Technology Focus

Solder Products Evolve for Higher Performance

Ten years have passed since lead-free production became the norm, and lead-free mounting technology has advanced from the infancy period to maturity. The time has come when manufacturers choose materials in accordance with purposes and applications. The key point in mounting technology of the future will be the selection of best materials for various applications, including ultra-high-density mounting, low-cost mounting, high-reliability mounting for automotive application, void-free mounting, and semiconductor mounting.

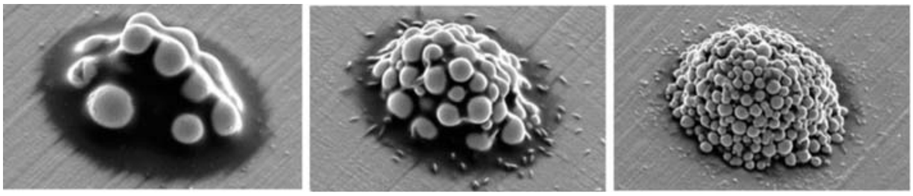
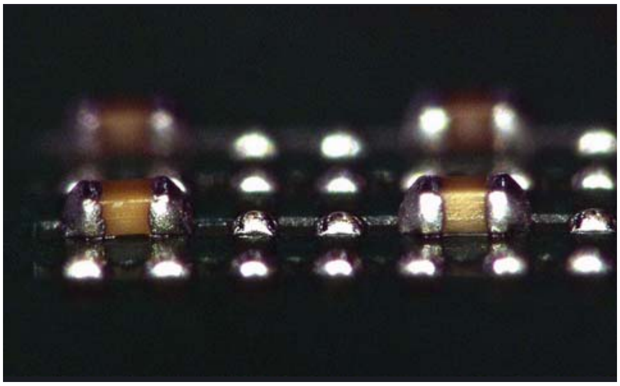


Fig. 2: Solders are printed using a pattern with an aperture of 130μmϕ and mask thickness of 60μm.

Solder Paste for 0201-Size Parts

With the practical application of wearable products, chip components have entered the period of 0201-size components. However, even though 0201 components have been developed, questions, like "How will they be soldered?" always arise. Senju Metal Industry Co., Ltd. (SMIC) has commercialized the M705-RGS800HF solder paste through mass production of Type 6 alloy powder with an average grain size of ϕ10μm and the development of the RGS800HF halogen-free flux, which improves melting performance, thereby solving this problem.



A package on which 0201 chips are mounted (Chip capacitors: Courtesy of Murata Manufacturing Co., Ltd.)

The miniaturization of components means finer lands, and in order to print paste, it is necessary to make mask opening smaller (Fig. 1).

Type 4 and Type 5 solder powder with an average grain size of ϕ30μm and ϕ20μm, respectively, have been adopted for 0603 and 0402 components, which presently are in the mainstream. If solder powder of these sizes are printed on 0201 component-specification lands, apertures of the mask are not filled with solder because the grain size is large, resulting to insufficiency in the amount of solder printed (Fig. 2).

As a measure to solve this problem, SMIC has adopted Type 6 powder. However, Type 6 powder has twice the surface area as that of Type 5 powder, and oxide film also doubles. Existing fluxes cannot remove the oxide film, and soldering residue of the solder develops, causing defective soldering. SMIC has solved this problem through the development of the RGS800HF flux, which has an increased active force and suppresses reoxidation in the reflow process, thereby enabling the mounting of 0201-size components with high joint reliability (Fig. 3).

