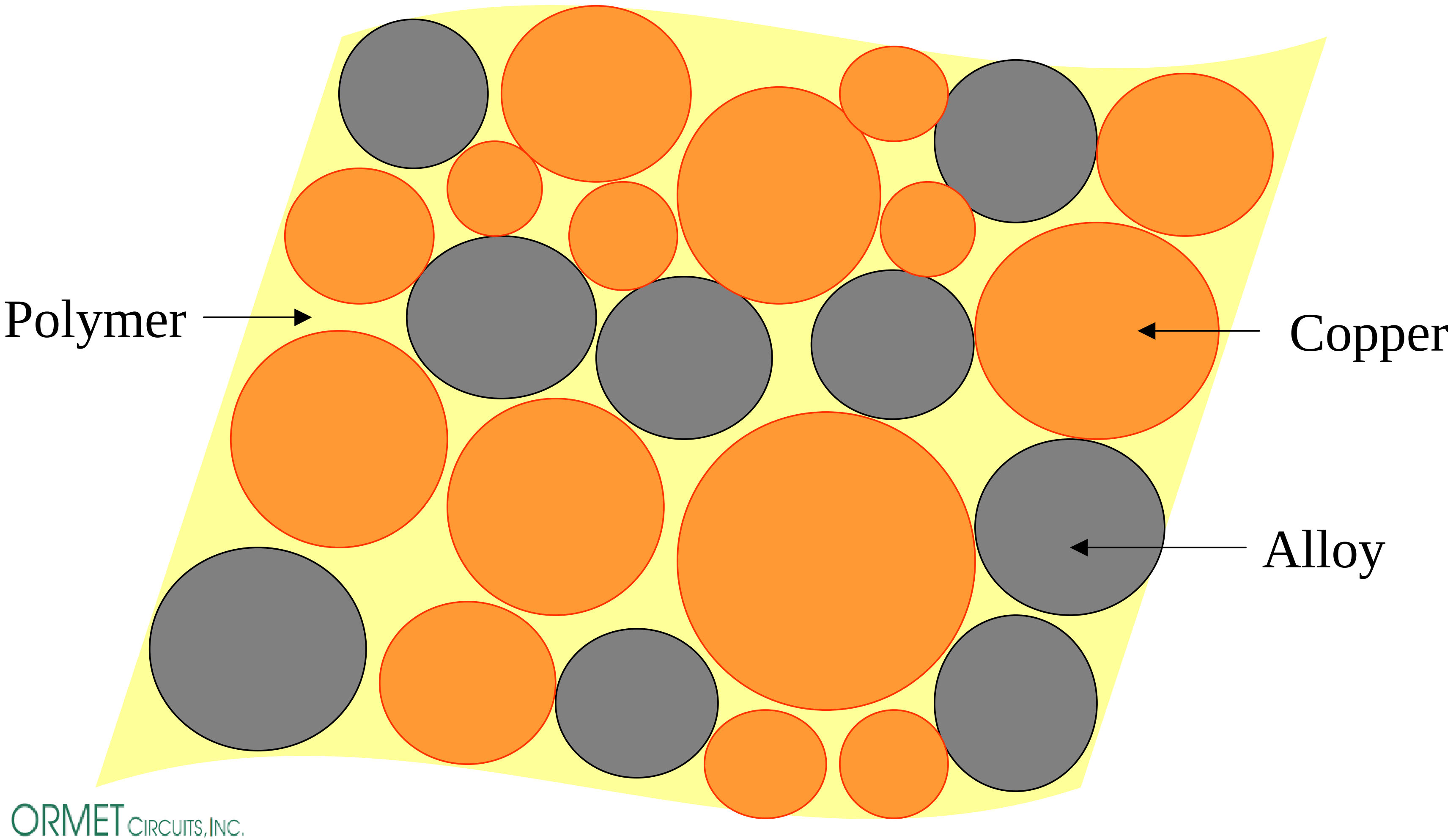
Ormet Microvias

What Happens During and After Lamination

Sept. 27, 2011

ORMET CIRCUITS, INC.

Ormet Lead-Free Materials:
What happens during temperature processing?



