Nihon Superior "Cracks the Code" for Reliable Low-Temperature Solder Formulation

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The construction of IC packages, with their multiple layers of different materials with different coefficients of thermal expansion (CTE) means that, as the temperature to which they are exposed increases beyond the temperature at which the layers were bonded, the package will warp.

That problem has been recognized since the early 2000s when, for example, the Japanese Electronics and Information Technology Association (JEITA) proposed, on the basis of careful measurements, the limit that needed to be placed on the amount of warpage that could be tolerated without compromising the quality of the solder joints.

However, the advance of integrated circuit capability could not be constrained. During the past decade, as the size and complexity of IC packages increased, package warpage moved beyond the limits of the proposed JEITA specification. The consequence was a steady increase in the incidence of the solder joint defects that are a direct consequence of warpage exceeding that specification. Examples include "head-in-pillow," which results from splitting of the fillet of molten solder between the pad and the package, and "non-wetted opens," in which there is complete separation of the molten solder from the pad or the components as the gap between the component and the substrate widens further.

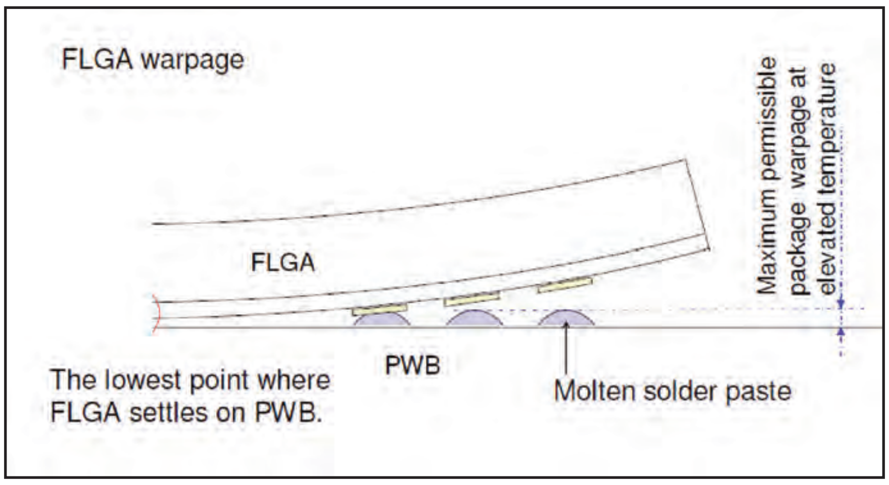


Diagram showing large IC package warpage.

While a switch from polymer to glass substrates offers the promise of an ultimate solution to the problem of warpage of IC packages, technical and cost factors seem likely to mean that, for some time yet, electronics manufacturers are going to have to assemble packages that suffer significant warpage at the reflow temperatures required by the current generation of lead-free solders.

Low-Temperature Solder

A solution to the warpage problem, which could potentially come with several additional cost and environmental benefits,

Continued on next page

Nihon Superior “Cracks the Code”

Continued from previous page

would be to switch to a solder alloy that can form reliable joints at a peak reflow temperature lower than the 482 to 500°F (250 to 260°C) required by the Sn-3.0Ag-0.5Cu (SAC305) alloy that has become the standard lead-free alloy for reflow soldering.

On the basis of the characteristics of widely used IC packages the requirement for the avoidance of warpage-related defects is that it should be possible to form a solder joint that meets the usual quality criteria with a peak reflow temperature less than 392°F (200°C).

Because of its relatively low melting point and its unique ability to react with most of the termination finishes used in electronics, tin (Sn) is an essential ingredient. Nature offers only two elements that can reduce the melting point of the resulting alloy to a temperature that makes reflow at less than 392°F (200°C) possible without introducing other complications: bismuth (Bi) and indium (In). The high cost of indium means that its use is likely to be limited to specialized high value applications.

Bismuth, which is typically cheaper than tin, provides a significant saving in material cost, and the long history of the use of bismuth salts for the treatment of indigestion means that its non-toxicity is well proven.

There is a tin-bismuth eutectic, Sn-57Bi with a melting point of 282.2°F (139°C) and wetting and flow characteristics that suggest that, with its sharp melting point, it might be the ideal solution. However, because of the particular characteristics of the near-pure bismuth phase that forms in Sn-Bi alloys, a consideration that is as important as its effect on melting point is its mechanical properties.