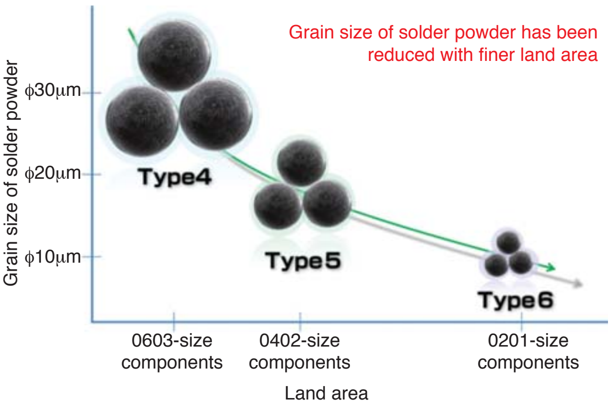


Fig. 1: Solder paste for 0201-size chip components

Flux Cored Solder with 0% Ag

At the time when Restrictions on the Use of Hazardous Substances (RoHS) Directive was introduced, SMIC pro-

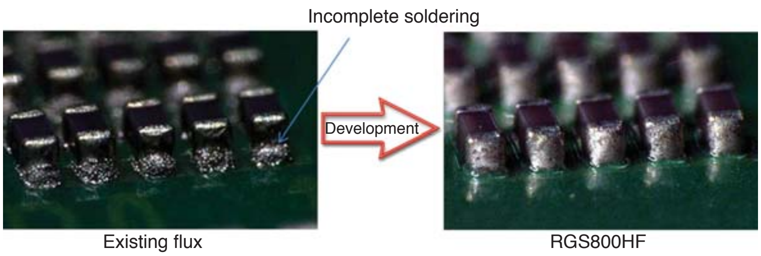


Fig. 3: Melting condition of Type 6 powder under the same condition

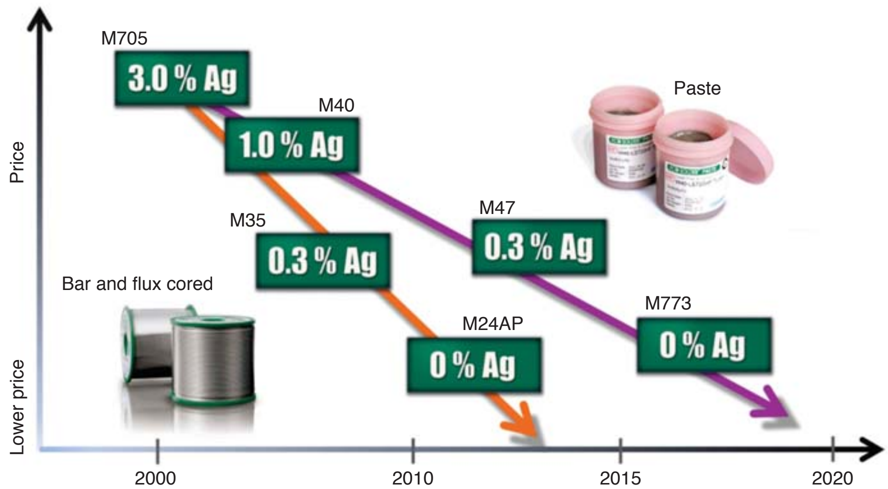


Fig. 4: SMIC has achieved no-Ag solder through verifying reliability.