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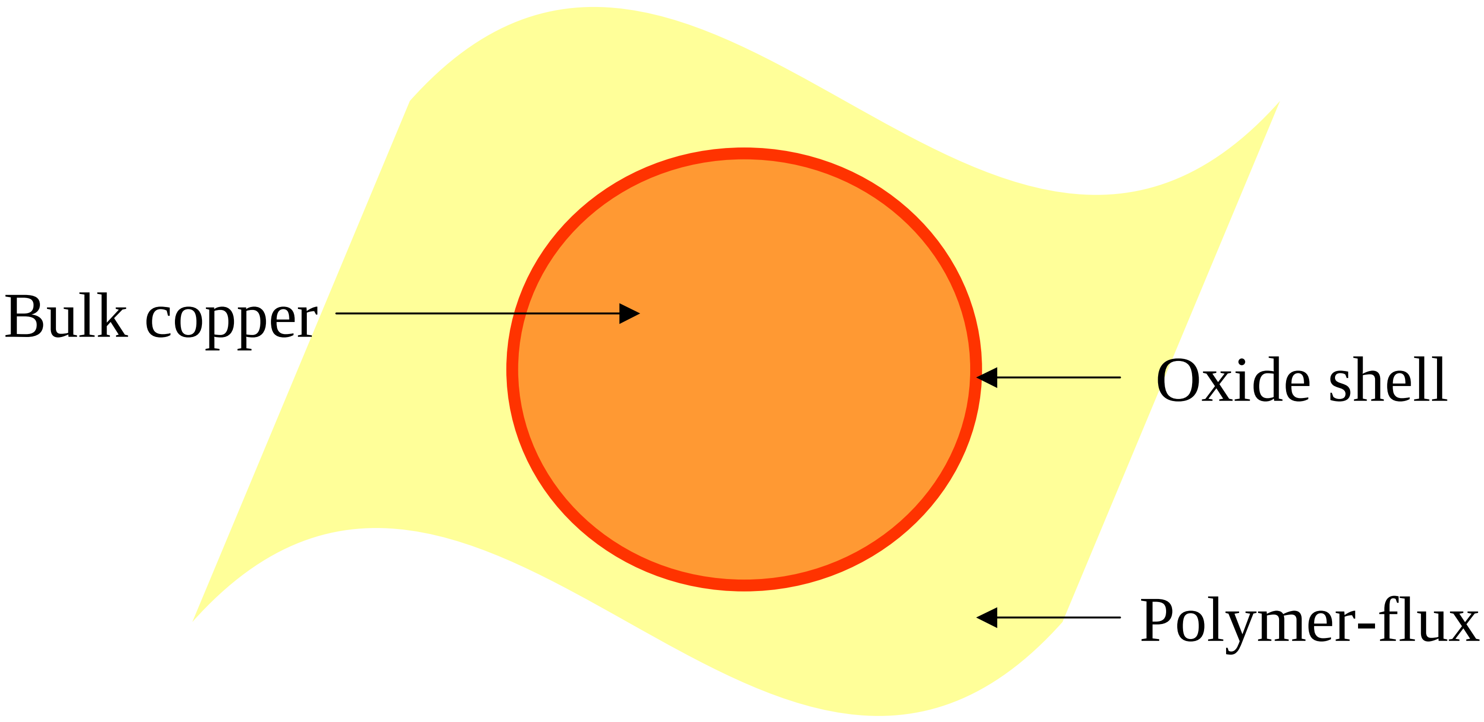
Room temperature – 120°C



The flux in the polymer composition removes the oxide shell from the copper particles.

