Understanding the Role of Ultrasonic Welding in Wire Bonding

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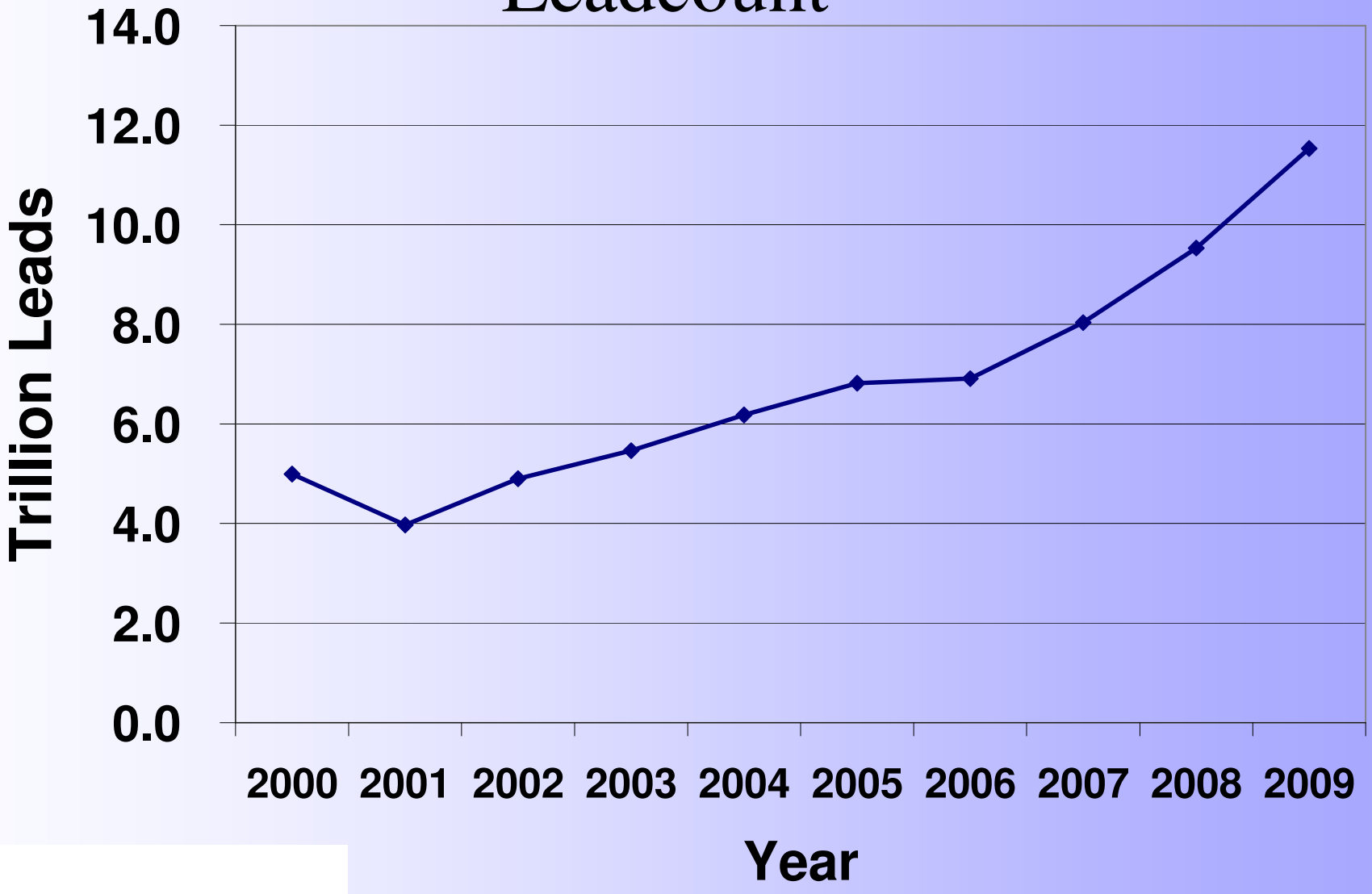
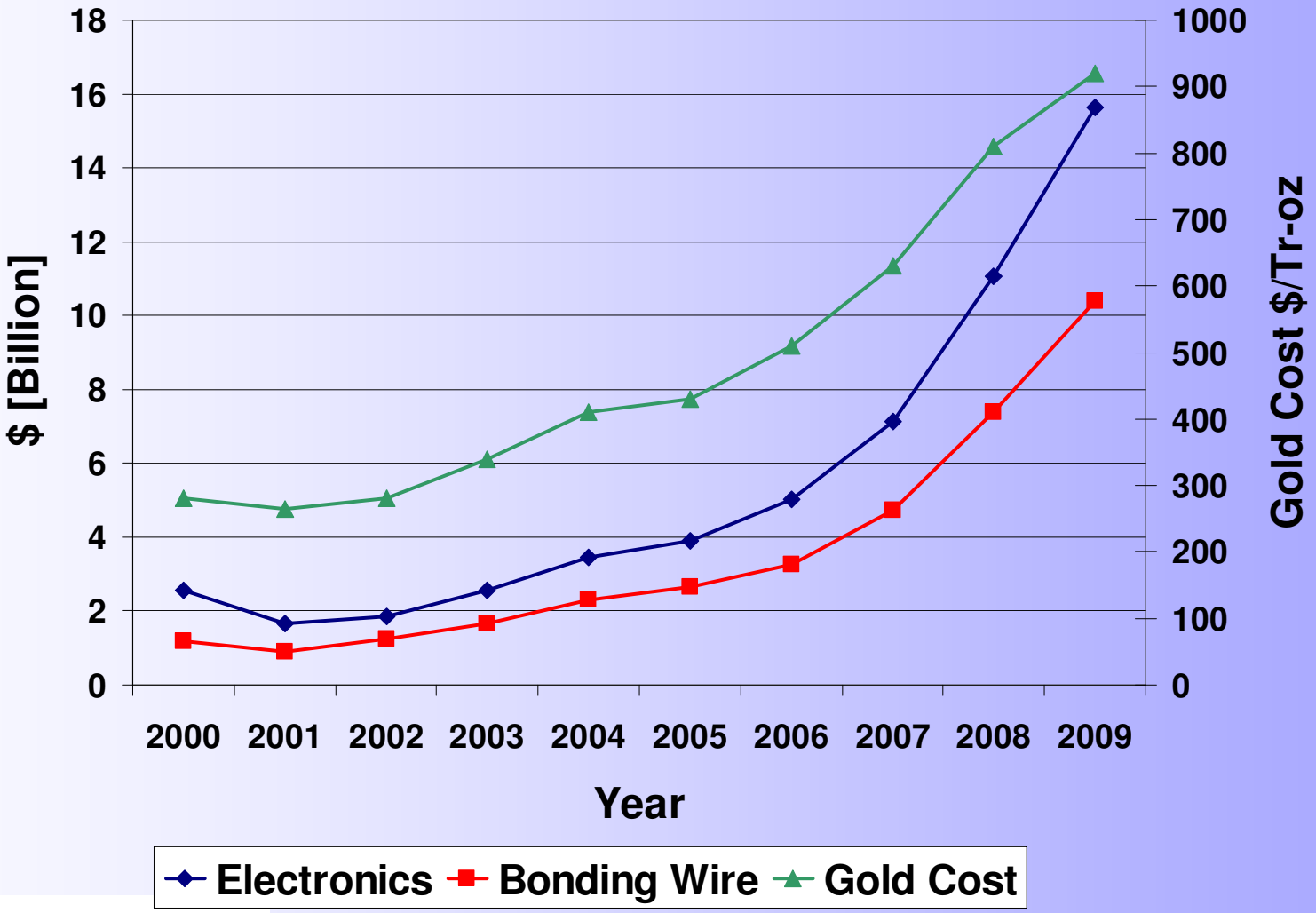
Contents