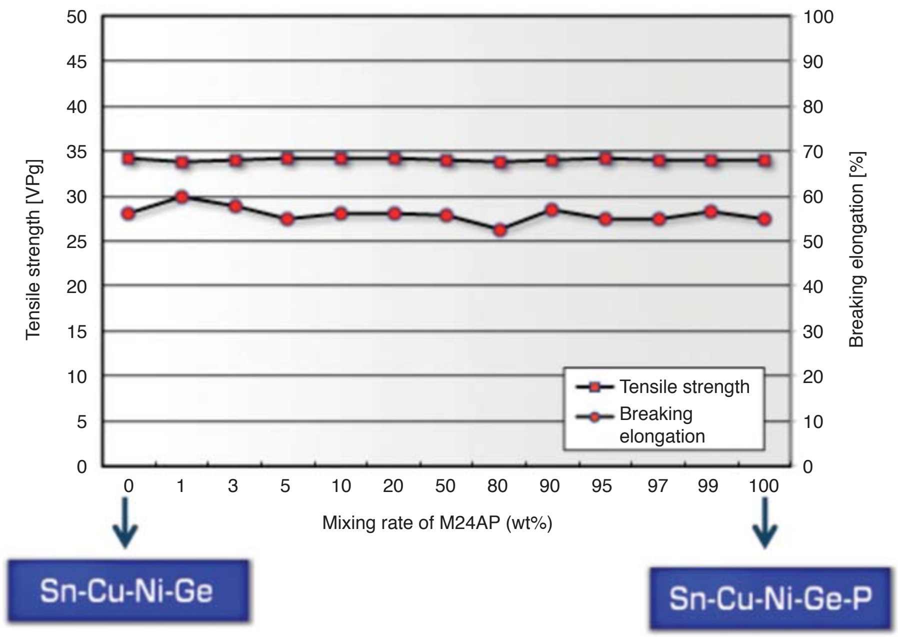


Fig. 5: No degradation verified even when M24AP is mixed with different Sn-Cu-based materials

NEO M24AP
ECO SOLDER CORED

vided M705 with 3.0%Ag as an industry standard. The company has then commercialized low-silver (low-Ag) and no-silver (no-Ag) materials in stages, from 1.0%Ag to 0.3%Ag and 0%Ag, while verifying reliability. As a flux cored solder and solder for the flow process, SMIC has developed the M24AP alloy with 0%Ag, and commercialized the flux cored solder as NEO2-M24AP and LSC-M24AP (Fig. 4).

M24AP has been produced by adding phosphorus (P) and germanium (Ge) to Sn-0.6Cu-Ni, whereby reducing the generation of dross by about 70 percent. In terms of reduction of waste, the M24AP has achieved environmental protection and reduction of bare metal price. In general, the reduction of wettability is concerned with 0%Ag flux cored solders. However, SMIC has overcome the challenge through the adoption of newly developed NEO2 and LSC fluxes. Furthermore, SMIC has verified that reliability does not deteriorate, including tension strength and breaking elongation, even if M24AP is mixed with different Sn-Cu-based materials, such as Sn-Cu-Ni-Ge material (Fig. 5).

No-Ag Solder Paste Reduces Voids

As an alloy for solder paste, SMIC has developed M773 0%Ag alloy, and commercialized it in combination with the LS730HF halogen-free flux, and LS720V, which reduces the generation of voids.

In general, joining strength is a concern with 0%Ag products. However, the M773 0%Ag alloy exhibits higher joint strength than Sn-Cu and Sn-Cu-Ni-Ge solders without the progress of crack through solid solution strengthening by Bi and by making the joint interface structure finer through the addition of Ni (Figs. 6, 7, and 8).

High-Reliability Solder for Cars

With the migration of on-vehicle electronic and electric devices from the in-car space (85°C) to the engine room (115°C), and further to direct mounting on the engine (125°C), temperatures of the device environment have increased. In addition, devices have become smaller with higher densities. Given this backdrop, electronic and electric devices that provide high reliability

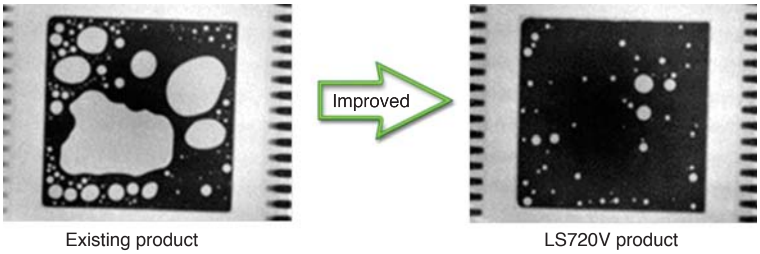


Fig. 6: LS720V flux reduces the generation of voids.