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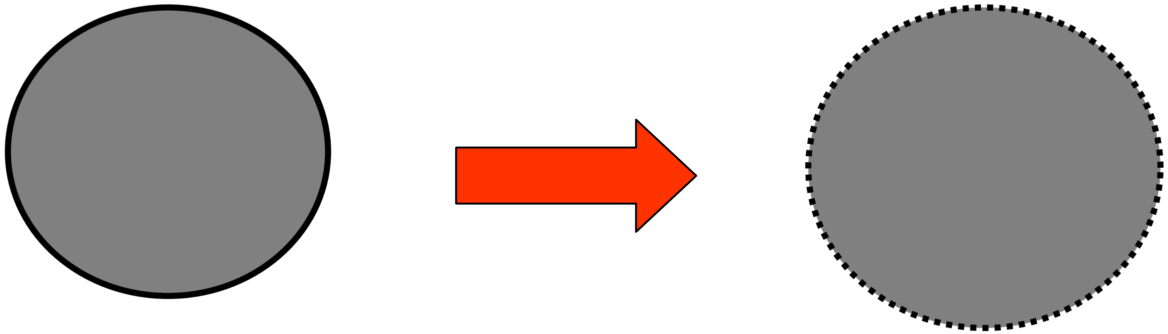
120°C - 137°C

Alloy particle with oxide shell

The oxide shell of the alloy particle breaks as the alloy <u>begins</u> to melt.



120°C

137°C

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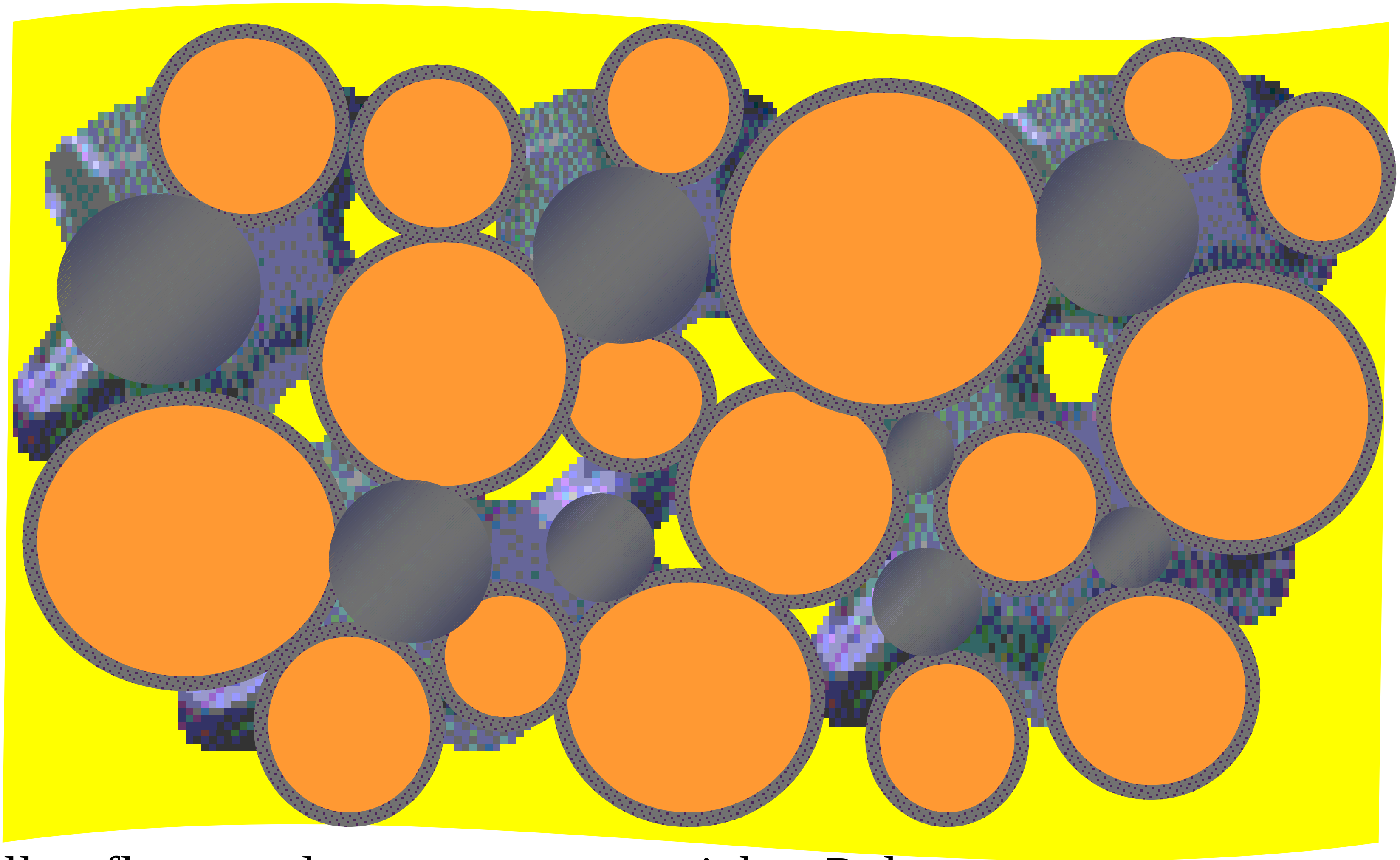
137°C ~ 190°C



