Fluxless Soldering Technology for MEMS and Photonics

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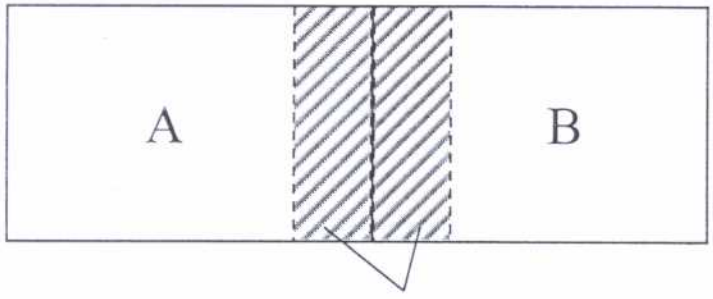
Outline

1. Introduction: Bonding Principle
2. Soldering Action
3. Flux Action
4. Scanning Acoustic Microscopy
5. Oxidation-Free Fluxless Bonding Technology
   - How?
   - Au-Sn Phase Diagram
   - Multilayer Composite Design
   - Bonding Principle
   - Experimental Results
6. Systems Studied
7. Summary

What makes materials stick (bond) together?

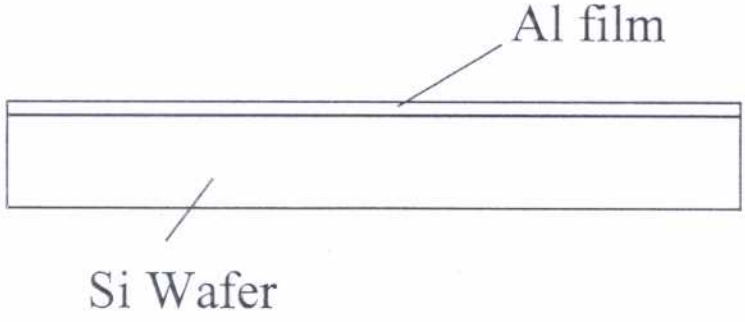
Mass Transfer

Example : Diffusion bonding in welding process

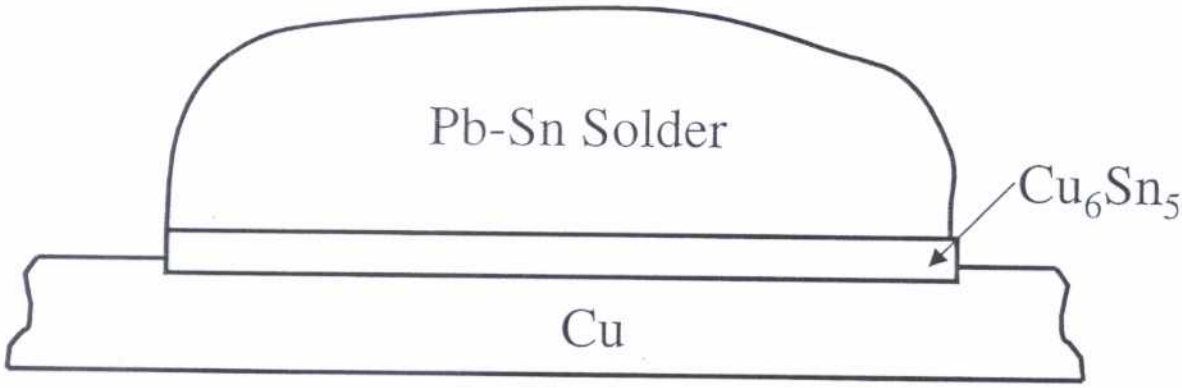


Charge Transfer

Example: Deposition of films in high vacuum



share electrons

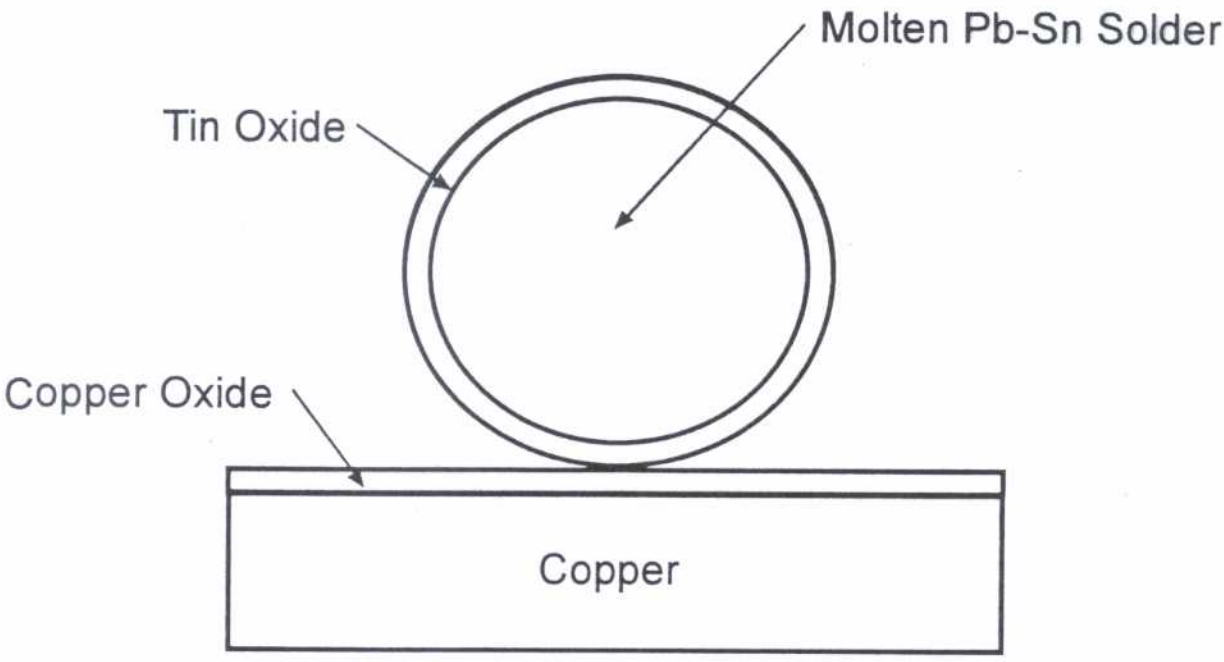


Solder Joint Formation

Charge transfer + mass transfer

Without solder, how do you join 2 Copper wires?

