摩托罗拉需要一种峰值回流温度较低、提供更宽的过程窗口的焊膏，可用于各种产品，从基站、汽车应用到计算机和手机。摩托罗拉分析了七家制造商的十九种不同材料，最后认定了Henkel的Multicore LF320材料。LF320的最低峰值回流温度为摄氏229度，向摩托罗拉提供了所需质量和可靠性，在产品灵活性方面有摄氏10度的优势。本文说明由摩托罗拉开发的测试基准以及Multicore LF320焊膏的测试结果。

Making the 'Centigrade'

Vahid Goudarzi and Grahame Freeman

How Motorola tested – and approved – a lead-free solder paste.

Motorola began lead-free material evaluations several years ago, in large part because the company realized that finding a supplier to meet the unique and challenging requirements would be a long process. While lead-free pastes abound on the market, most formulations are suitable for a particular product – cellphones, for example – where a higher peak reflow temperature of 240°C is perfectly acceptable and reliable. But Motorola wanted a material that provided a wider process window with a lower peak reflow temperature for use on a variety of products from base stations to automotive applications to computers and, of course, cellular phones.

During its trials, Motorola analyzed 19 different materials from more than six vendors. What follow are the test criteria developed by Motorola and results from the solder paste it ultimately qualified.

Motorola worked with preferred paste suppliers to develop a lead-free solder paste to meet the company's quality and product reliability standards. Tests were performed in several phases defined by different paste formulations from each vendor and every material had to undergo intense evaluation against stringent process metrics, including

- Stencil printing volumetric assessments.
- Nine different, challenging reflow profiles.
- Tackiness measurements.
- Solder joint quality evaluations.
- Modified surface insulation resistance (SIR) testing.

Based on Motorola's requirements, the paste alloy composition for all tested materials was 95.5 Sn3.8Ag0.7Cu (SAC 387), the variable in each paste being the flux vehicle. The test boards had an organic solder preservative (OSP) finish and were reflowed in an air atmosphere. For material characteristic comparisons, the control paste used in the study was a tin-lead paste.

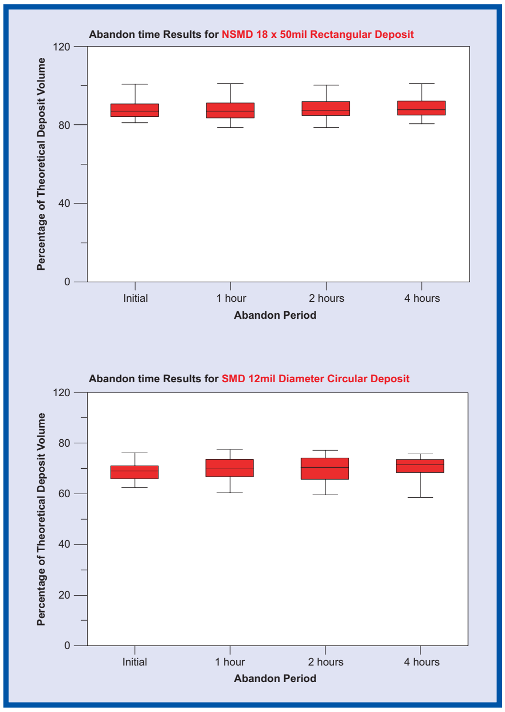

FIGURE 1: Novel paste abandon time results from two different aperture shapes and sizes, non-soldermask defined and soldermask defined.

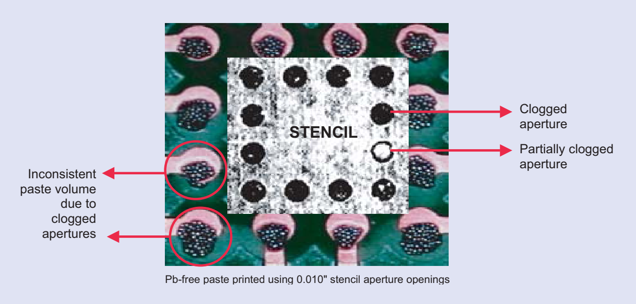

FIGURE 2: Inspection used for aperture openings of <0.012".

Screen Printing Analysis

To analyze screen-printing performance, pastes were tested based on their release characteristics at abandon times of 0, 1 and 4 hours when printed through stencil aperture openings of various shapes and sizes: 10 to 18 mm circular apertures; 12 to 25 mm square apertures; and 9 x 50 mm to 18 x 50 mm rectangular apertures. Optimum print speed, squeegee pressure and snap-off parameters were set based on the individual paste suppliers' recommendations.