Alloy flows and coats copper particles. Polymer starts to set up.

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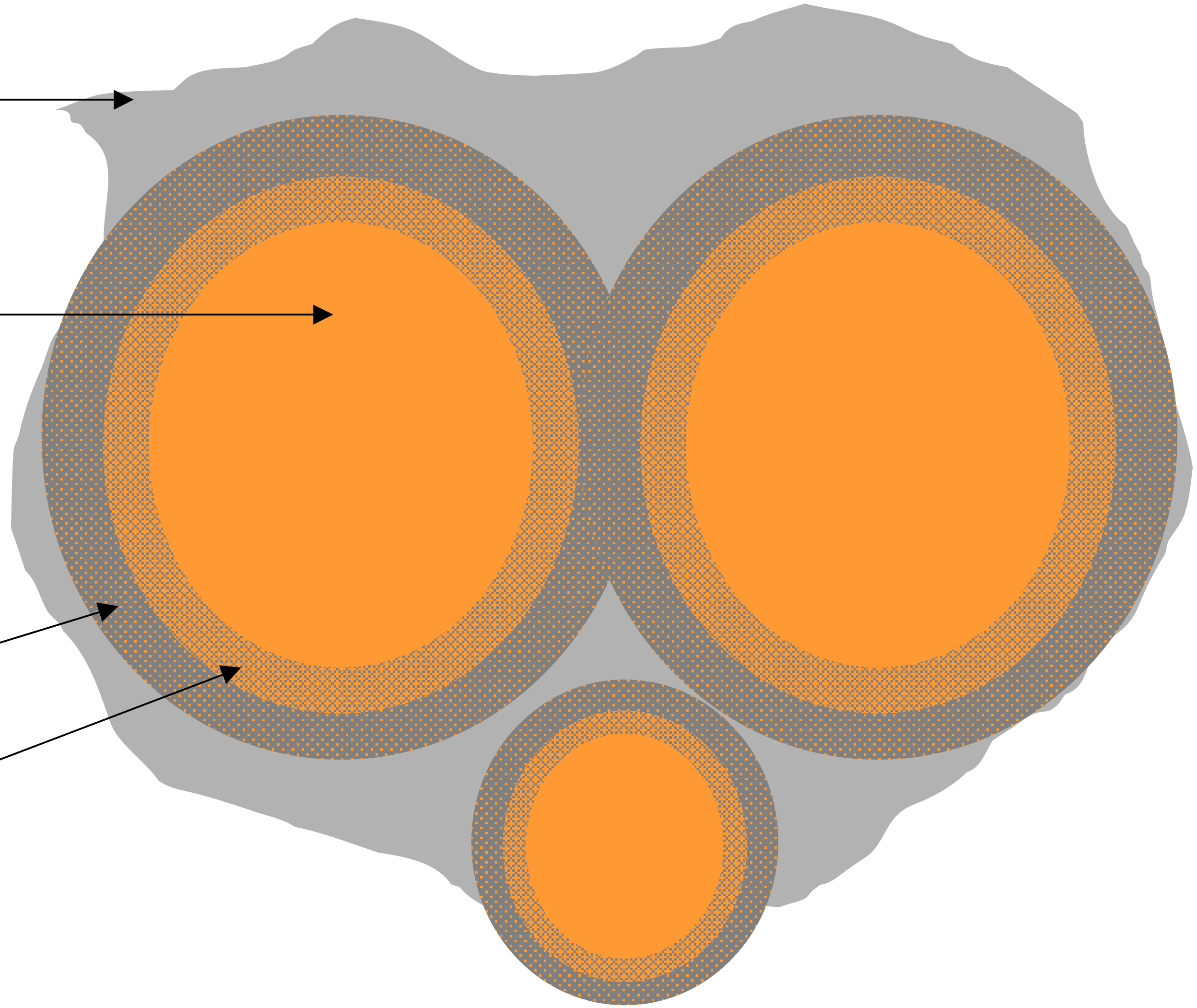
After < 3minutes at 190°C