- Wire bonding market
- Welding
- Ultrasonics- horns, tools, amplitude
- Effect of ultrasonics on deformation
- FEM, slip, strain rate
- Conclusions

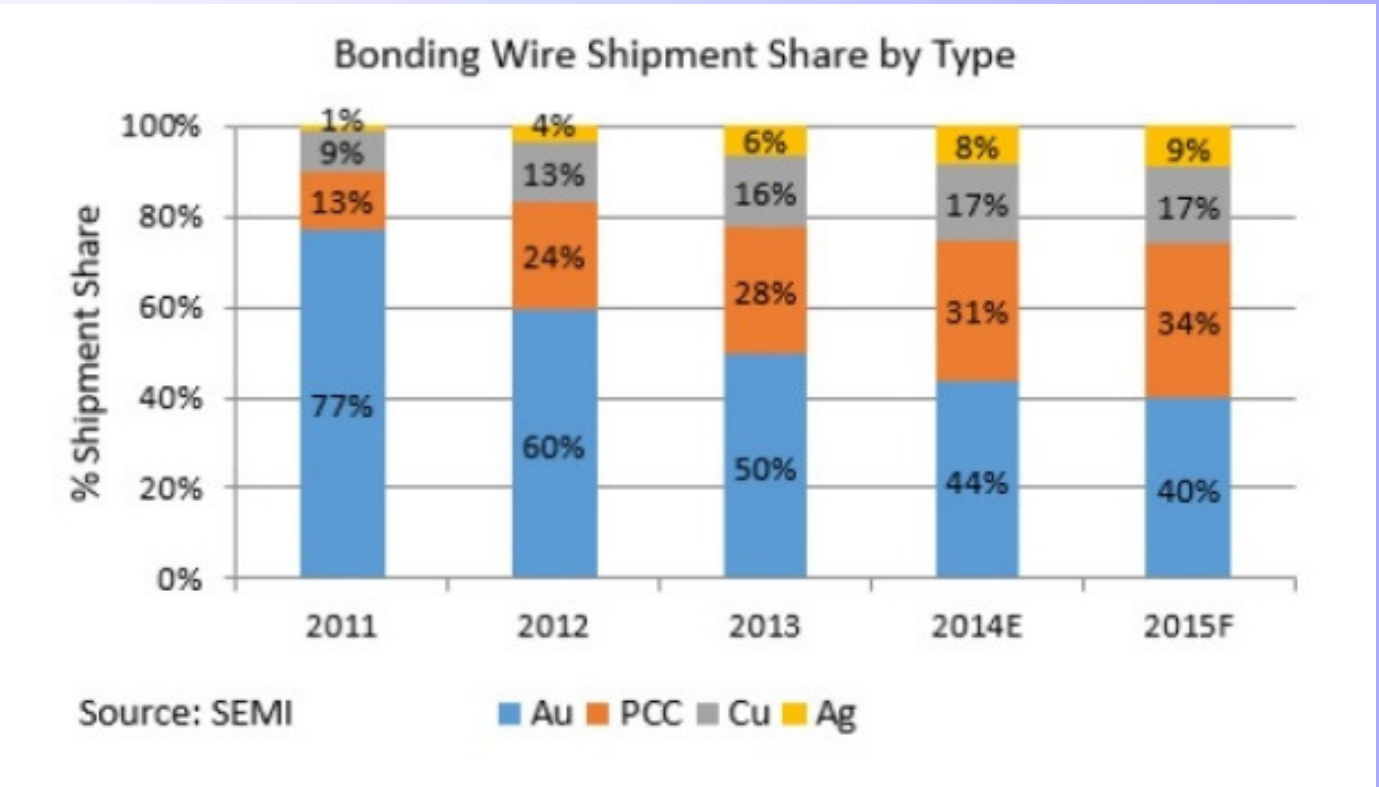
Electronics Packaging Peripheral Leadcount



