

# Hi-reliability Low Ag Lead Free Solder Paste

Patent Pend.

## S01X7C48-M500

Newly invented **Sn0.1Ag0.7Cu0.03Co+X ALLOY** which offers vastly improved solder joint **RELIABILITY** in comparison with conventional low Ag SAC solders.

**PREVENTS** the occurrence of the **HIDDEN PILLOW DEFECT** (Head-in-Pillow) and ensures the highest quality of solder joints.

Significant **REDUCTION** of **HALOGEN** from the flux formulation helps to promote the environment.

### Background of development

Until last year, solders have been adversely affected by the high cost of metal materials. At present, the SAC305 (Sn-3wt%Ag-0.5wt%Cu) is the main stream lead-free solder. Its chemical composition contains 3 percent of silver (Ag), which is a precious metal. The price increase of metals, especially silver has become an additional burden to soldering cost. Using large quantities of precious metal, which is a target of metal market speculation, is not helpful for the industrial sector. To respond to the high cost of metals, the Second-Generation Flow Solder Alloy Standardization Project of the Japan Electronics and Information Technology Industries Association (JEITA) has recommended several low-Ag solder compositions for flow (wave) soldering. Such solders also pose lesser problems with regard to the reliability of joints.

When flow(wave) soldering is performed, a large quantity of solder must be put into the wave solder pot. This makes low-Ag solder, or solder containing a lower amount of Ag in its composition, very effective in reducing cost. Although low-Ag solder compositions recommended by JEITA are intended exclusively for flow(wave) solder applications, they have been extended to some applications that involve the SMT reflow soldering method, which uses solder paste.

These low-Ag solder compositions have started to gain notice in countries outside of Japan and other regions where mass production of low-cost products are being built.

Second-generation lead-free solders can also help reduce cost. The melting point of these solders however tends to be higher and their wettability lower than the first generation lead-free solders. As a result, their workability(solderability) can be poor as well. In addition, joint reliability becomes an issue, particularly with regard to thermal heat cycle endurance. The results from the JEITA Project report noted that discovering a composition better than SAC305 among the compositions investigated was not possible.

Because of the above reasons, low-Ag solder alloys that feature improved thermal heat cycle endurance equivalent to the conventional lead-free Sn3Ag0.5Cu solder, whilst at the same time contributing to reduced costs are being called for.

By improving the above mentioned characteristics, Koki have jointly developed the S01X7C low-Ag, lead-free solder alloy and produced the **S01X7C48-M500** solder paste.

### Characteristics of S01X7C solder

The S01X7C solder alloy has composition Sn-0.1Ag-0.7Cu-0.03Co.

This lead-free solder has superior joint reliability and demonstrates high joint strength and flexibility, among other features. These features have been achieved by adding 0.03 percent of Cobalt (Co) that complement the characteristics of cobalt to the low-Ag Sn-0.1Ag-0.7Cu alloy.

Although this solder is a low-Ag type, it has higher shear strength and more shock absorbing ability than Sn-3Ag-0.5Cu. Table 2 summarizes the characteristics of the S01X7C solder.

Characteristics of the **S01X7C** alloy

Properties	S01X7C	Sn-0.3Ag-0.7Cu	Sn-3Ag-0.5Cu
Melting point	217-227	217-227	217-227
Specific gravity	7.3	7.3	7.4
Tensile strength (N/mm <sup>2</sup> )	36	34	36
Tensile elongation (%)	50	41	45
Hardness (Hv)	13.6	14.7	18.2
Joint strength (N/mm <sup>2</sup> )	52	42	50
Impact strength (J/cm <sup>2</sup> )	66.3	62.5	64
Creep rupture time (hour)	35.3	16.2	287
Copper erosion amount (g)	0.14	0.3	0.32