Bi:Sn mixture of alloys
Melt onset 195°C
~20% of total matrix

Cu
Melt 1085°C
(Cu and Sn will
continue to interdiffuse)

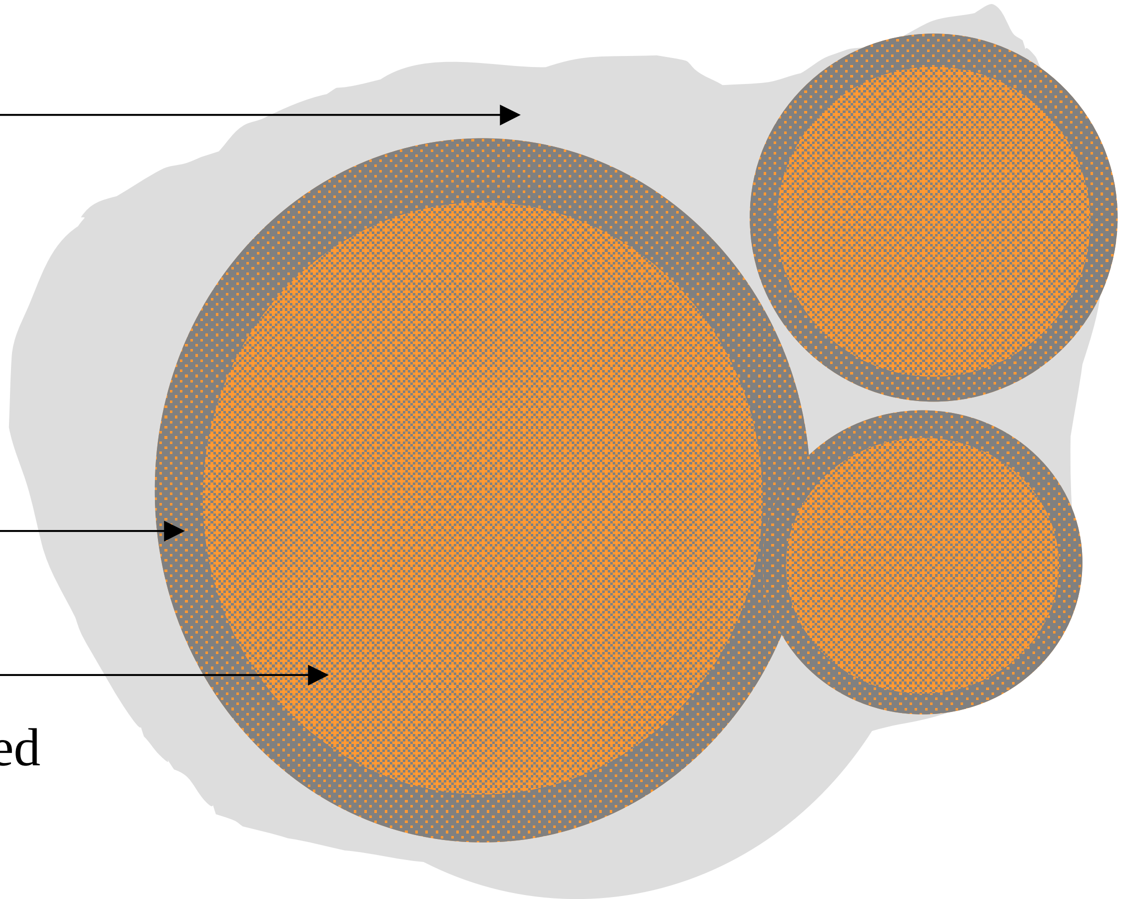
Cu_6Sn_5 intermetallic
Melt 415°C
Cu_3Sn intermetallic
Melt 640°C