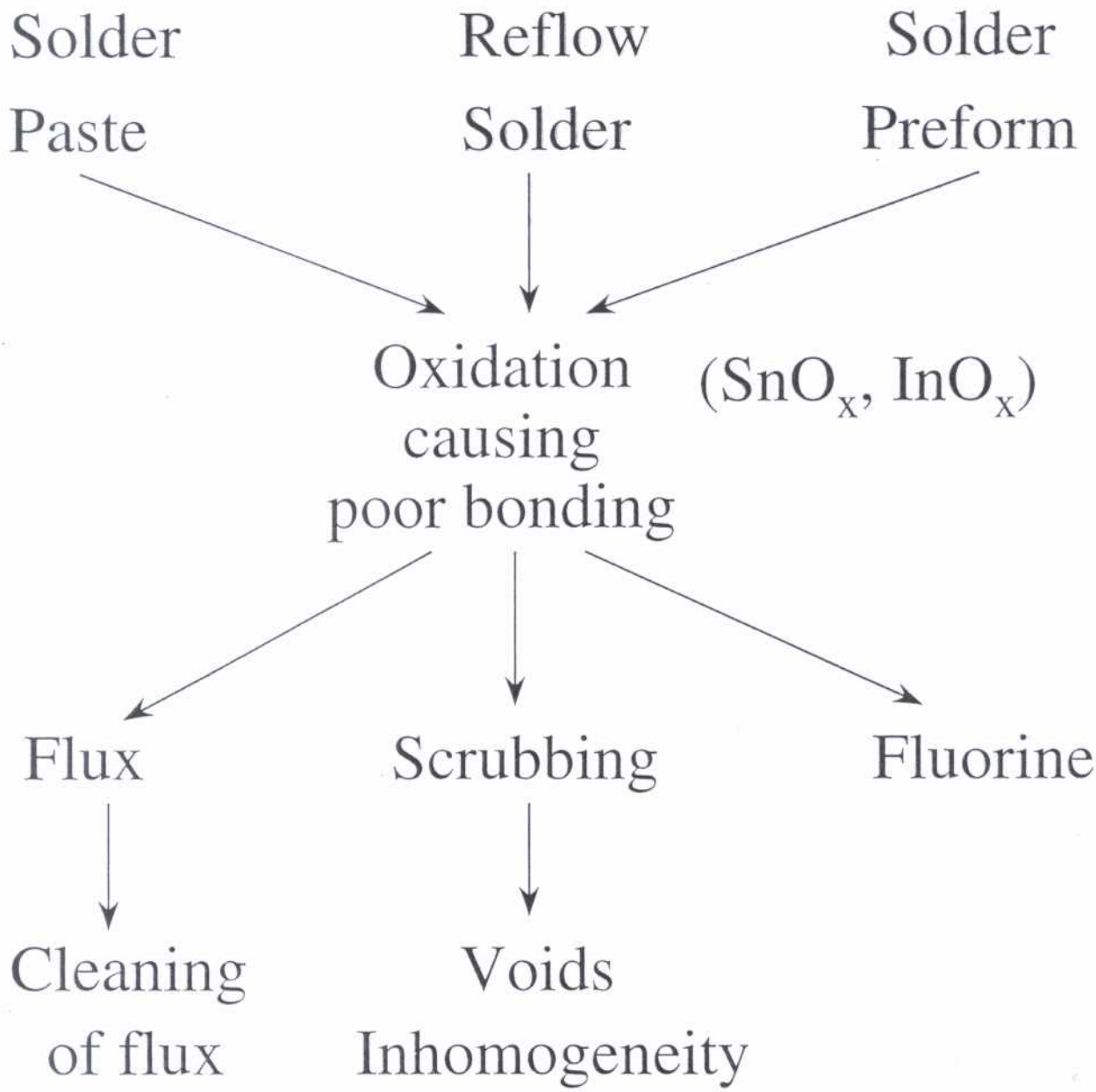
High m.p. & lighter



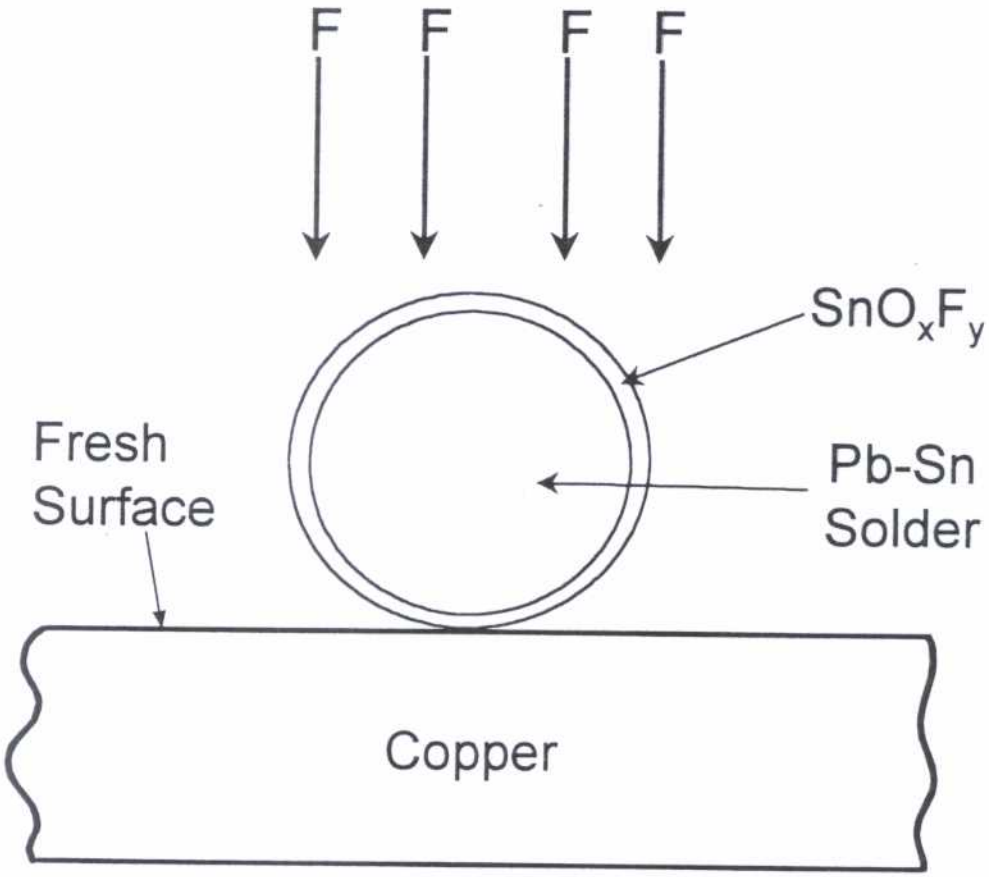
Oxides and Oxidation

Chemical reaction won't happen.

Soldering Methods

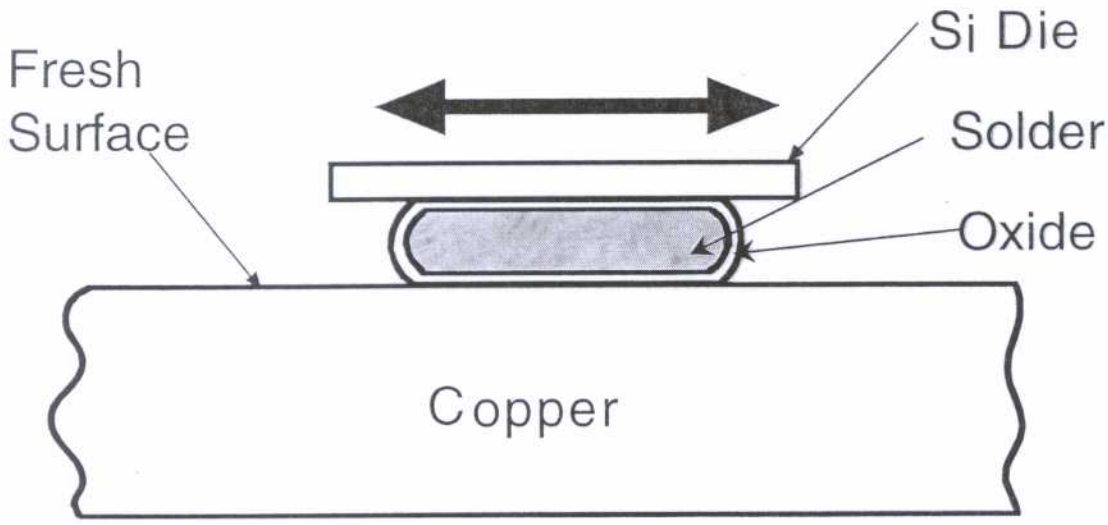