## High joint strength & outstanding copper erosion resistance

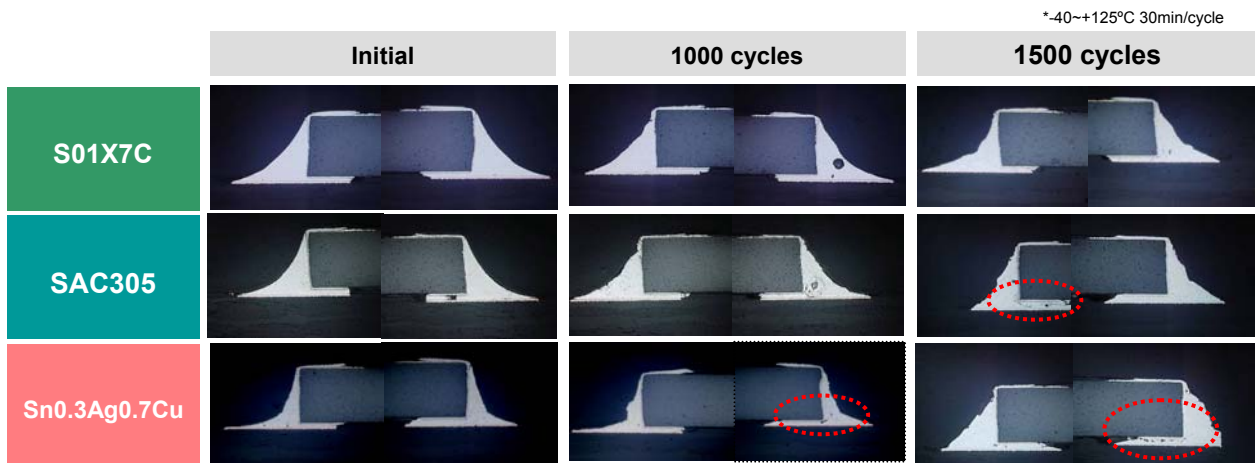
S01X7C48-M500 paste assures robust wetting action to BGA/CSP solder bumps even with intentional oxidation. A comparatively uniform layer defined as (Cu,Co)6Sn5 is formed for the solder added with cobalt, by replacing a portion of the copper (Cu) (which would have formed an intermetallic compound of Cu6Sn5 produced on the surface between the copper and the solder) with cobalt. As this layer reinforces the surface between the copper and the solder, a high joint strength can be achieved. Copper erosion caused by the solder interaction with the copper through the surface layer. Because a portion of the copper in the (Cu,Co)6Sn5 layer is replaced with cobalt, this layer serves as a barrier against the erosion of copper. As a result, this new solder demonstrates superior copper erosion resistance.

Unlike Cu6Sn5, the heat load-induced growth of this layer is slow. For that reason, the creep rupture time of the S01X7C solder is longer than the common low-Ag solder, Sn-0.3Ag-0.7Cu.

## Excellent thermal cycling reliability

The disadvantage of low-Ag solder alloys is the thermal heat cycle endurance. Consequently, it has been confirmed that the newly developed low-Ag solder alloy, S01X7C, has a heat cycle endurance equivalent to SAC305.

The below photos show the cross sectional joints of the three types of solder alloys, the SAC305, the Sn-0.3Ag-0.7Cu, and the S01X7C. A crack was detected on the Sn-0.3Ag-0.7Cu low-Ag solder sample at 1,000 cycles. This sample ruptured after 1,500 cycles, although it is not clearly visible in the photo. A minor crack was detected on the SAC305 alloy sample after 1,500 cycles, while little or no cracks occurred on the S01X7C alloy sample even after 1,500 cycles.

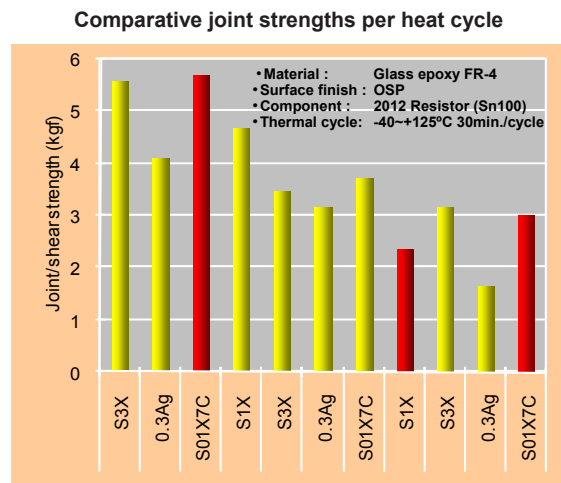


In the case of the Sn-0.3Ag-0.7Cu, a series of cracks occurred on the underside of a component, and the electrode on the right side in the photo which is in an almost ruptured state. The condition of cracks similar to these cracks were confirmed even at 1,000 cycles. The analysis indicates that these ruptures occurred at a comparatively early stage. Because the ruptures occur at an early stage and the stress is released, there is less damage on the other electrode (left side in the photo).