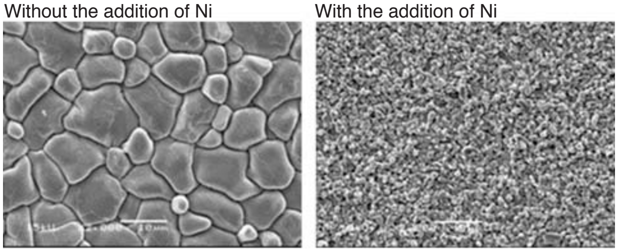
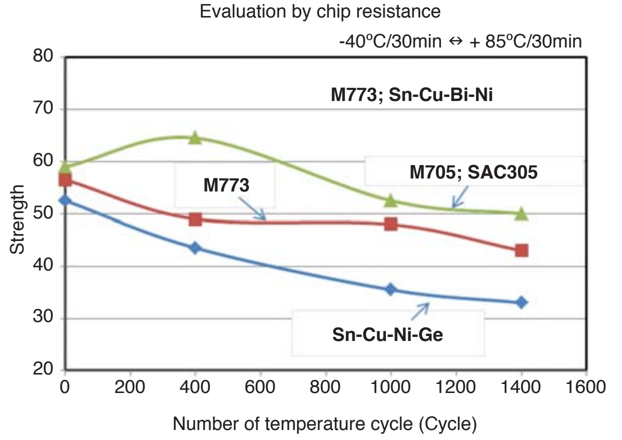
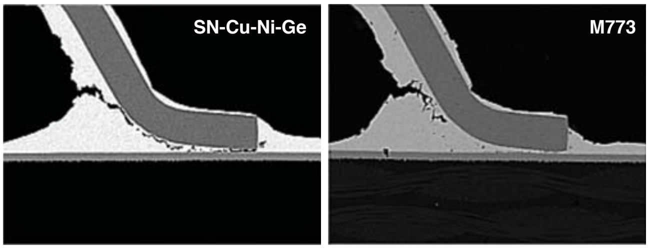


Fig. 7: Comparison of IMS alloy structure after subjected to a reflow oven four times.



• Comparison of the progress of crack between Sn-Cu-Ni-Ge and M773

Cycle condition: After 1,000 cycles in -40 to +125°C environment



Crack progresses 100 percent

Progress of crack stops at about 30 percent

Fig. 8: Evaluation results of no-Ag solder

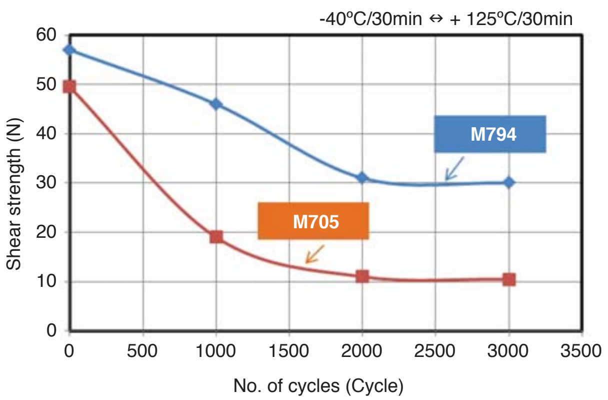
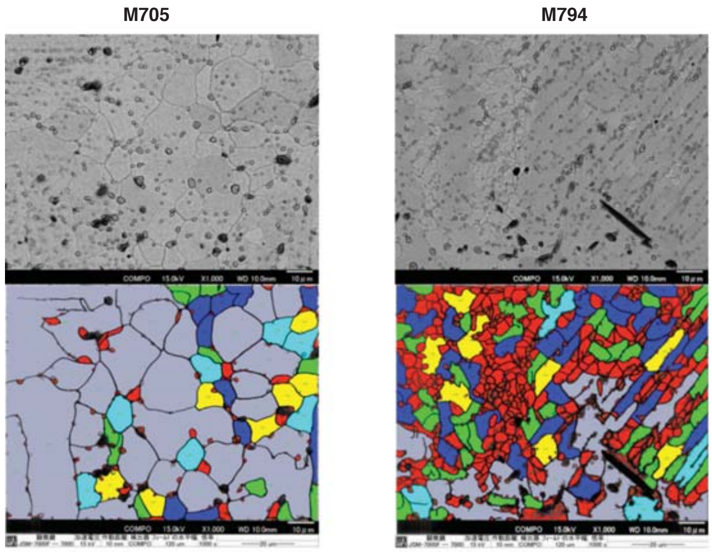