Effect of Fluo. on Devices



$$SnO_x + yF \longrightarrow SnO_xF_y$$

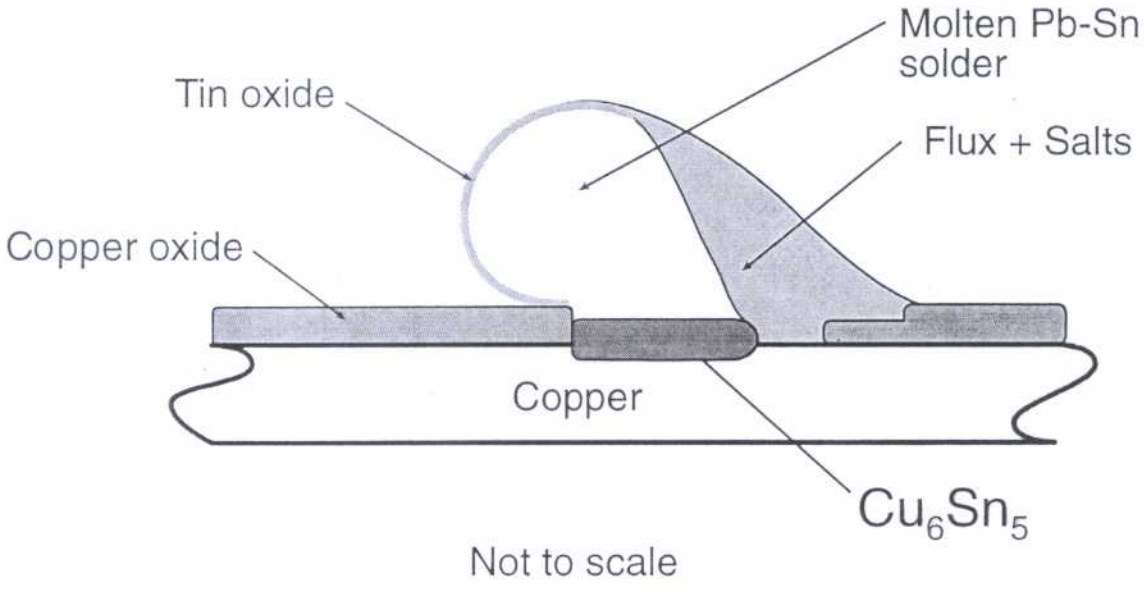
Fluorine Treated Fluxless Process



Scrubbing Action

what is flux ?