In the case of S01X7C, almost no changes are detected at first glance. Upon examining the enlarged cross sections of the joints, a very small crack at the corner portion of the electrode after 1,500 cycles was detected. In general, the initial crack tends to occur on the underside of the electrode. In the case of the S01X7C however a crack occurred at the corner of the electrode. Thus, it may be concluded that the S01X7C solder has a structure that can help to relieve stress.

With regard to shear strength, the joint strength of the Sn0.3Ag0.7Cu (0.3Ag) solder alloy sample is lower than the other two samples at the initial state. The joint strength of this sample tends to decline with each test cycle. On the other hand, the shear strengths of the SAC305(S3X) and S01X7C solder alloy samples decline at around 1,000 cycles, but the shear strength drop between 1,000 and 1,500 cycles is very small. This graph reveals that S01X7C has a joint strength that is almost equal to SAC305, while the low-Ag solder Sn-0.3Ag-0.7Cu does not.

Based on the above investigations, it was concluded that the S01X7C alloy has the strength and heat cycle endurance higher than the conventional low-Ag (Sn0.3Ag0.7Cu) solder and a joint reliability almost equal to SAC305.



## Anti-pillow

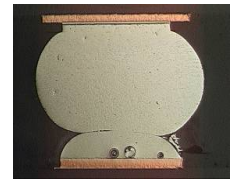
Significant enhancements in the heat resistance of the flux and wetting reaction speed have succeeded in reducing the occurrence of hidden pillow (Head-in-Pillow) defects.

**S01X7C48-M500** assures robust wetting action to the BGA/CSP bumps even with intentional oxidation.

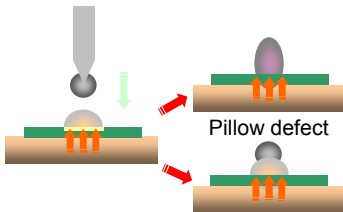
### ► Retention of flux activation

The test shows the influence of progressive oxidation of the flux/molten solder versus retention of flux activation.

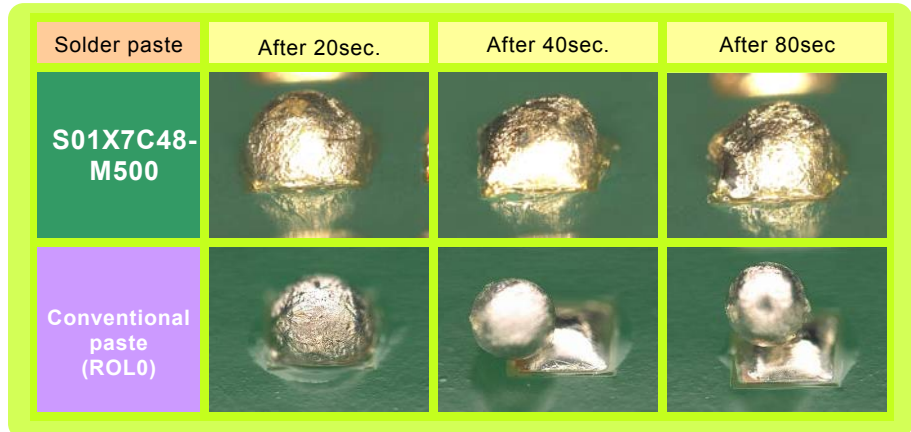
- Stencil : 0.12mm(5 mils) thickness, 100% aperture to pad size
- Pad : 0.8 x 0.8mm chip pad
- Solder ball : Sn3Ag0.5Cu, 0.76mm diameter
- Test procedure : Melt solder paste on hot plate and drop solder ball into paste every 10sec.