Success and failure results were determined through volumetric measurement using a laser system, along with visual inspection for smearing or clogged apertures. To meet Motorola's standard, the paste-on-pad percentage of theoretical deposit volume had to be consistent at each abandon time. In other words, the volumetric paste measurements at 1, 2 and 4 hours had to be statistically indistinguishable from each other.

Due to unstable flux chemistry, many paste materials are sensitive to environmental factors such temperature or humidity. Motorola found that as abandon time was increased from 0

Peak Temperature	Time Above Liquidus: 60 sec.	70 sec.	80 sec.
229°C	P1	P4	P7
237°C	P2	P5	P8
245°C	P3	P6	P9

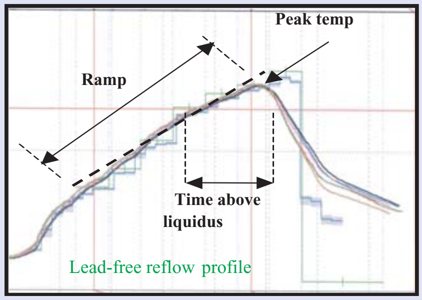

FIGURE 3: Lead-free solder pastes had to perform successfully in nine different reflow profiles.

hours, paste volume failures began to appear. The material that passed qualification – Henkel's Multicore LF320 – achieved optimal results at each abandon time (**Figure 1**).

To inspect aperture openings of <0.012", stencils were backlit and visually inspected post-print at each abandon time. An example of a Pb-free paste failure printed through a 0.010" aperature is shown in **Figure 2**. Note the clogged and partially clogged apertures, which resulted in inconsistent paste volume.

Pastes were also evaluated for flux tackiness to determine if it was sufficient to secure components in place during various manufacturing processes. Tack was evaluated at 0, 1, 2, 4 and 8 hours.

Based on the IPC-TM-650 test procedure, tackiness was analyzed by measuring the force required to separate a 5 mm diameter probe from the paste. For analysis, paste was printed through a 6.3 mm diameter circular aperture with a stencil thickness of 250 µm onto a ceramic substrate and stored until evaluated. Measurements for tackiness were taken immediately after printing and defined storage periods. Flux tackiness had to be consistent at 0, 1, 2, 4 and 8 hours.

Reflow Profile Development

Because Motorola wanted a paste that could be used on a variety of products, it required a material with a relatively low peak reflow temperature to protect temperature-sensitive components. Only a material that performed equally well in all profiles would be selected.

Each paste was put through nine different reflow profiles where the interaction between peak temperature and time above liquidus was varied (**Figure 3**). Then, coalescent performance on a small pad (0.012" diameter circular apertures on copper-defined and soldermask defined areas) was assessed. Poor coalescence for the failed pastes was attributed to powder oxidation during air atmosphere reflow (**Figures 4** and **5**).

Wetting performance was also evaluated on three areas of the test board. Material was printed onto nine test boards: three virgin boards, three boards that had been pre-oxidized by a single pass through the reflow oven and three boards that had been pre-oxidized by three passes through reflow. Following reflow, the specified areas were examined to assess each material's wetting characteristics (**Figures 6** and **7**).

Solder balling and coalescence tests were conducted to assess reflow performance of a deliberately over-printed paste deposit. Material was printed onto 12 test boards: six virgin boards and six boards

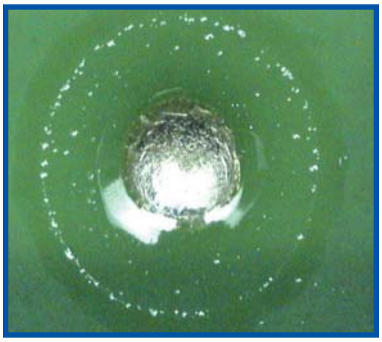

FIGURE 4: Poor coalescence attributed to powder oxidation during reflow in an air atmosphere.

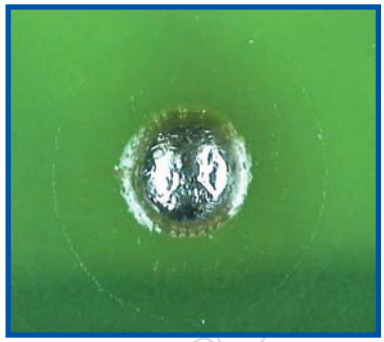

FIGURE 5: The qualified paste shows good coalescence.