Fig. 9: Comparison of thermal fatigue resistance of alloys



Comparison of alloy structure after 3,000 cycles

Fig. 10: Effects of the addition of Ni+x

have been sought. M705 lead-free alloy has satisfied thermal fatigue resistance in a -40 to 125°C thermal cycle testing. However, it does not meet applications that require resistance to 3,000 cycles as an essential property. SMIC has developed M794 lead-free alloy for automotive application, which has achieved tin (Sn) crystal grain with higher strength through the addition of solid solution elements bismuth (Bi) and antimony (Sb) to Sn-3.4Ag-0.7Cu, which is close to SnAgCu ternary eutectic composition with excellent precipitation strengthening effect. Furthermore, through the addition of minute amounts of Ni+x, M794 has suppressed coarsening of Sn crystal grains in high temperatures, which becomes a factor of the progress of crack (Figs. 9 and 10).

Solder Balls, Cu Cored Ball (Fig. 11)

SMIC provides a multitude of products that can be selected from semiconductor packaging, such as three-dimensional (3D) packaging, in accordance with purposes and applications. In recent years, solder balls that are used in mobile devices, such as tablet terminals, and automobiles have come to be required to have thermal fatigue resistance and drop impact resistance at the same time, which was not the case with conventional devices. For solder materials, technological options for achieving these two properties contradict each other, and no such solders existed. However, SMIC has developed M770 solder ball by means of precipitation strengthening and interface response controlling technologies, thereby satisfying contrary technological requirements.

Pursuing high-density mounting leads to larger semiconductor chip sizes, and even greater stress is applied to the joint section stemming from the difference in thermal expansion coefficients between the mounted substrate and the wafer, leading to fracture. To solve this problem, SMIC has developed M758 solder ball, which features good wettability with copper (Cu) plating film of the wafer electrode, and has good bump strength at the package level owing to the interface reforming effect through the addition of nickel (Ni). M758 exhibits excellent thermal fatigue resistance compared with conventional SAC305 and SAC405 through solid solution strengthening with the addition of Bi, and exhibits drop impact resistance equivalent to or better than those of SAC305 and SAC405.

When 3D packages are built by embedding components using solder balls, there are cases, where solder balls are crushed, causing short circuit defects. SMIC has solved this problem by making mechanical and electrical connection in the vertical direction using Cu cored balls made by applying Ni and solder plating to a Cu ball, which does not melt in the melting temperature range of solder, and at the same time completely securing adequate space at the component embedded section. Furthermore, due to these characteristics of Cu cored balls, high hopes are placed on Cu cored balls also as a ma-