Pillow defect



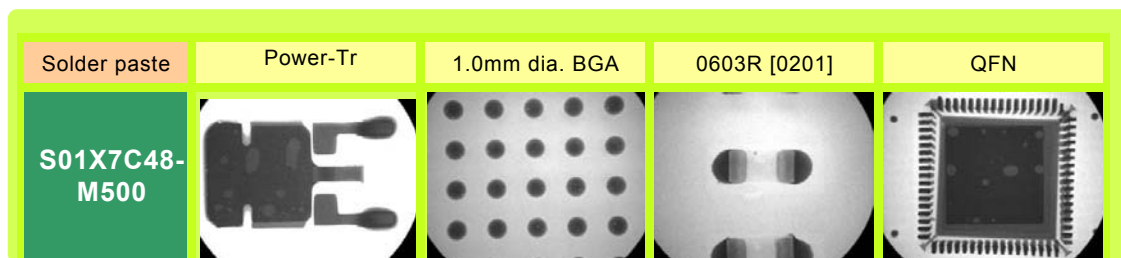
Drop solder ball every 10 sec. after the solder paste has melted to evaluate heat durability of flux.



## Low voiding

A variety of optimizations to the flux formulation combined with a newly adopted flux activator system and much lower boiling point flux materials have succeeded to remove flux gases from the solder joint more easily. This dynamic evacuation is swift and highly effective regardless of the types of surface finish and components used in the assembly.

- Material : Glass epoxy FR-4
- Surface treatment : OSP
- Stencil thickness : 0.12mm (5 mils) (laser cut)
- Components : All 100% Sn plated



## Halogen Free

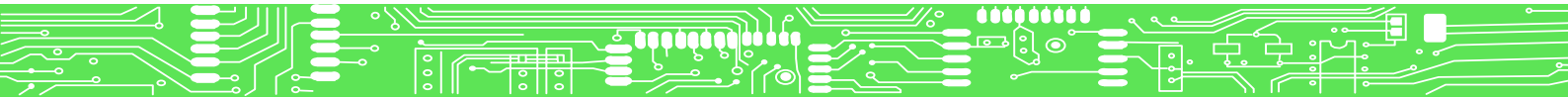
Recent increasing environmental awareness on a global scale has initiated certain restrictions of certain elements within soldering materials used in the electronics industry.

Ever since it has been reported that dioxins can be generated when specific kinds of halide are combusted, there have been moves to eliminate or reduce halogens from soldering materials, such as in solder pastes and wave soldering fluxes.

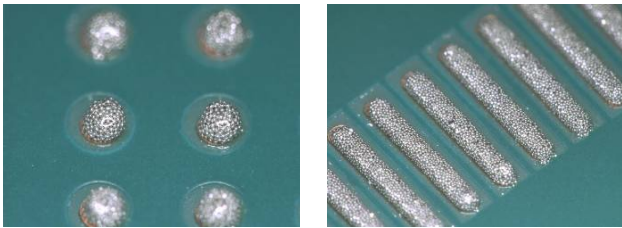
Koki's research and development team have been working on the "halogen free" issue for many years and provided various products. **S01X7C48-M500** is the latest developed product which is a "halogen free" solder paste meeting the Halogen Free criteria below.

Test method: EN14582: 2007

Substance	Permissible limit (by weight)	Actual halogen content (Analysis results by outside lab)
Chlorine (Cl)	≤ 900 ppm (0.09%)	ND
Bromine (Br)	≤ 900 ppm (0.09%)	103 ppm
Total concentration of Cl+Br	≤ 1500 ppm (0.15%)	103 ppm