After a few minutes >205°C

Stable residual SnBi
alloy phase
Remelt ~200°C

Cu_6Sn_5 intermetallic
Melt 415°C
Cu_3Sn intermetallic
Melt 640°C
>80% of total matrix combined



To Recap:
The Ormet Lead-Free Reaction (1)

- After drying (solvent removal) heat the Ormet to ~190°C and hold for at least 5 minutes. What happens?
  - The copper is cleaned by the flux
  - The initial alloy melts, flows and wets the copper
  - The polymer entraps the flux byproducts and begins to cure
  - The composition of the alloy reaches approximately Bi:Sn (80:20) and solidifies
- What is the result?
  - The metallic matrix between copper particles has been formed
  - The b-staged polymer matrix is entwined with the metallic matrix
  - The ~20% of the metal matrix formed from the Bi:Sn (80:20) alloy demonstrates a thermal transition at about 195°C
  - The material demonstrates stable CTE through the thermal transition temperature
  - Resistance changes will occur with thermal exposure unless the matrix is exposed briefly to a conditioning step above 205 °C – this annealing step creates a matrix with very stable resistance

The Ormet Lead-Free Reaction (2)
What Happens Next?

- To eliminate the resistance shift post-fabrication thermal conditioning is required.
  - At temperatures between 195°C and 205°C, the mechanism is mostly solid-solid diffusion and may take many hours or days to drive the tin into the copper
  - At temperatures above 205°C, the mechanism is liquid-solid diffusion and occurs within seconds to minutes.
  - One solder reflow cycle is completely sufficient to condition the laminated board

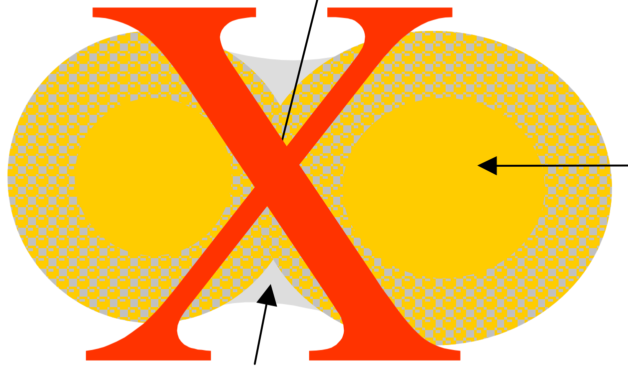
The Implications

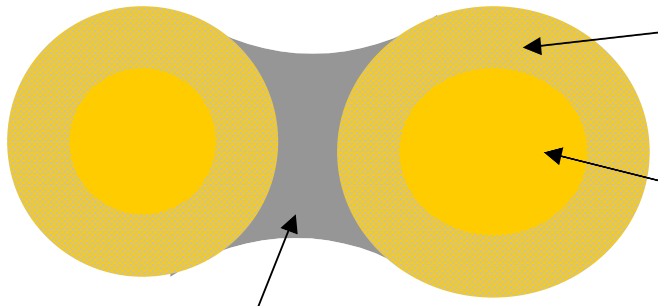
- To achieve stable resistance, the matrix must be subjected to a thermal exposure in excess of 205 °C
  - This consolidates the residual alloys into the most thermodynamically stable species and drives the interdiffusion with copper to completion
  - A post-fabrication conditioning step is not unusual in the industry
- Does the presence of a small remelt in the matrix after conditioning constitute a problem?
  - On the contrary, it is believed to be beneficial
  - Resistance and CTE are stable through the transition temperature (~200°C)
  - 80% of the matrix melts above 400°C.
  - The transition alloy may act as a stress sink during subsequent assembly or other high temperature operations