Gold Usage in $



Costs and Market Status



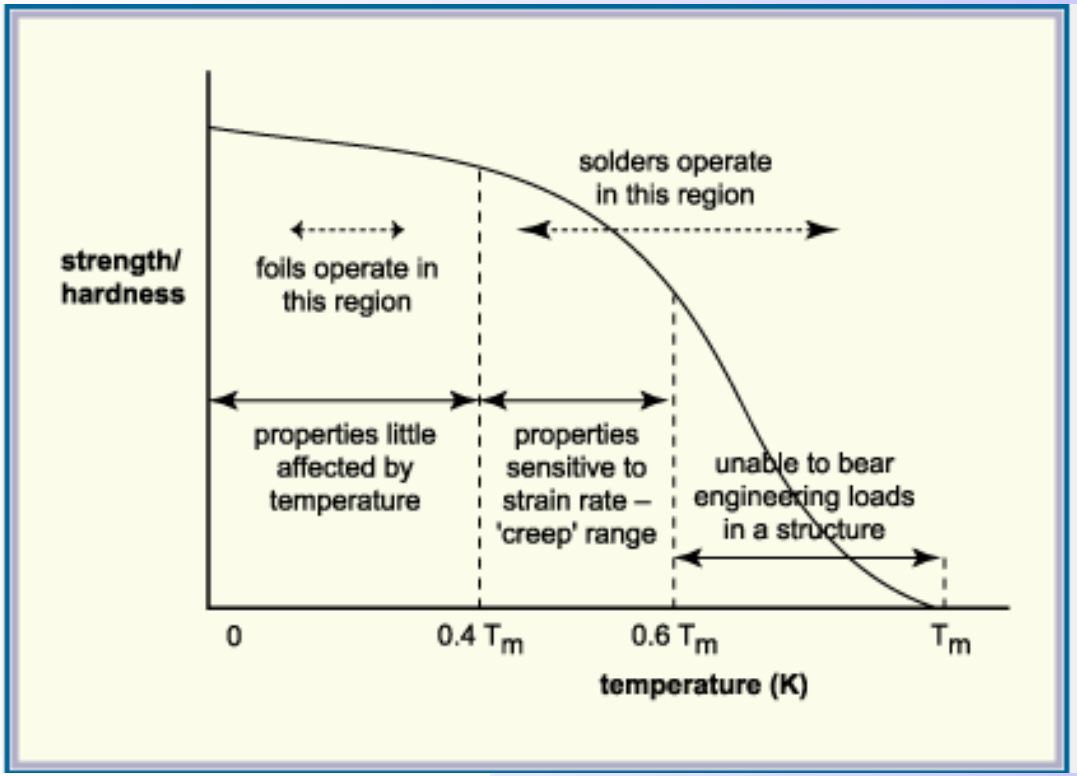
- 2014 > 20 billion meters total wire shipments
- 2014- 48% Cu + PCC (>9.8 billion meters)
- Growth and market share continue to rise

Welding

- Wire bonding is a welding process
- In welding two metals are joined by the formation of an intermetallic nugget that is an alloy composed of the two base materials. There is no intermediate material required as in soldering or brazing.
- The intermetallic is an normally stronger and more brittle than either of the two base materials.

Wire Bonding is a Welding Process

- The Homologous Temperature is the % of the melting point (MP) in ^{0}K

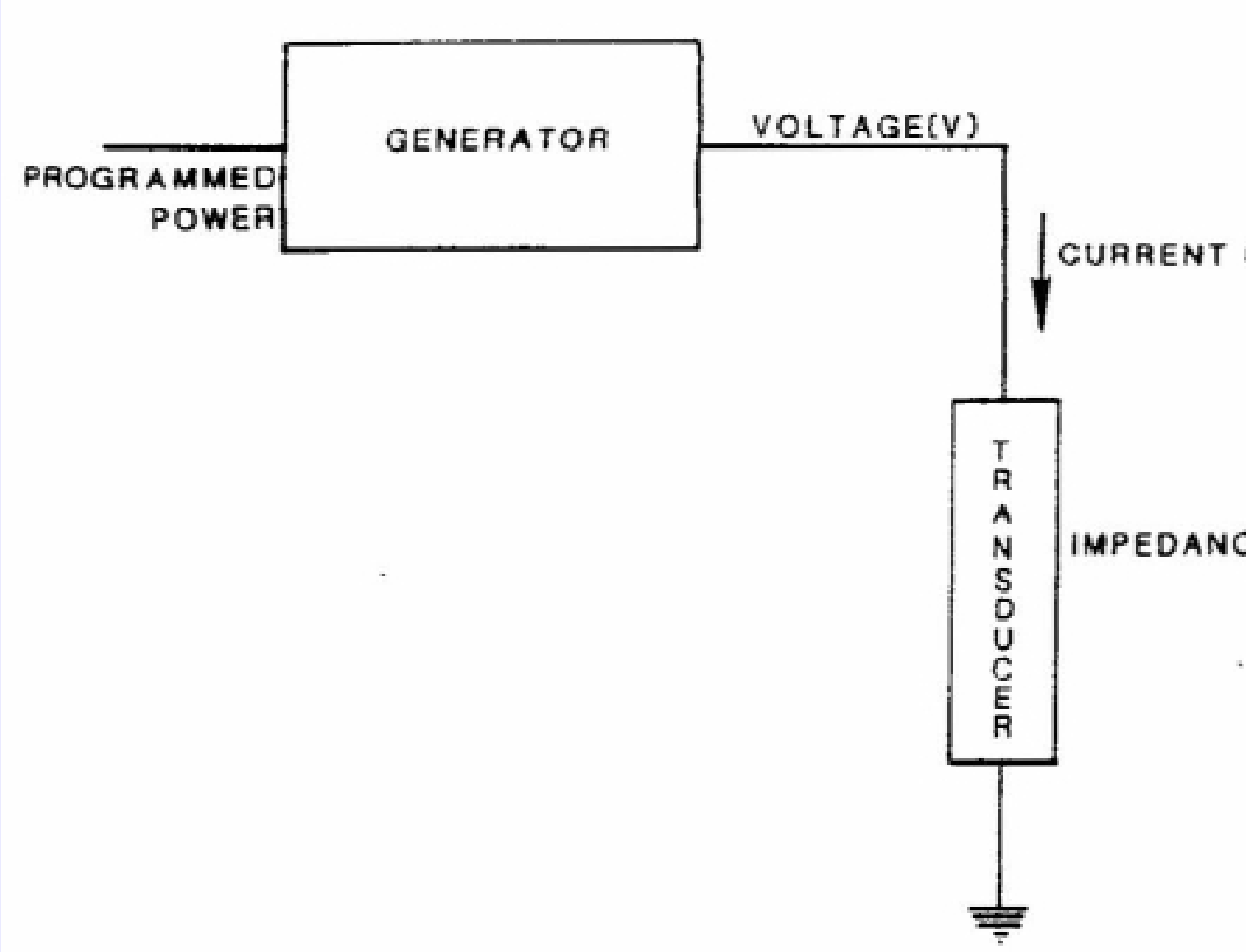


			% Homologous Temp	
	MP[C]	MP[K]	Room Temp	150^{0}C
Al	660	933	31	45
Au	1064	1337	22	32
Cu	1084	1357	22	31
AuSn(Eutectic)	280	553	53	77
PbSn(Eutectic)	183	456	64	93

Calculation
660C + 273=933 K
18C (RT)+273=291K
291/933= 31%

Ultrasonics allows "easier" deformation by unlocking dislocation movement mechanisms

Ultrasonic System Block Diagram



Constant Current or Constant Voltage?