Flux Action



$$2\ \text{R-COOH} + \text{CuO} \rightarrow (\text{R-COO})_2\ \text{Cu} + \text{H}_2\text{O}$$

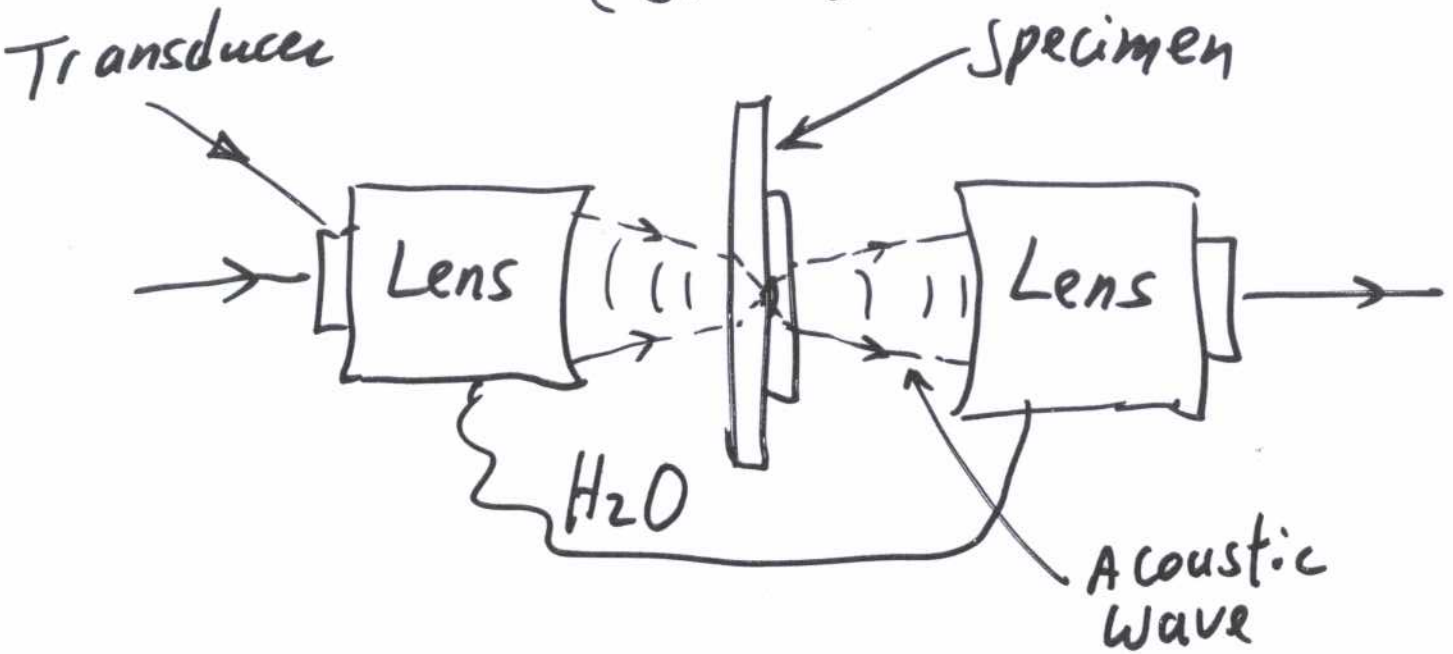
$$2\ \text{R-COOH} + \text{SnO} \rightarrow (\text{R-COO})_2\ \text{Sn} + \text{H}_2\text{O}$$

For Abietic Acid, R = $C_{19}H_{29}$

fresh

Molten flux converts oxides into salts to expose ~~flesh~~ solder and base metal, and shield them from further oxidation

Scanning Acoustic Microscope (SAM)

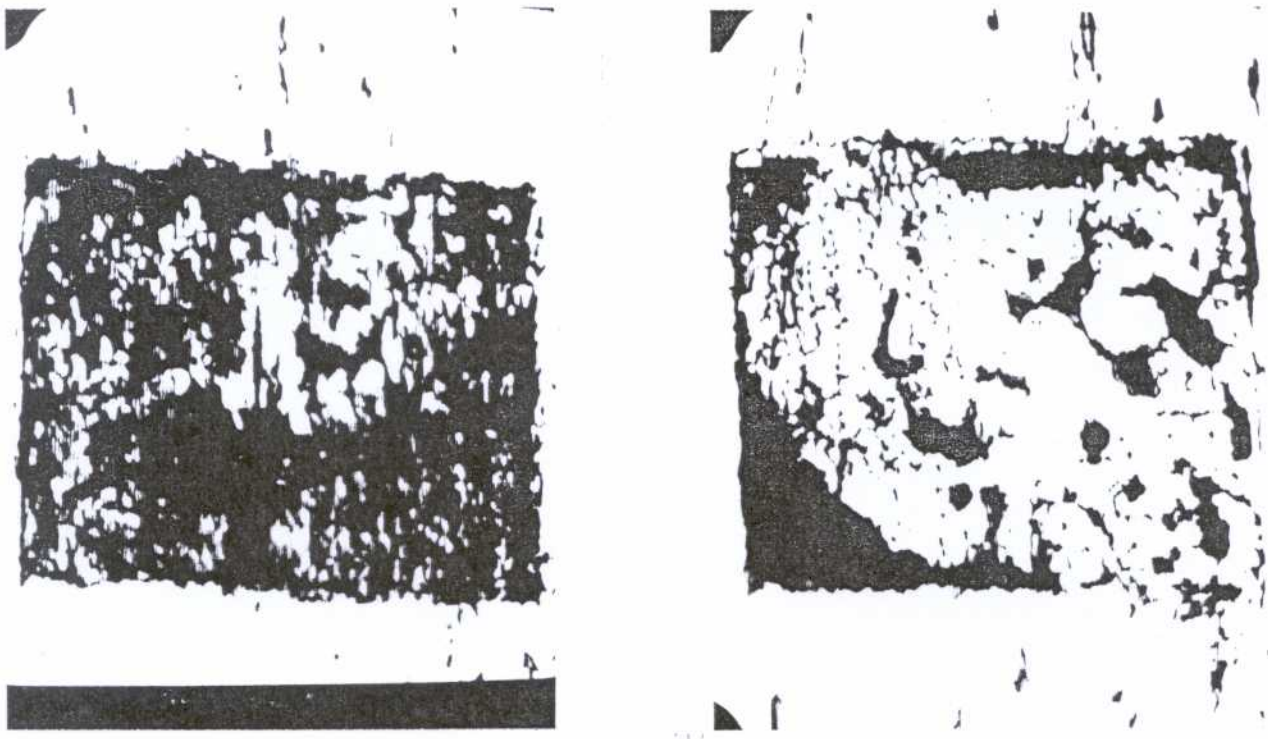


f : 140 MHz

Resolution : 10 – 20 μm

Extremely Sensitive to: Voids, Delamination, Cracks, Defects

5-8-92



SAM image of 125 μm-thick GaAs die bonded on 0.83 mm-thick Be-Cu substrate using soft solder