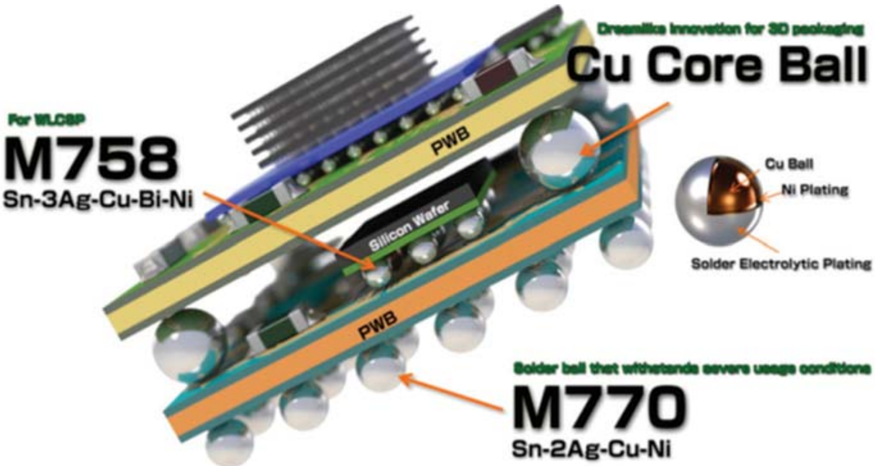


Fig. 11: M770 and M758 solder balls, and Cu cored ball

terial for narrow-pitch packaging that replaces Cu pillars. Among these include high-density packaging achieved using three types of chip solders, Injection Molded Solder (IMS) equipment for forming bumps, and SVR-625GT vacuum reflow oven achieves void-free soldering.

About This Article:

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SMIC's High-Reliability Solder Alloy Suits In-Vehicle Environment

Direct mounting of electronic devices on ECUs involves a more severe temperature, requiring alloys that exhibit enough thermal resistance.

Senju Metal Industry Co., Ltd. (SMIC) has developed a high-reliability lead-free solder alloy, M794, for electronic control units (ECUs) in automobiles.

As electric and electronic devices in vehicles have come to be mounted directly on an engine (125°C), these devices have become subjected to higher temperatures. As a result, smaller solder materials with higher density and higher reliability have come to be sought.

When temperature difference occurs in electric and electronic devices, such as ECUs, a certain level of thermal displacement develops owing to the difference in coefficients of thermal expansion between those devices and components and substrates.

While solder alloys have excellent properties to alleviate the thermal stress through plastic deformation and creep deformation, when the thermal stress is applied repeatedly, plastic strain and creep strain accumulate, leading to the development of cracks, and ultimately solder alloys fracture.

Withstands Hotter Temperature

Conventional lead-free alloy, SAC305, has satisfied thermal fatigue resistance required for solder alloys for use in general consumer products (-40 to +85°C). However, it cannot withstand the severe environment involved in direct mounting on an engine. This is considered to occur because plastic deformation and coarsening of the alloy structure develop easily, and the strength of solder bulk tends to deteriorate easily under severe high-temperature environments as in automobiles.

The newly developed solder alloy, M794, has achieved tin crystal grains with higher strength through the addition of solid solution elements, bismuth and antimony, to tin-silver (3.4 percent)-copper (0.7 percent), which is close to the tin-silver-copper ternary eutectic composition with excellent precipitation strengthening.

Furthermore, through the addition of minute amounts of nickel and an undisclosed element (x), M794 has suppressed the coarsening of tin crystal grains in high temperatures. It is considered that this is because the existence of x in the

The M794 Series solder alloy

tin crystal grain boundary promotes the refining of the alloy structure with x becoming the nucleus of recrystallization. In addition, it is also considered that pinning effect is working, aside from precipitation strengthening.

Nickel and x have effects to reform the solder junction interface (effect to smooth the intermetallic compound (IMC) layer through the refining of IMC crystal grains), and have also improved the interface strength.

As a result of temperature cycle test (from -40 to 125°C), M794 did not completely fracture after 3,000 cycles, exhibiting remarkably improved electrical reliability against thermal fatigue compared with SAC305. As a result of the observation of the alloy structure, noticeable coarsening of the structure was not observed after 2,000 cycles.

M794 not only has electrical reliability against thermal fatigue, but it also allows mounting using the conventional reflow profile as it has the melting point of 210 to 221°C, and the melting temperature range of 11°C. ❑

Alloy composition of M794

Manufacturer	Product name	Alloy composition (Weight ratio in the whole alloy)
Conventional industry standard	SAC305 (Name given by the industry)	Tin-silver(3 percent)-copper (0.5 percent)
SMIC	M794	Tin-silver (3.4 percent)-copper (0.7 percent) -bismuth (3.2 percent)-antinomy (3.0 percent)-nickel-x