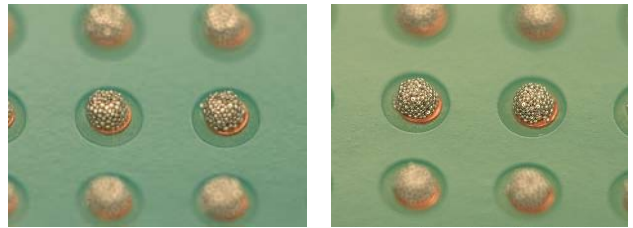
### Continual print



0.3mm dia. CSP pattern

0.4mm pitch QFP pattern

### Stencil idle time

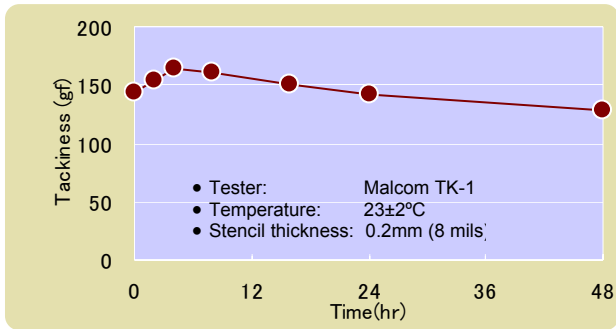


1st print

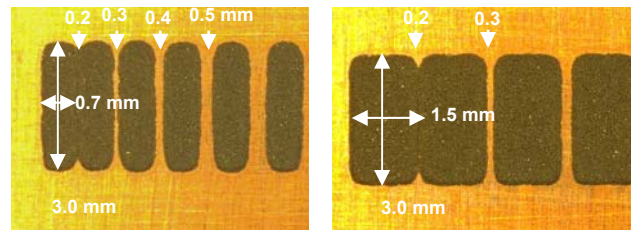
1st print after 60min. idle time

0.3mm dia. CSP pattern (OSP)

### Tack time



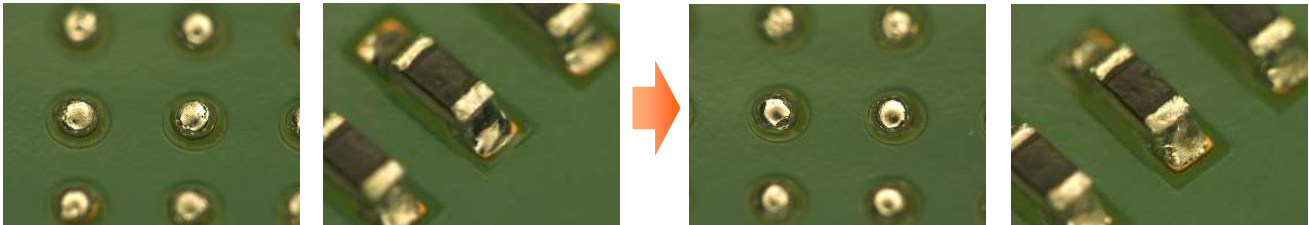
### Heat Slump



\*Heating condition: 180~190°C for 5mins by JIS Z 3284

### Solder wetting

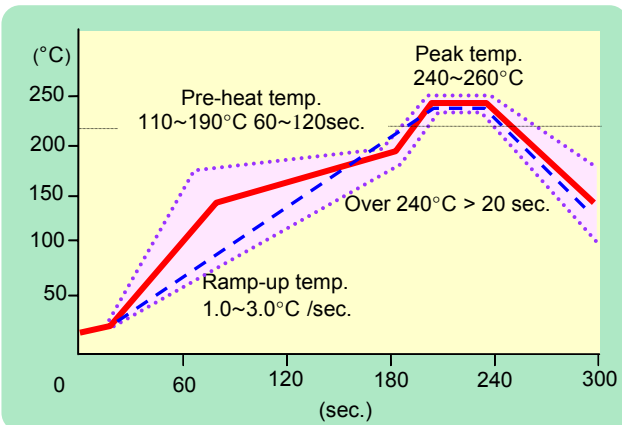
The newly developed solder paste has excellent wetting properties as well as excellent solderability on the 0.3mm diameter Chip Scale Package pattern and 0603 [0201] chip components. The solder paste maintains the same solderability even after 4 hours of stencil kneading.



Initial results

After 4-hour kneading on stencil

### Recommended reflow profile



### Specifications

Application		Printing - Stencil
Products		S01X7C48-M500
Alloy	Composition (%)	Sn0.1Ag0.7Cu0.03Co
	Melting point (°C)	217 - 227
	Particle/ Powder size (µm)	20 - 45
Flux	Halide content (%)	0.0
	Flux type*	ROL0
Product	Flux content (%)	11.3
	Viscosity (Pa.S)	220
	Copper mirror*	Pass
	Quantitative halide content (%)*	< 0.05
	SIR*	Pass
	Tack time	> 48 hours
Shelf life (5 to 10°C)		6 months

\*ANSI/J-STD-004A (IPC-TM-650)

Specifications are subject to change

# KOKI COMPANY LIMITED

32-1, Senju Asahi-cho, Adachi-ku, Tokyo 120-0026

Tel : + 81 (03) 5244-1521 Fax : + 81 (03) 5244-1525 <http://www.ko-ki.co.jp>