Oxidation-Free Fluxless Approach

Remove the Origin of
Problems - Oxidation
in

1. Material Production

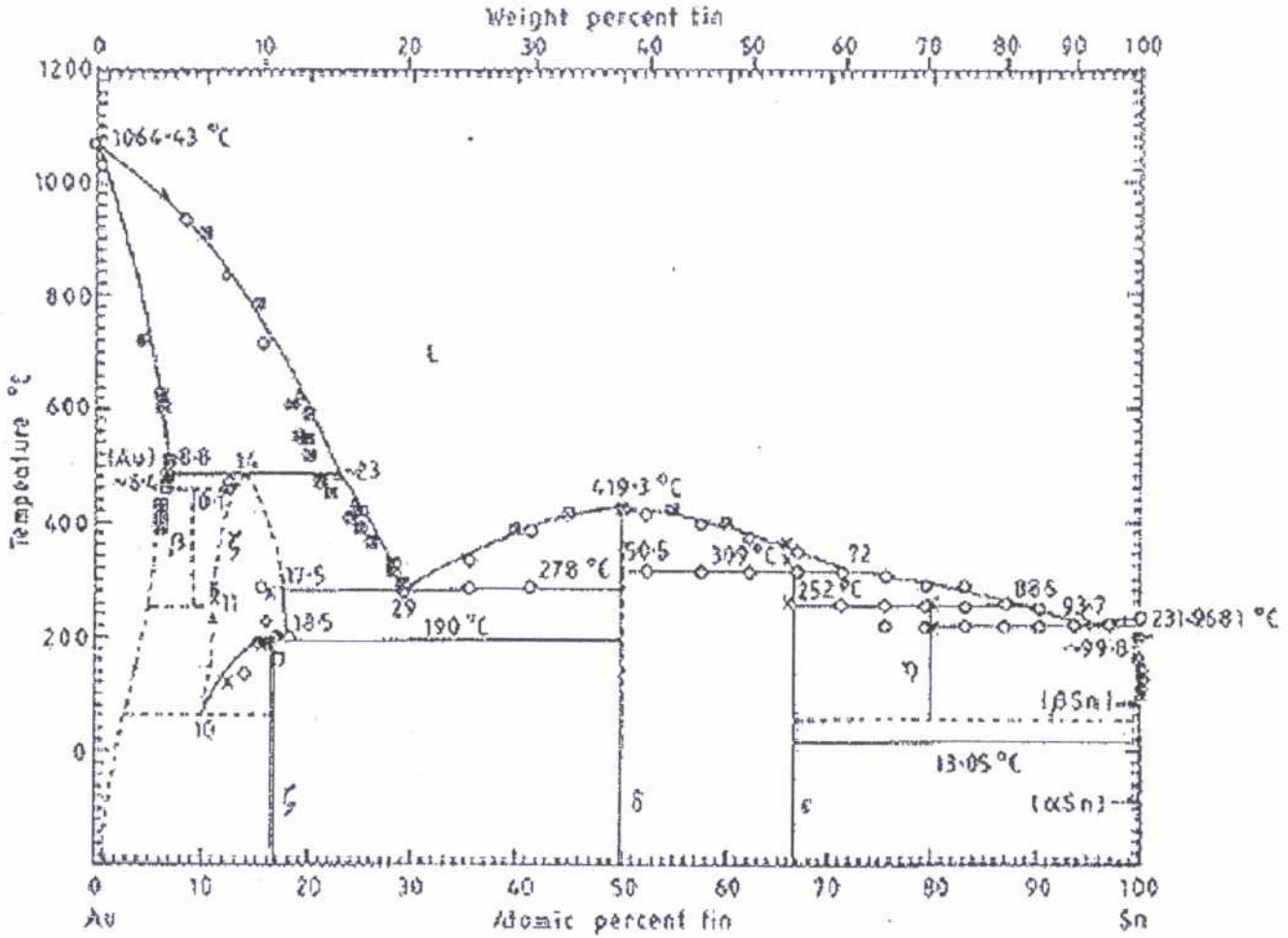
2. Bonding Process

How ?

1. Vacuum Deposition
2. Outer Protection Layer
3. Processing in Inert Environment
4. Dissolution of Protection Layer

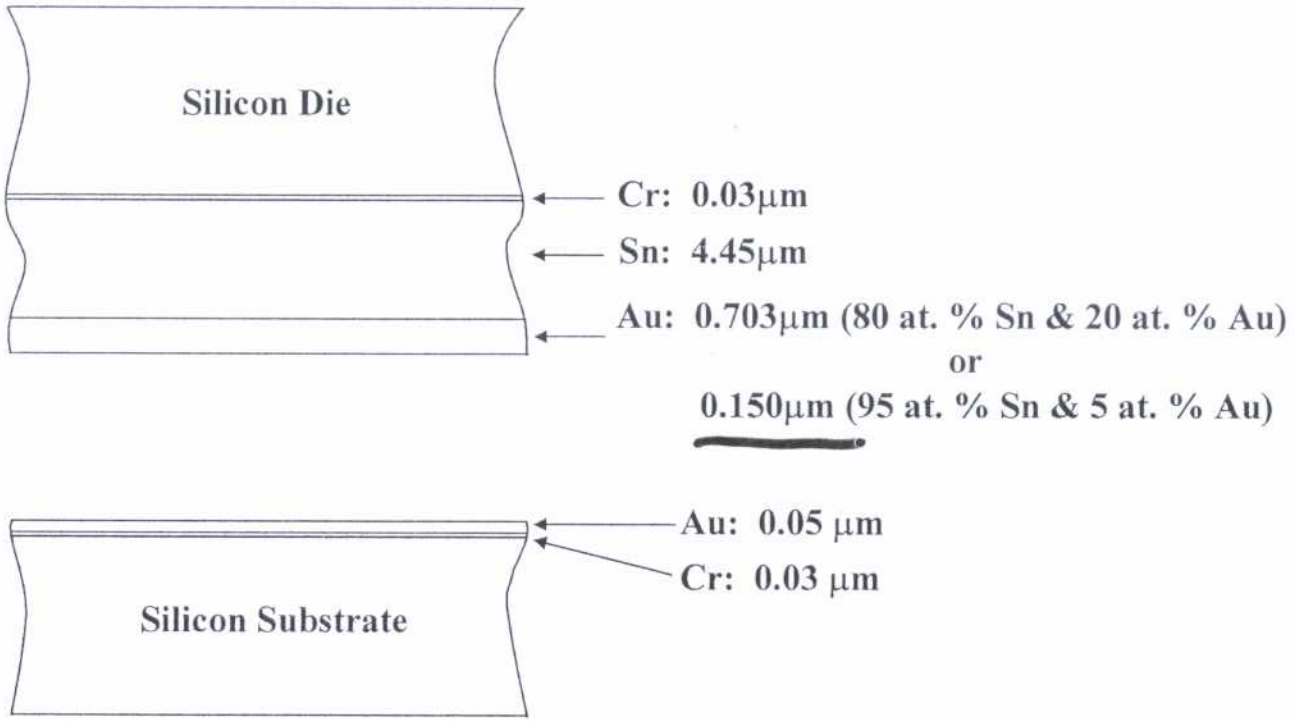
Yes & No.