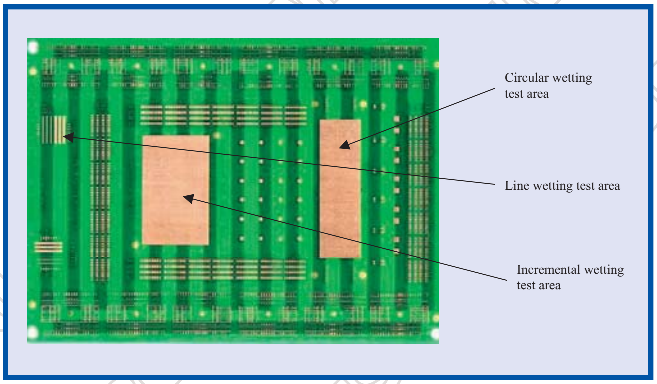

FIGURE 6: Goop troop test board for wetting analysis.

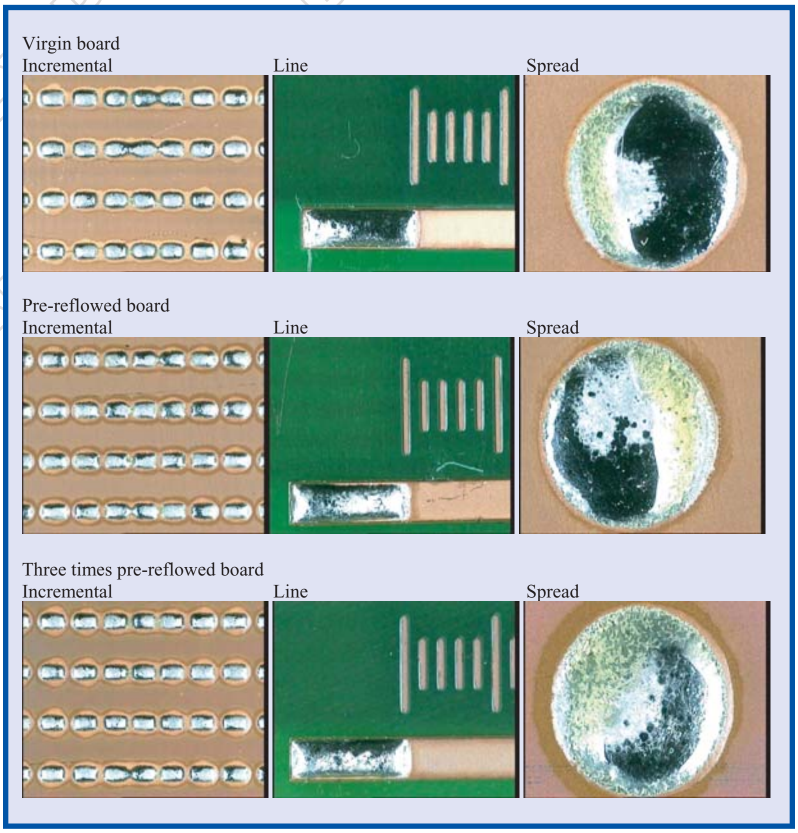

FIGURE 7: Wetting test results of the novel paste.

that had been pre-oxidized by a single pass through the reflow oven. Two boards from each set were reflowed immediately, two from each set were reflowed after 2 hours storage at ambient conditions and two from each set were reflowed after 1 hour storage at 30°C, 90% RH. The over-printed paste deposit was examined for coalescence and evidence of solder balls on the mask.

To further determine long-term solder joint quality and product reliability, accelerated life testing (ALT) was also performed on all materials.

> **To further determine long-term solder joint quality and product reliability, accelerated life testing (ALT) was also performed on all materials.**

Modified SIR Testing

Finally, SIR testing was performed to determine whether the pastes would be likely to produce shorts due to metal migration between conductors. Motorola performed SIR analysis with an IPC-B-25 modified test board, altered with the addition of soldermask. Resistance measurements were taken at varying intervals from 24 to 168 hours, over five different channels with a minimum voltage requirement of 10^8 Ω.

One of the pastes that passed all test criteria and qualified for use by Motorola was Multicore LF320. And while the material had to meet stringent technical requirements, Motorola also recognizes the importance of excellent global customer support. Open lines of communication, cooperation between the technical staffs and a commitment to success were all critical for the development of a robust, versatile material. The cooperation, perseverance and partnership of customer and supplier cannot be underestimated in such analyses. ■

__Vahid Goudarzi__ is a distinguished member of the technical staff at Motorola (Motorola.com); evg001@motorola.com. __Grahame Freeman__ is product development manager at the electronics group of Henkel (henkel.com/electronics); grahame.freeman@henkel.co.uk.