- For impedance based systems Ohms Law is V=IZ where Z is the system impedance
- The best predictor of bond strength is ultrasonic amplitude, the displacement of the tip. Amplitude is proportional to I, the driving current

For Constant Current mode:

- During bonding Z increases as the bond pins to the surface and grows
- As Z increases the current stays constant therefore V also increases. Displacement is constant.

For Constant Voltage mode:

- During bonding Z increases as the bond pins to the surface and grows
- As Z increases Voltage is constant, therefore I must decrease. Displacement decreases as the bond forms.

- For fine pitch ball bonds constant current gives better control of the ball deformation and smaller bond variations.
- Some people believe that stitch bonding is better with constant voltage mode.
- Newer machines allow mode choice for each bond.

The Classical Ultrasonic Transducer:

(The left arrow indicates electrical US power input)

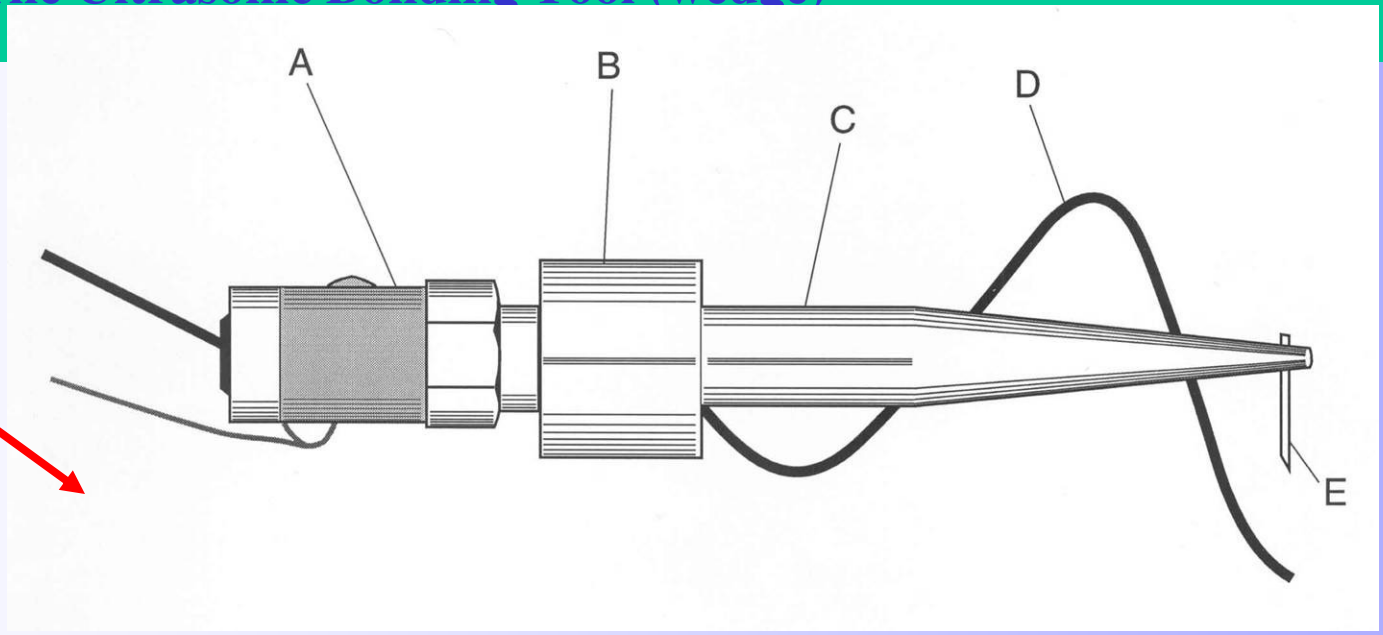
A). The Electro-Mechanical (PZT) Transducer

B). The Clamp

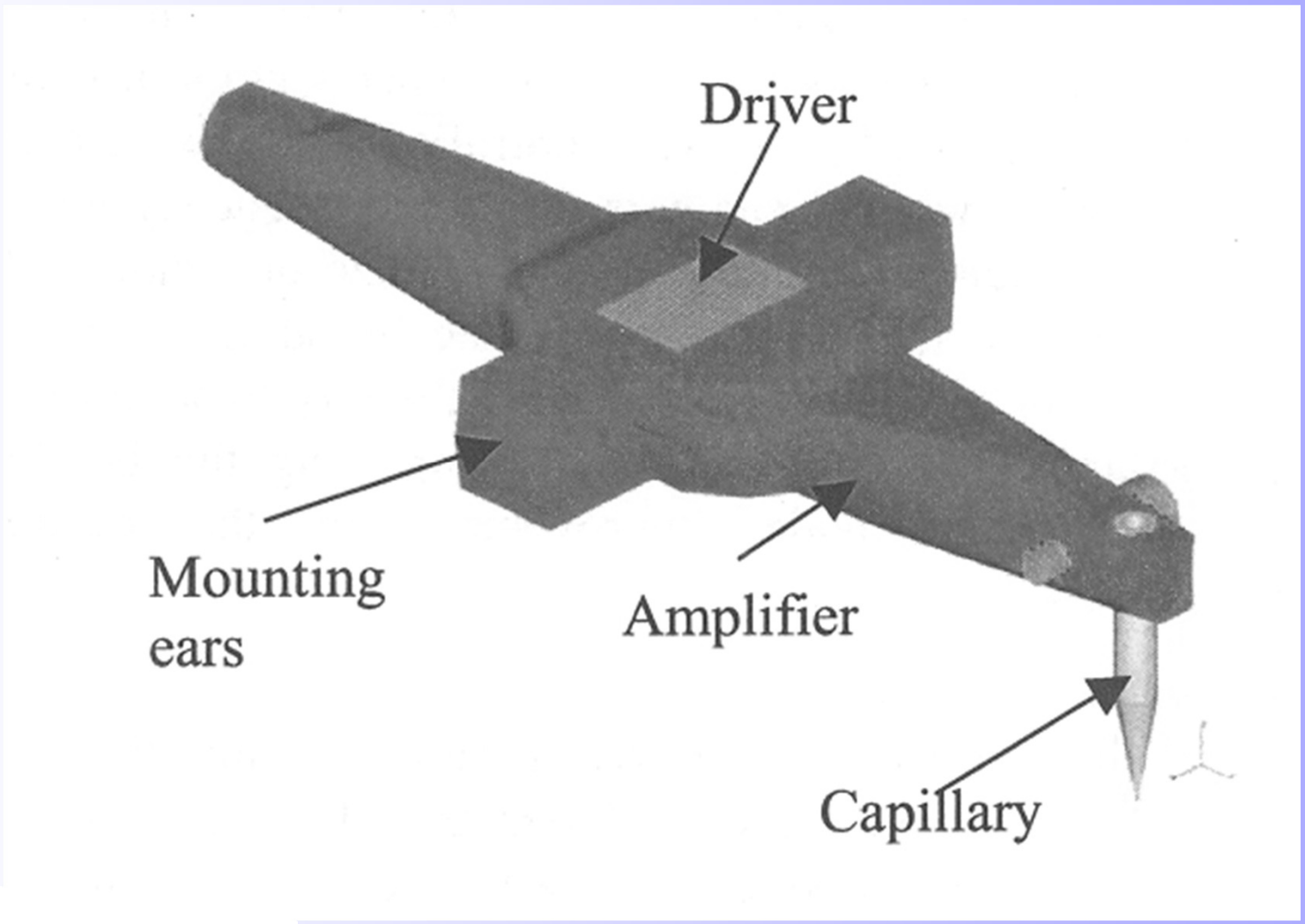
C). The Horn with Taper at End (taper amplifies US wave)