The Gold-Tin (Au-Sn) Phase Diagram



Gold-tin equilibrium phase diagram, with stable intermetallic compounds depicted: δ - AuSn, ε - $AuSn_2$, and η - $AuSn_4$.

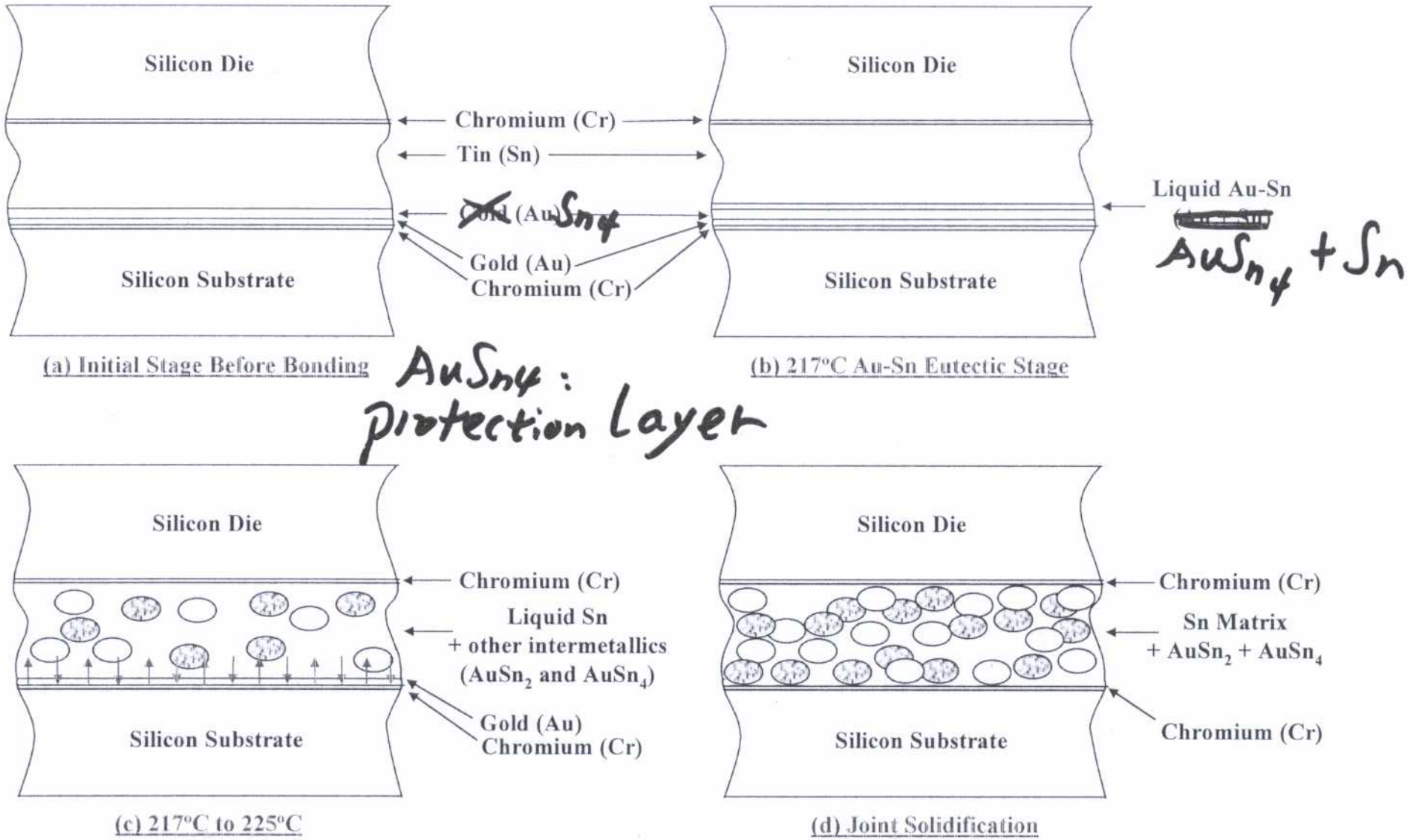
Multilayer Composite Designs



(Figure not drawn to scale)

Two different multilayer composite designs adopted for fabricating non-eutectic gold-tin solder joints.