Optimizing Bismuth Content

Studies of the failure mechanism in Sn-Bi alloys indicate that at strain rates at the higher end of the range to which solder joints can be exposed in service the Bi phase cracks in a brittle manner with the crack propagating into the tin phase in which it is embedded triggering brittle failure of the whole solder joint.

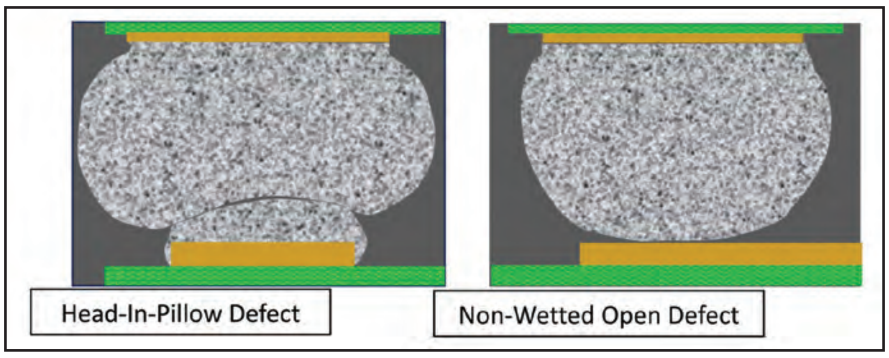
The Nihon Superior view was, therefore, that careful consideration had to be given to the volume fraction of the bismuth phase in the solder joint. Recognizing that reality, in their formulation of a solder that would meet the less than 392°F (200°C) peak reflow temperature criterion Nihon Superior reduced the Bi content to the lowest level that would still leave the alloy with melting characteristics that would make it possible to meet that criterion. That Bi level was identified as 37 wt% and that provided the basis for the alloy that, with further optimization, was introduced to the electronics manufacturing industry under the brand name TempSave B37.”

Nihon Superior acknowledges that by reducing the Bi content to 37 wt% they have increased the melting behavior from the sharp 282.2°F (139°C) of the eutectic to a melting range of 282.2 to 345.2°F (139 to 174°C).

There was a view in the industry that such a melting range would increase the likelihood of a phenomenon known as hot tearing,” the result of which is a cavity or crack.

However, the behavior of metals in what is sometimes known as “the pasty range” is

Continued on page 72



Two common defects caused by package warpage.

The State of the Art in Flying Probe Test

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and the CAD data from the design to automatically generate a complete test program.

In order to minimize the setup times for prototype, pre-series, and production tests this process is streamlined to be fast and easy, and the optimized management of the software allows the parallelization of different types of tests, saving precious operational time.

It can also include a smart analysis functionality that, using a set of algorithms based on the principles of artificial intelligence, further optimizes the test flow during execution, while keeping coverage objectives unchanged.

Full compatibility with the smart factory is now an essential requirement, and the software platform of an advanced flying probe system is able to provide smart integration with all aspects of the customer's production processes (data collection, traceability, interaction with MES, repair operations).

The platform can also include onboard machine industrial management solutions for remote monitoring of current and voltage consumption, checking the status of the power network and temperature level, for the status of the light indicators, parameters useful to indicate the correct functioning of the test, and to provide information related to predictive maintenance in real time.

Seica's Solution

Seica's PILOT VX is a flexible and configurable test system, with a set of technologically advanced tools and features, capable of providing the test solutions required by the enormous diversity that characterizes today's electronics.

An extraordinarily powerful resource, the system is usable in every phase of the product lifecycle.

Its ability to provide immediate and extremely precise access to all test points, combined with a vast suite of hardware and software measurement tools, allows the testing and validation of prototypes and pre-series quickly, without requiring operators to have in-depth and specific training on how to generate and execute test programs.

The PILOT VX has established itself as a new benchmark in terms of speed and performance, a fully automated test solution that responds to the fundamental concerns of electronic board manufacturers who want to optimize their investments.

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Nihon Superior Attains Reliable Low-Temp Solder Formulation

Continued from page 67

complex and solidification over a temperature range is not the only prerequisite for the occurrence of hot-tearing. As predicted by traditional solidification models, hot tearing has not been an issue for the TempSave B37 alloy.

With the optimal bismuth level determined, the next step in the development of TempSave B37 was to fine-tune the mechanical properties of the tin and bismuth phases with further additions. The objective was to adjust the mechanical properties of those two phases until, when the solder was subjected to stress, they worked together to accommodate the resulting strain in a way that ensured maximum ductility.