D). The Ultrasonic (mechanical) Wave-Form

E). The Ultrasonic Bonding Tool (wedge)



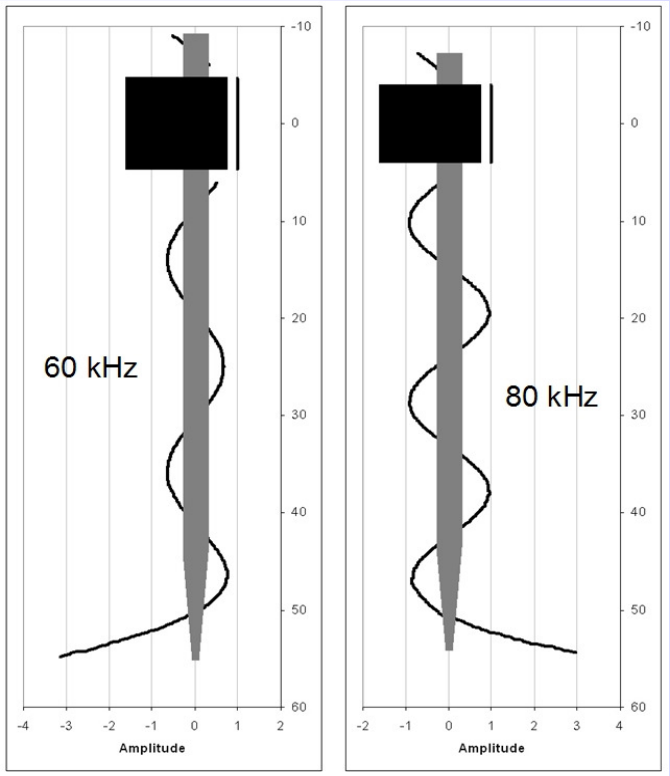
A Modern 120 kHz Autobonder Transducer, About 4 cm (1.6 in.) Long! (courtesy of K&S)

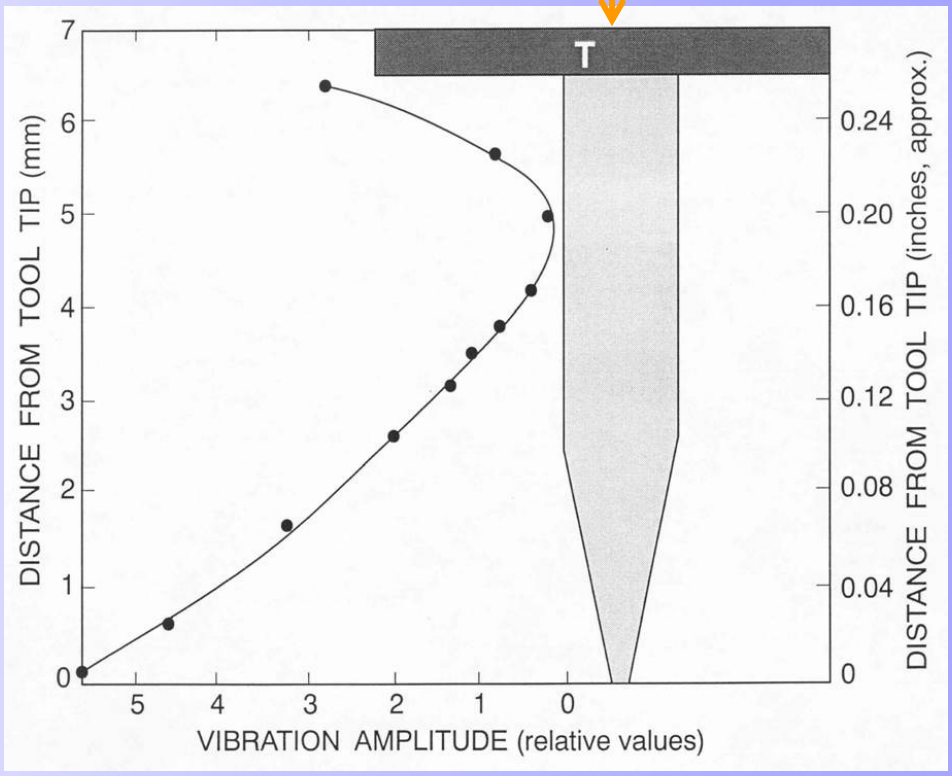


Vibration Modes (60 kHz) for:

Large wire Al—Left: (Orthodyne)