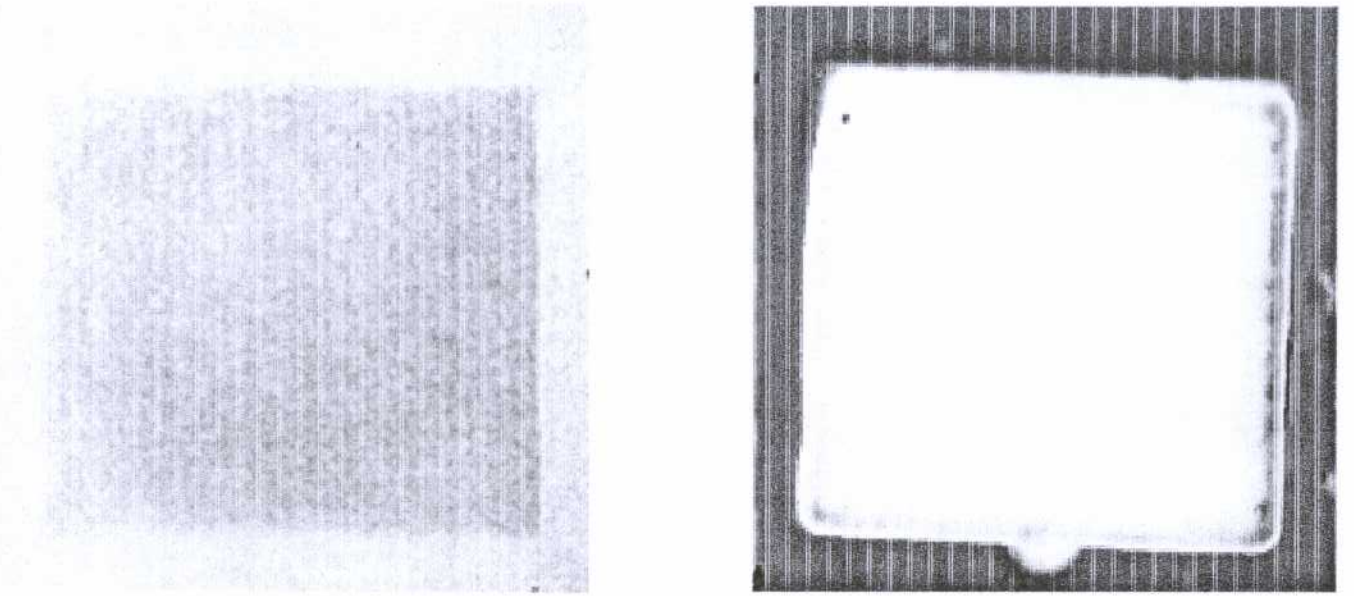
5Au-95Sn Fluxless Bonding Principle



AuSn4 : protection layer

in H_2 or Forming Gas

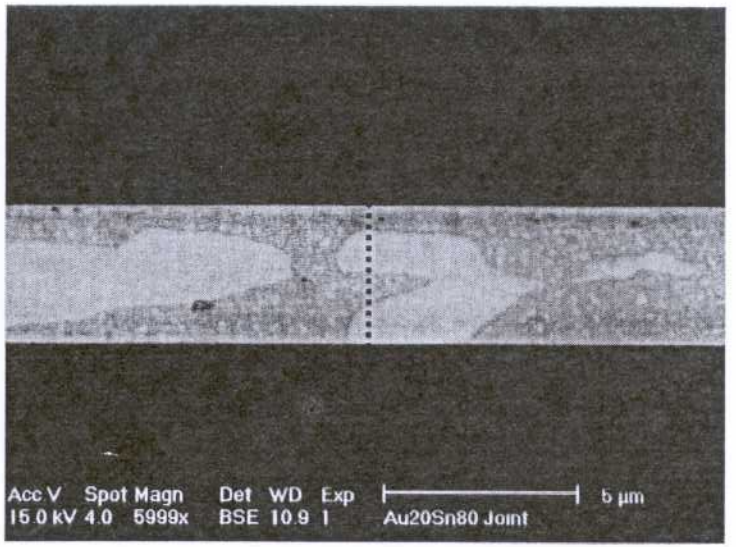
The X-Ray Microfocus and Scanning Acoustic Microscopy Images (95Sn-5Au Joint)



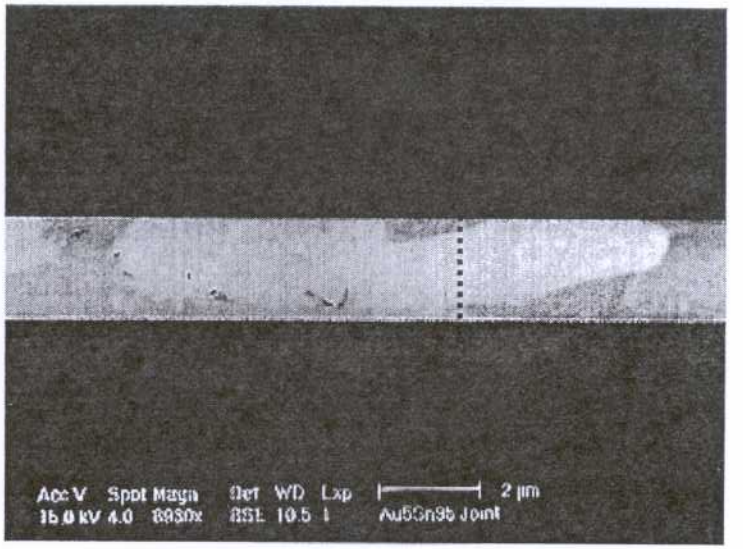
(a) **(b)**

(a) The X-ray microfocus image of a typical well-bonded 95Sn-5Au solder joint, and **(b)** the same solder is imaged using the scanning acoustic microscope (SAM).

