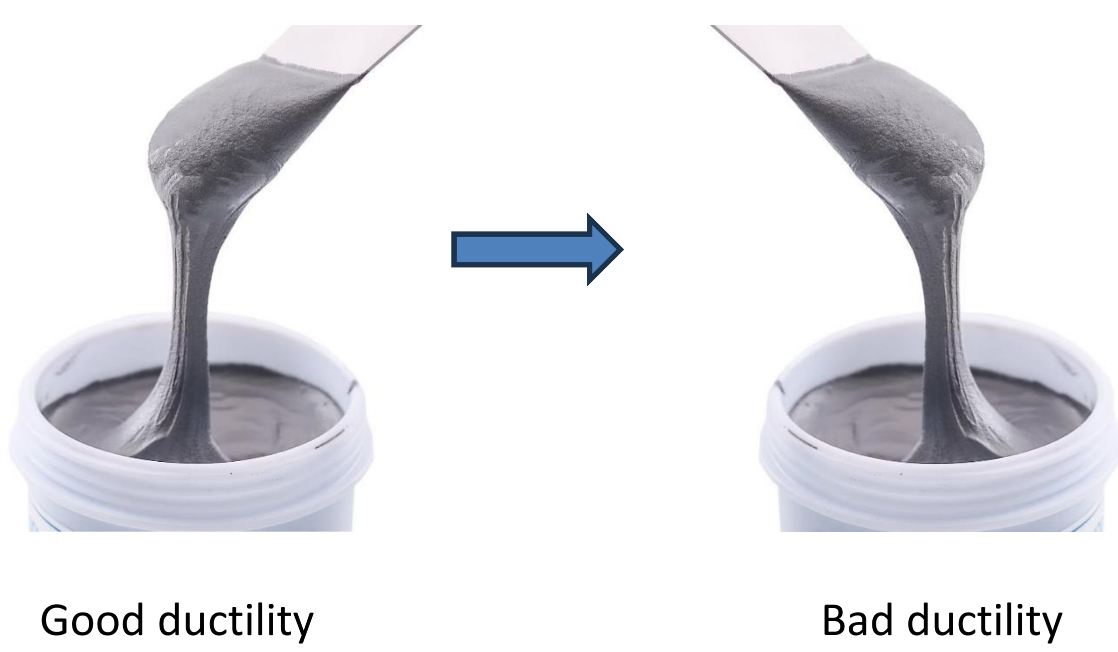
HYTEK © 2025

AIM Solder example

SAC305 / 480hr@150C	NA6 / 480hr@150C	NA2 / 480hr@150C
10 µm	10 µm	10 µm

HYTEK © 2025

From **high reliability** to **low reliability** in 5 seconds



Good ductility

Bad ductility

HYTEK © 2025