The Outcome

Ball shear testing identified the levels of Sb, Cu and Ni that optimized the toughness of the joint between the Sn-37Bi solder ball and the copper substrate as measured by the energy absorbed during the test and that is the alloy that Nihon Superior have introduced to the market as TempSave B37. Extensive testing by an independent laboratory and commercial evaluations have confirmed that the TempSave B37 has lived up to the expectation created by the development process and offers the prospect of high-yield low-temperature reflow of large IC packages.

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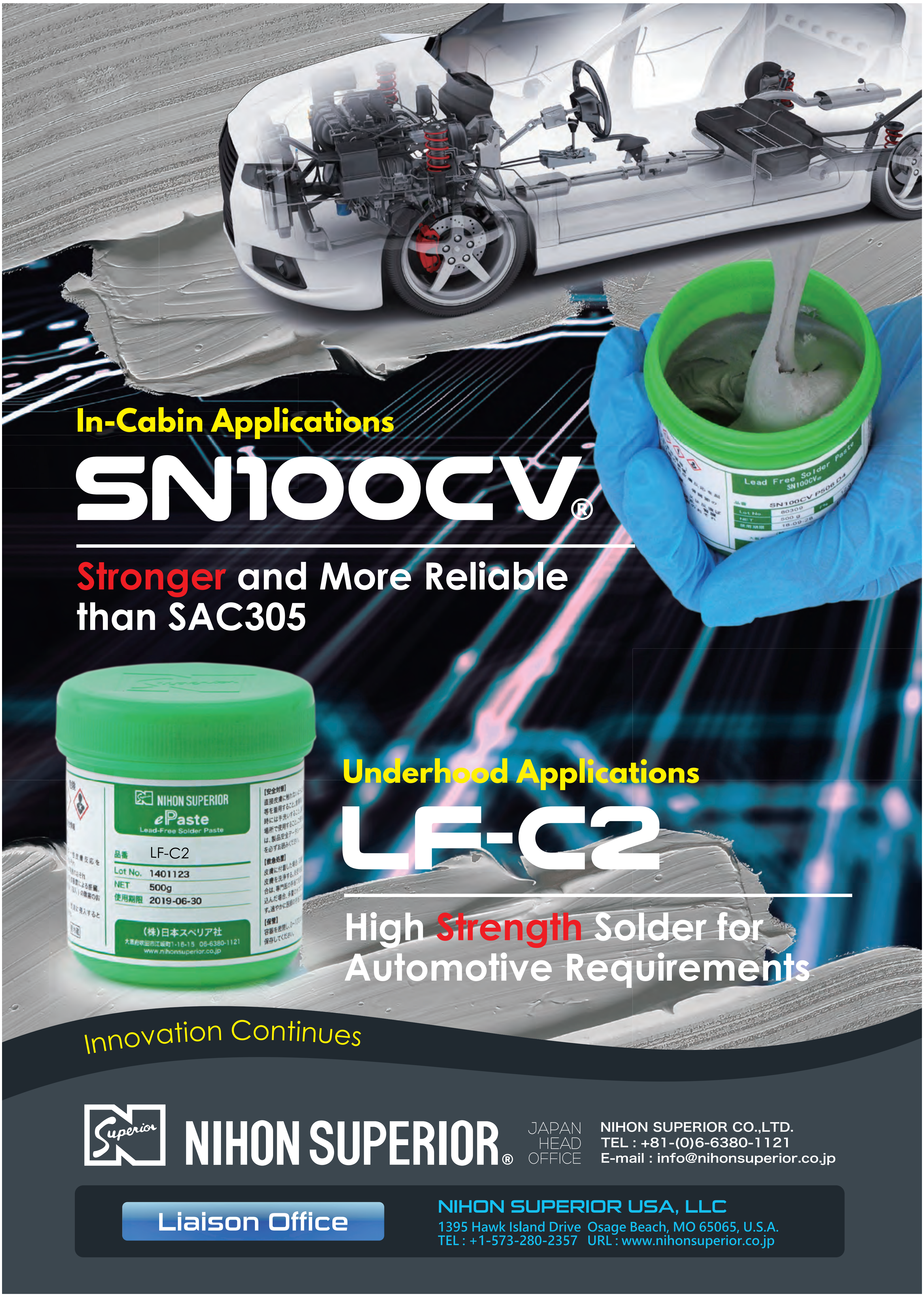
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