Formulation Concept

Permanent flux-polymer system with low crosslink density

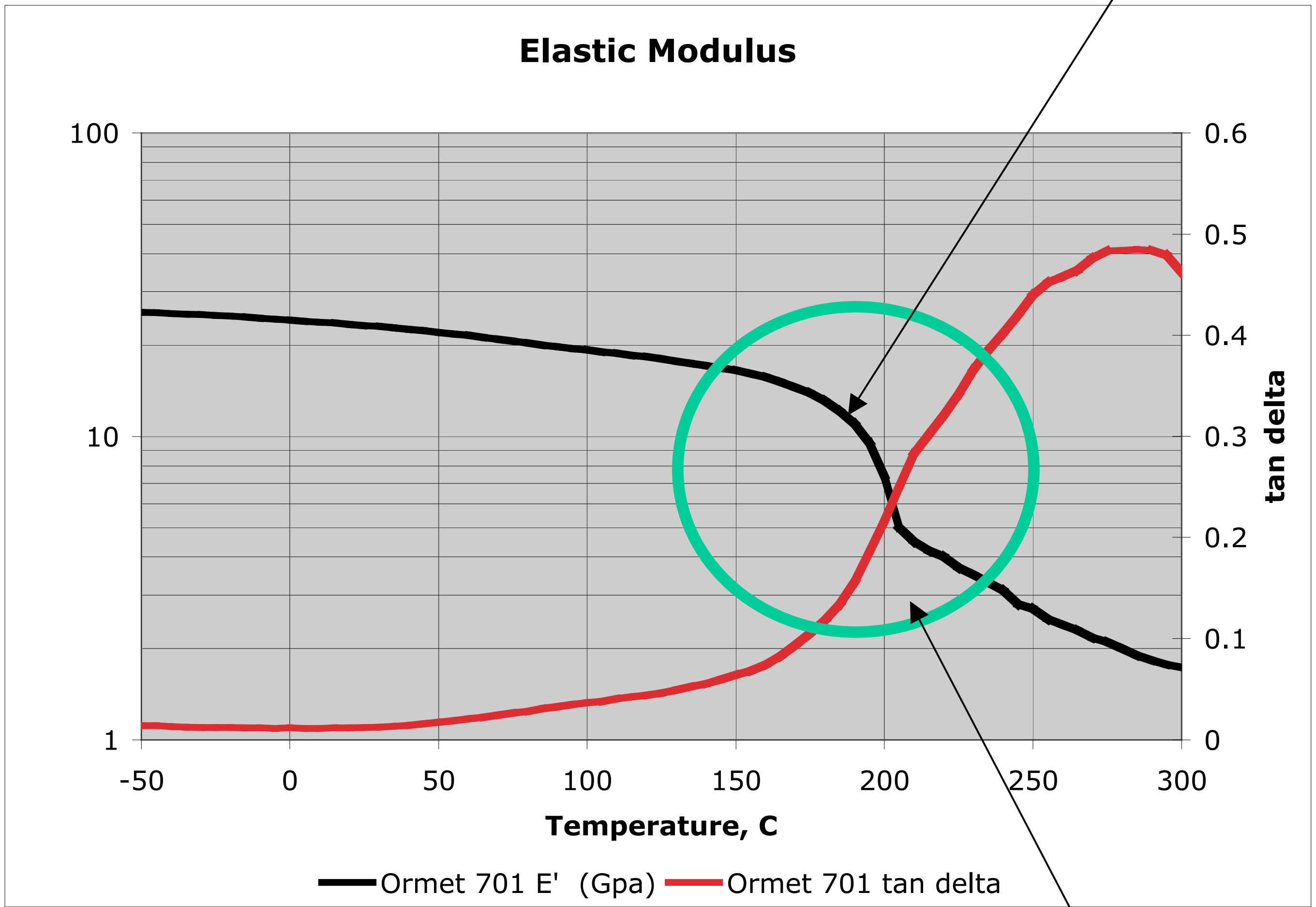
Thermosetting metallic matrix with an excess of alloy to form fusible bridges within the mesh.





Modulus

Laminate T_g



Critical drop for stress relief as laminate expands in the z-axis

The Short Answer

- Processing lead-free Ormet at 190°C in a standard lamination cycle
  - Creates a metal matrix in which 80% has a melt point above 400°C
  - Produces a transition alloy (20% of matrix) that has a thermal event at 195°C, but exhibits stable resistance after reflow conditioning
  - The residual alloy is present in fusible bridges that melt and absorb stress during thermal cycling through the laminate Tg.