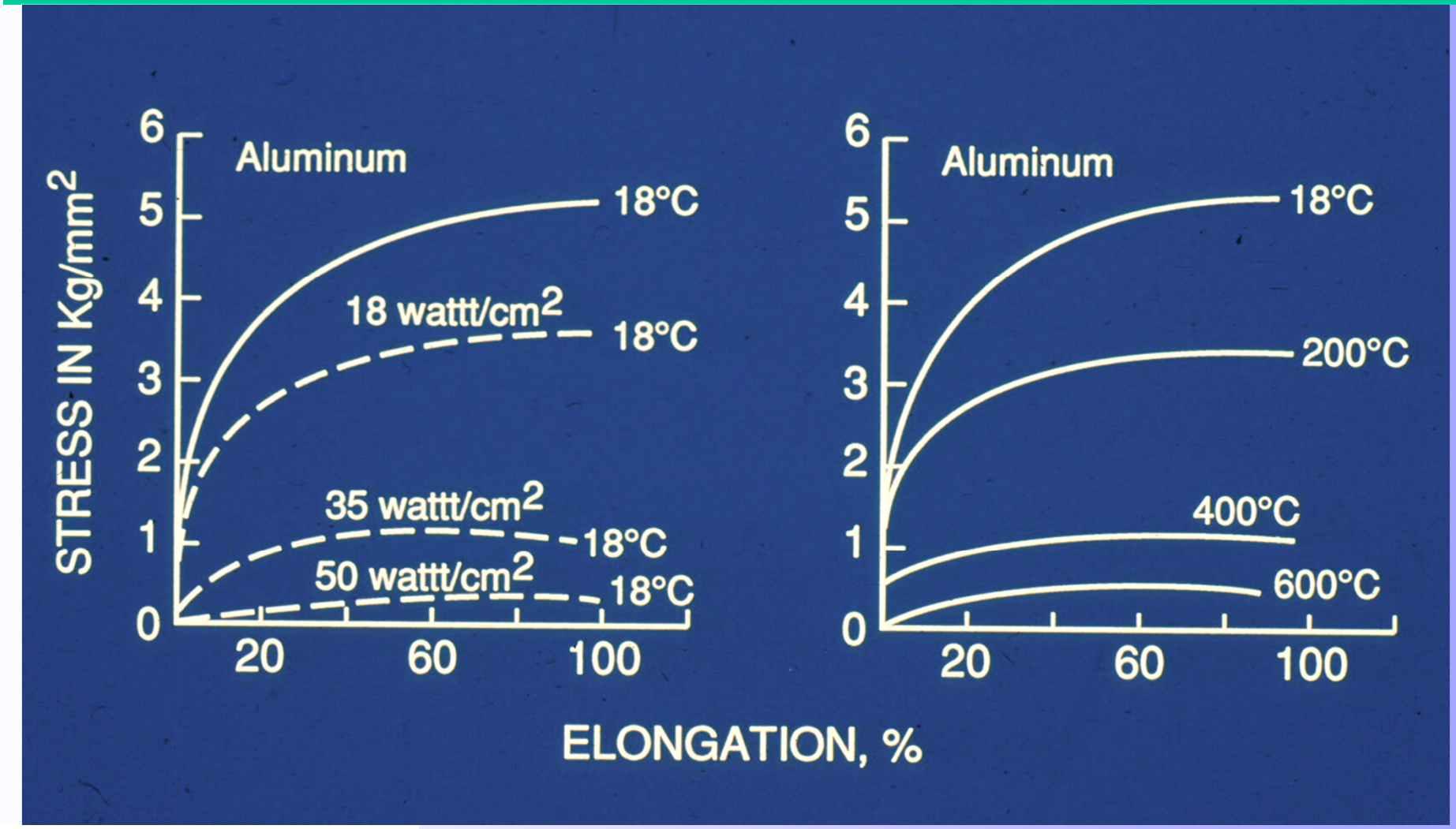
Gold ball-bonding Capillary--Right



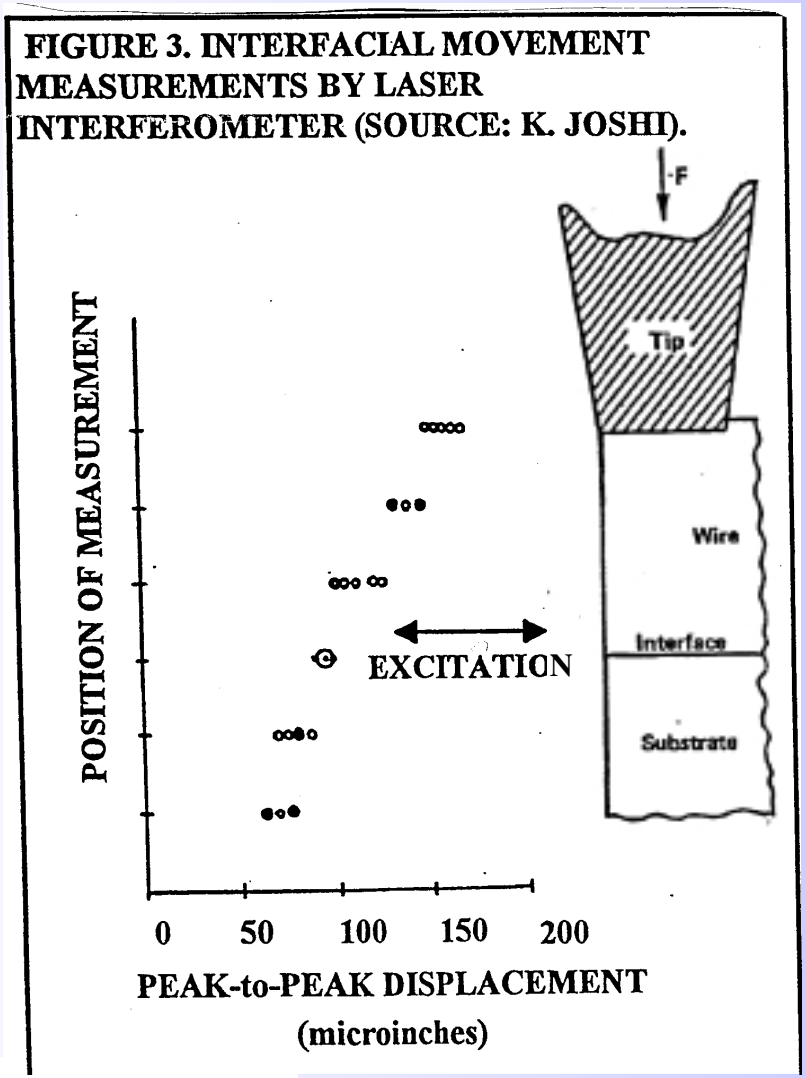


Thermal & Ultrasonic Softening of Al

[after Langenecker]



