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GEOMETRIC CHARACTERIZATION OF SOLDER JOINTS IN SMT ASSEMBLY USING SPI AND AOI FOR PRELIMINARY SCREENING OF LEAD-FREE MATERIALS

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Objective

To evaluate solder paste deposition using 3D SPI and post-reflow fillet geometry using 3D AOI, investigating the combined use of these techniques for preliminary material screening. Three lead-free formulations and one SnPb reference were studied on PCBs with four symmetrical modules.

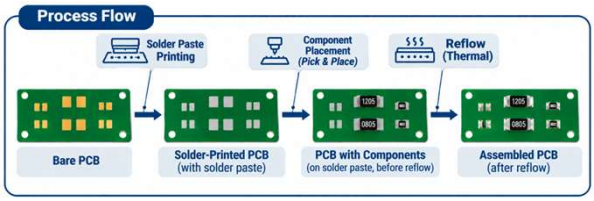
Methodology

Printing used a nano-coated stencil and one sacrificial board for initial paste conditioning for each formulation. A total of 48 PCBs were assessed by 3D SPI (12/paste) and 12 by 3D AOI (3/paste), focusing on 0603, 0805 and 1206 chip resistors.

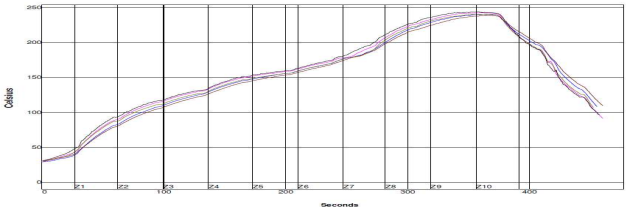
SMT Assembly Process



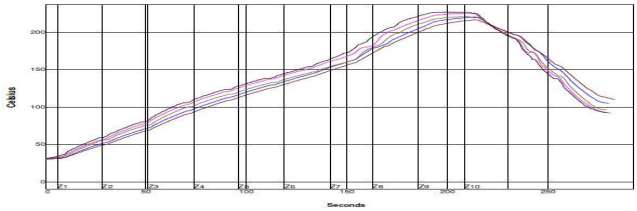
Industrial SMT assembly line



Measured Reflow Profiles

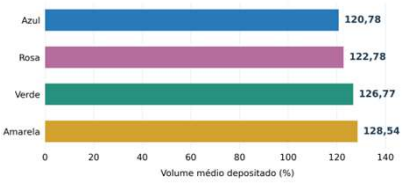


(a) Hybrid profile · three lead-free formulations

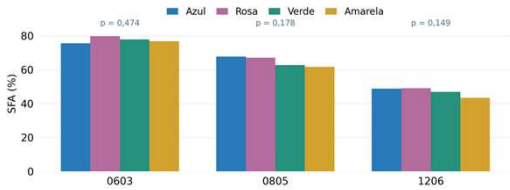


(b) Dedicated profile · SnPb reference

Quantitative results | industrial inspection



(a) 3D SPI · Deposited volume



(b) 3D AOI · Side Fillet Area

SPI: $F(3,44) = 14.49$; $p < 0.001$; largest difference between means: 6.43%. AOI: $p > 0.05$ for all three package sizes; lack of significance does not establish equivalence. SPI and AOI used different sample sizes.

X-ray images | exploratory supporting evidence

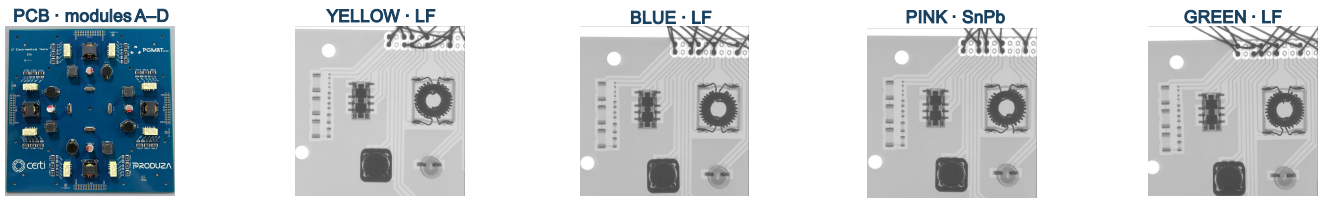


Figure 1. PCB and X-ray images (exploratory).

Optical inspection principles and representative AOI images



Figure 2. SPI/AOI principles and representative AOI images of 0805 resistors; images are not to a common scale.

Discussion and conclusions

SPI revealed significant differences in deposited volume among formulations ($p < 0.001$), indicating different transfer responses under the evaluated conditions. AOI found no statistically significant differences in side fillet area (SFA) for any of the three package sizes ($p > 0.05$). Combined SPI–AOI characterizes complementary stages of SMT assembly and supports preliminary screening, but does not replace reliability testing.

REFERENCES

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