Search this site
or the web

What's New

Site search
Web search

Tutorial 80 - - January 2008

PDF Version

Suppliers
Tutorials
Literature
Books
News
Photos
Newsletter
Updates
DrFlipchip
Home

Nano-particle Solder Paste

Alan Rae
Nano-Dynamics Inc.

Tutorial 80 is excerpted and adapted from a paper originally published in the 2007 SMTA International Conference Proceedings, and appears with the permission of SMTA.

Lead-free challenges

Environmental regulations require that solder alloys for electronic components and printed wiring board interconnections be lead-free. Lead-free solder alloys such as Sn/Ag/Cu have become common. However, they generally have liquidus points of 220ºC or higher, compared to the 183°C melting point of eutectic tin-lead solder. The high melting point alloys require higher processing temperatures, with reflow process temperatures typically above 240ºC.

These higher reflow temperatures may create greater residual stresses in board assemblies, which potentially reduce reliability. Components may be limited to those passing high-temperature qualifications. Higher temperatures sometimes require major changes in both manufacturing equipment and processes.

Nano-particle characteristics

Many materials, including pure metals, exhibit a change in properties as their particle sizes approach nanoscale dimensions. The increase in the surface-to-volume ratio, which occurs naturally as particle sizes shrink, necessarily increases the relative proportion of higher energy surface atoms. The effect may include a change in reactivity, such as in sinterability, the agglomeration of metal particles by heating. It may also appear as a change in electromagnetic properties, altering electronic or optical properties.

The particle size where these changes occur – the "tipping point" – depends upon both the individual element or compound and its environment. Property changes normally require particle diameters to be somewhere below 100nm. The tipping point shows as an abrupt shift in the slope of the measured curve. Figure 1 illustrates a tipping point in sinterability temperature as a function of the particle size.

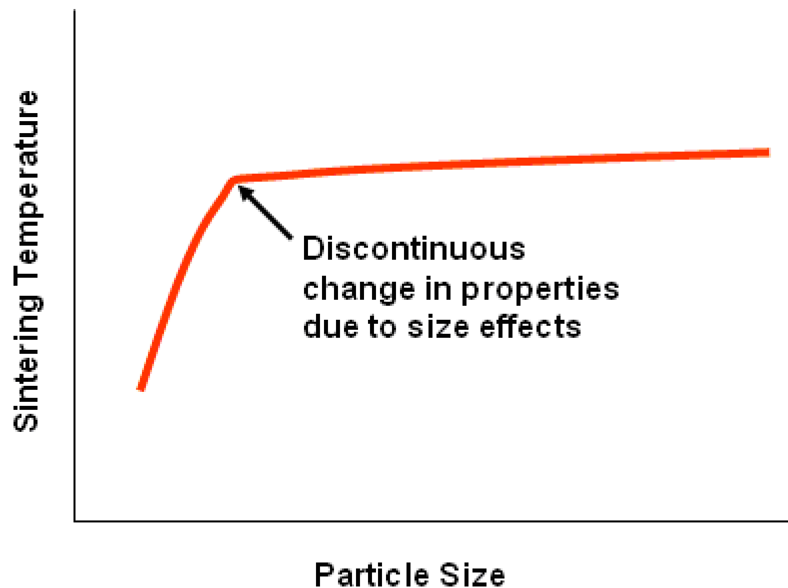

Figure 1. Tipping point example.

The phenomenon of melting point depression of nanoscale metal particles has been studied since the 1960s, when it was noticed that extremely thin evaporated particles of metal have a lower melting point than the bulk material. [1] Evaporated tin particles and gold nano-scale particles were studied by Buffat and Borel, who demonstrated melting point depressions of well over 50% compared to the bulk melting point of gold. [2]

More recent researchers have developed alternative experimental methods, such as nano-calorimetry, to measure the latent heat of fusion as a function of temperature. [3, 4, 5] This new calorimetric technique allows measuring nano-Joules of heat.

Based on these nano-calorimetry studies, a simple expression was developed that relates melting point and particle size. [4]

$$\mathbf{T_m(r) = 156.6 - (220/r)}$$

where $T_m(r)$ is the melting temperature in degrees Centigrade and r is the radius of the particle in nanometers. This equation reveals that significant melting point reduction occurs when the particle radius approaches 20 nanometers.

Nano-solder potential

Solder materials containing nano-sized metals exploit the high surface area and high surface energy of nano-sized particles to lower the apparent melting point below the conventional melting point. Pure metals, such as Sn, Pb, and Cu, are known to show significant melting temperature depression, with the amount of temperature depression increasing as the particle size decreases. Thus the melting points of tin, silver and copper, the ingredients of lead-free solder, can all be depressed below 200° C, well below the eutectic melting point of 217 °C.

Major challenges remain in developing lower temperature lead-free solders. The sub-20 nanometer particles must be uniform in size, well-dispersed, and oxide free. However, researchers continue to show progress towards low melting point nano-particle solder paste.

FOR MORE INFORMATION

The original paper "Nanotechnology Advances in Printable Systems for Conductors and Interconnects" by Dr. Rae includes the citations, additional details and graphics, and technical discussion of related topics. It is available in the 2007 SMTA International Conference Proceedings, available from SMTA.

Author Contact: arae@nanodynamics.com

FlipChips Dot Com
210 Park Ave #300
Worcester, MA 01609 USA

Phone 508-753-3572
FAX 508-757-0220
EMAIL DrRiley at flipchips.com

© 2007 G. Riley -- All rights reserved