The Backscattered SEM Images



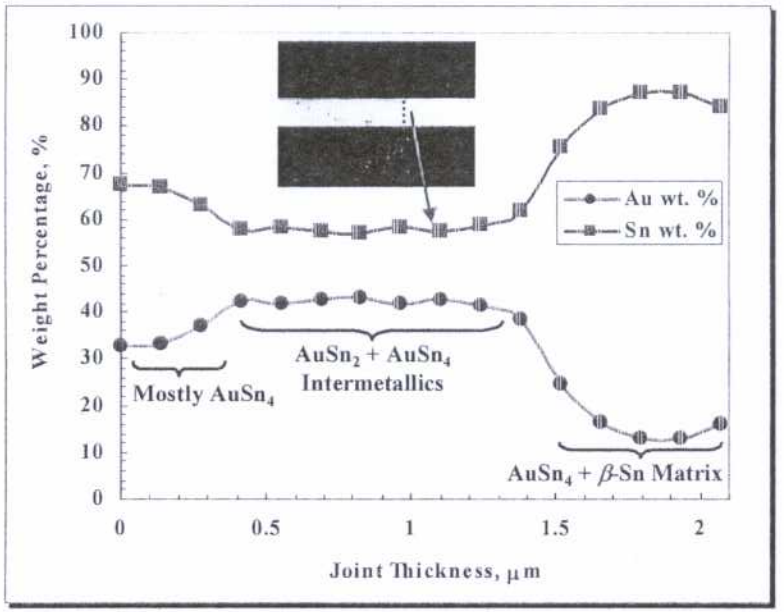
(a)



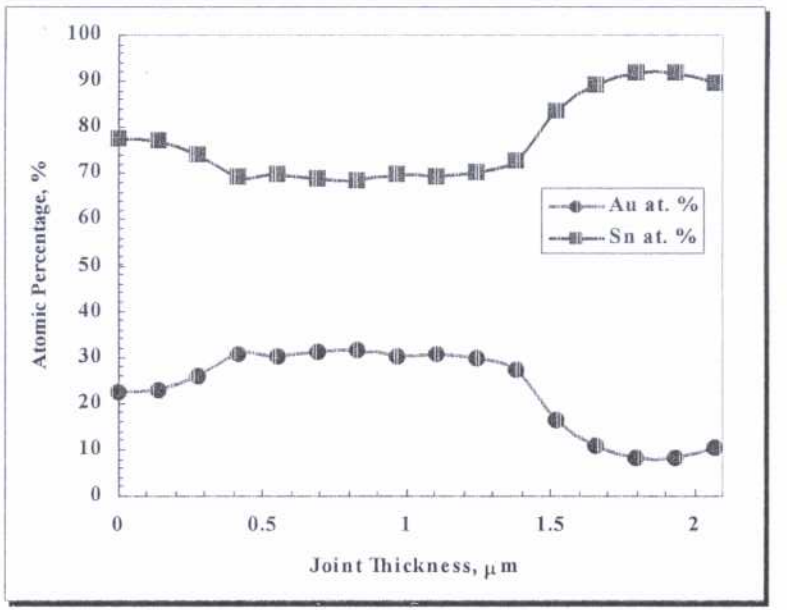
(b)

The backscattered electron SEM images taken from the cross section of a **(a)** 80Sn-20Au solder joint, and a **(b)** 95Sn-5Au joint of bonded specimens.

The EDX Measurements (95Sn-5Au Joint)



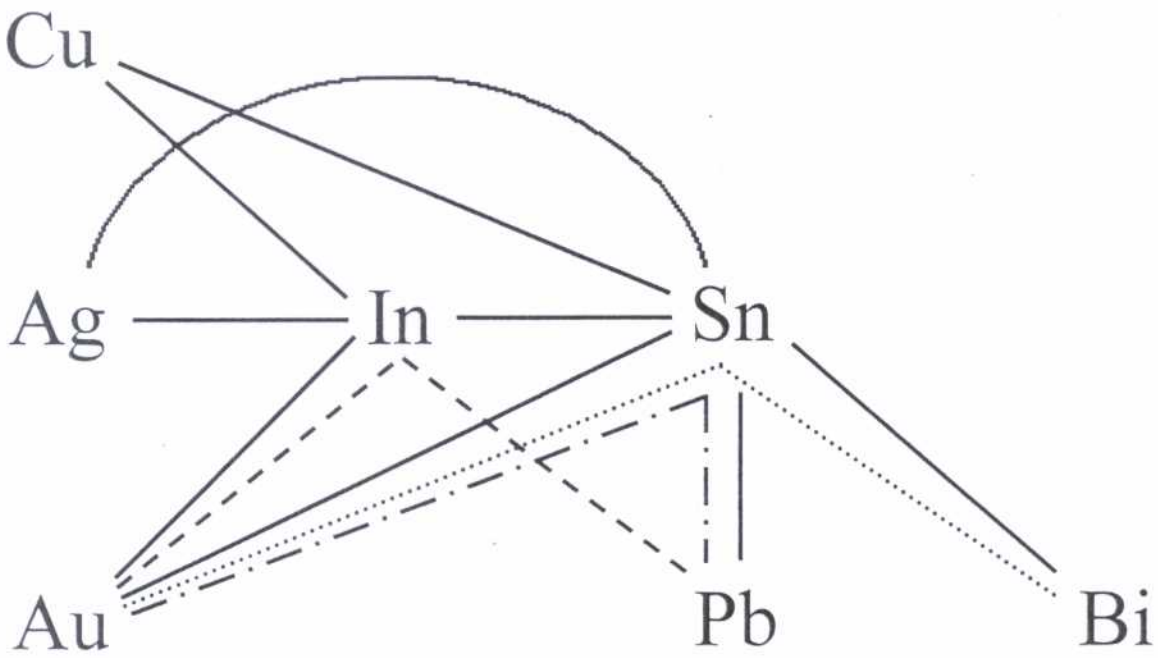
(a)



(b)

(a) The composition of a 95Sn-5Au solder joint manifested in weight percentage, as determined by the EDX, and also in **(b)** atomic percentage. The EDX linescan was performed in a direction from upper to lower interfaces on a bonded sample, as indicated by a dash line on the SEM image.

1B IIIA IVA VA



Binary :

Ternary :

In Consideration : Al, Ga, Sb, Fe, Zn

Material Systems Studied

Summary

1. Review of the soldering process
2. Oxidation-free fluxless processes
   - Nearly perfect joints achieved (SAM)
   - High shear strength
   - Control of joint thickness
   - Control of alloy composition and physical properties
   - High temperature joints at low process temperature
3. Fluxless bonding processes in air.
4. Applications : MEMS, photonics, and high temperature devices