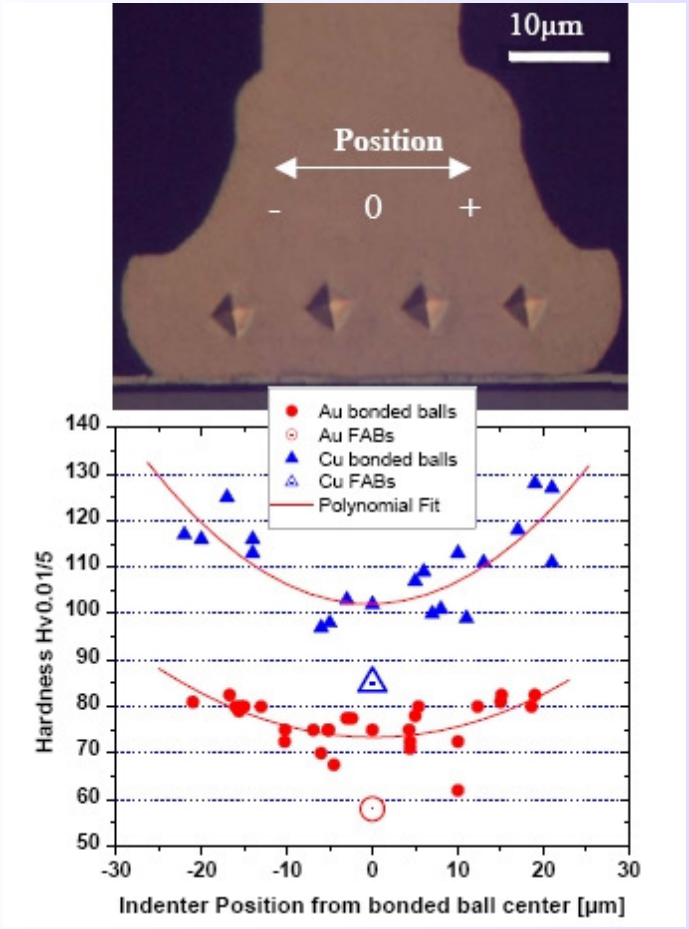
Interfacial Movement



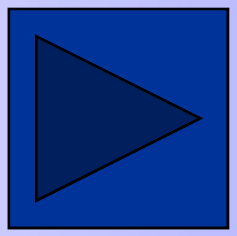
Note- No Displacement Discontinuity at Interface

The interface "PINS" almost immediately, bonding is not friction welding

Strain Hardening in Ball Bonding

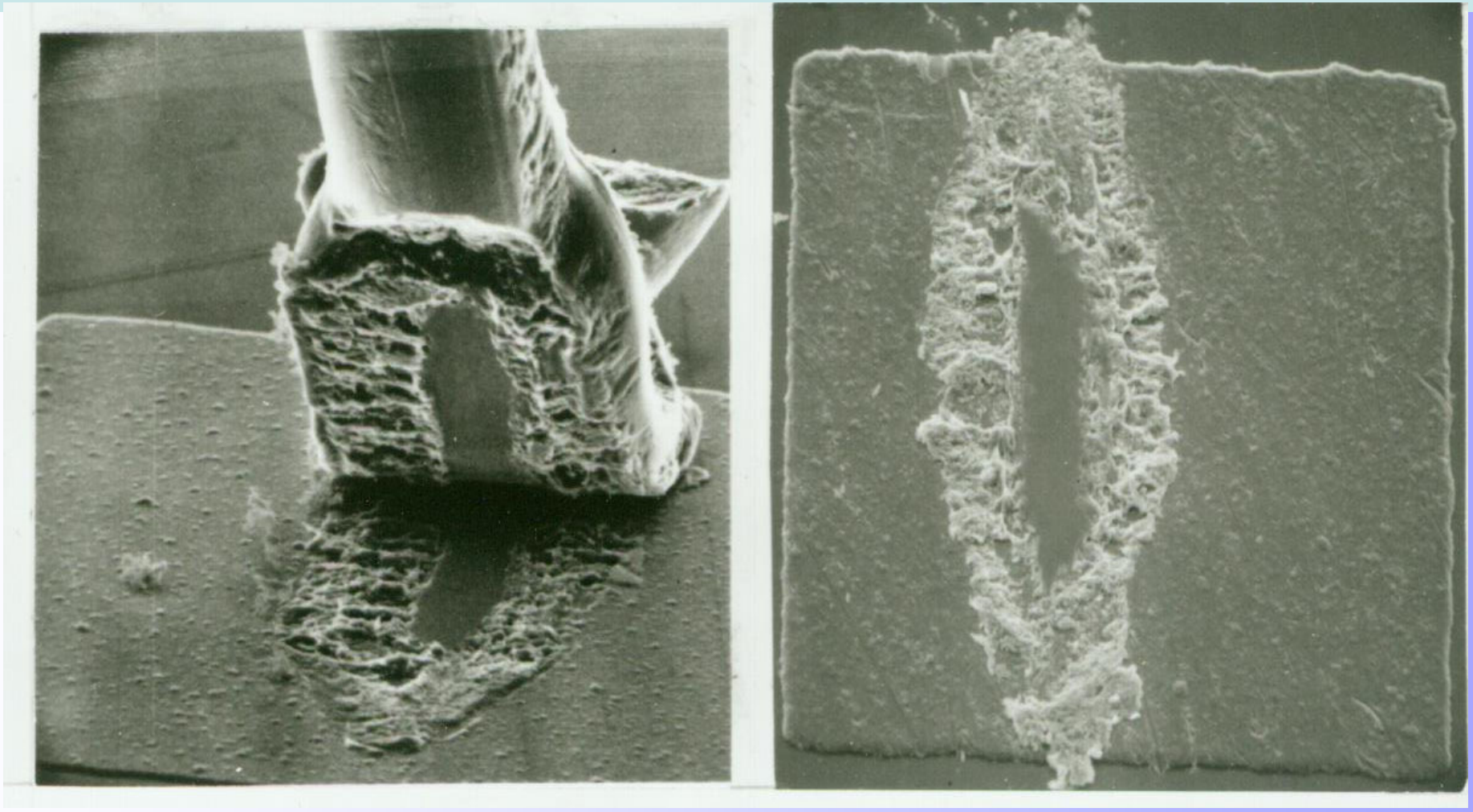


- **Video of ball deformation with ultrasonics**



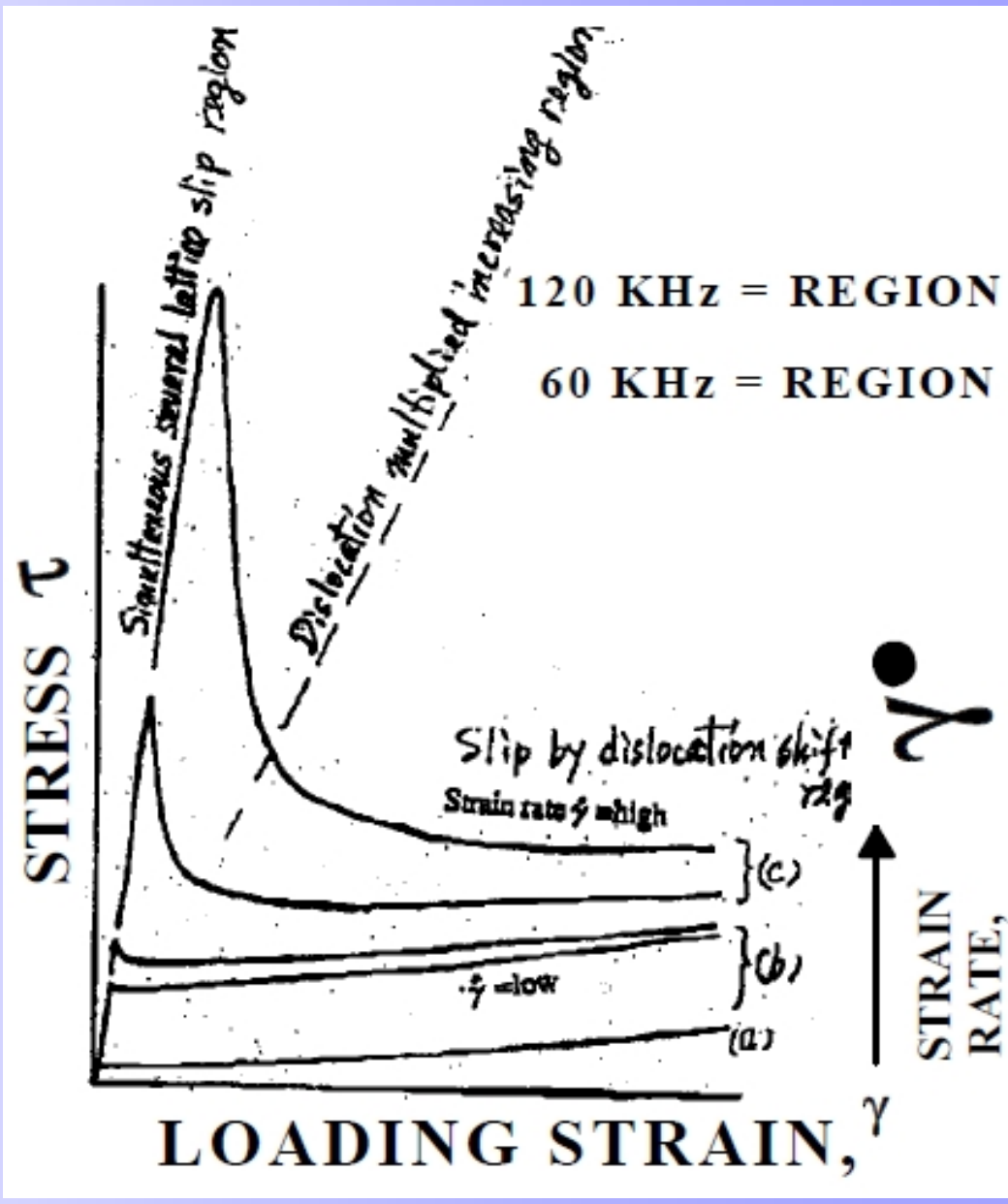
(Private Document from G. Schulze, K&S)

A Lifted up Al Wedge Bond, and its Pad, Revealing How the Weld was Formed



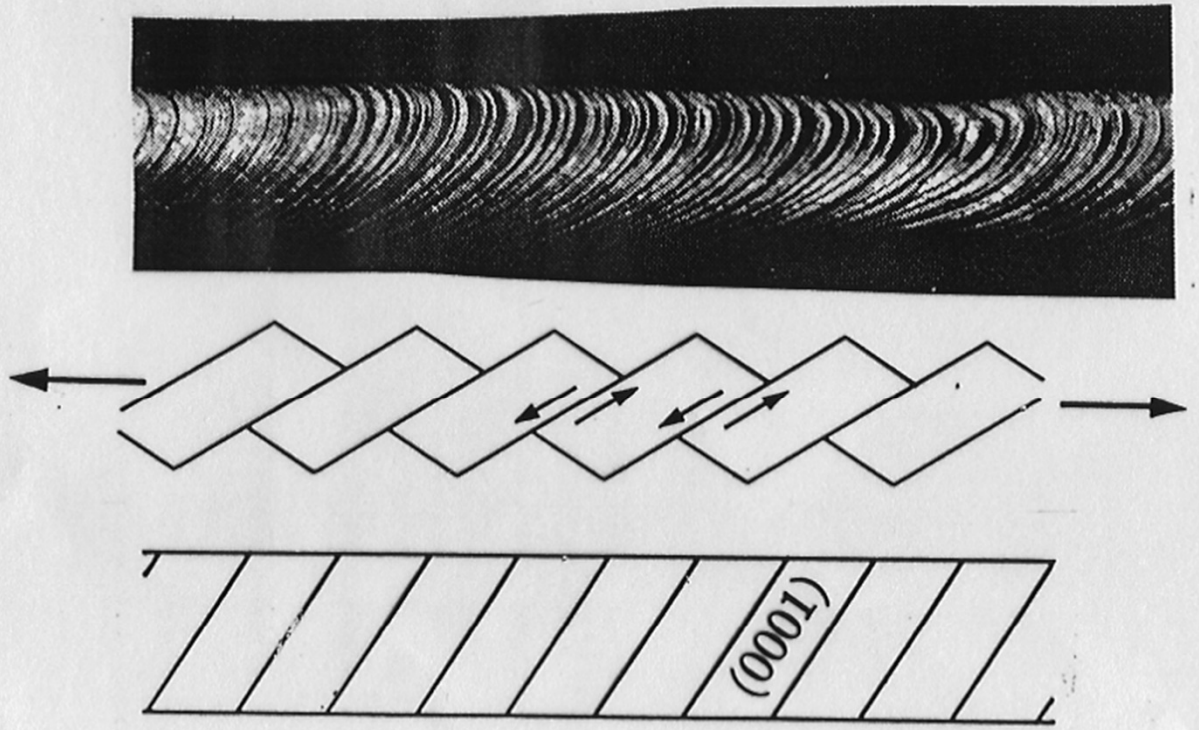
Strain Rate Sensitivity

- High frequency=higher strain rate
- At higher frequency material behaves with higher yield stress
- Higher yield transmits more energy to the bond interface with less deformation



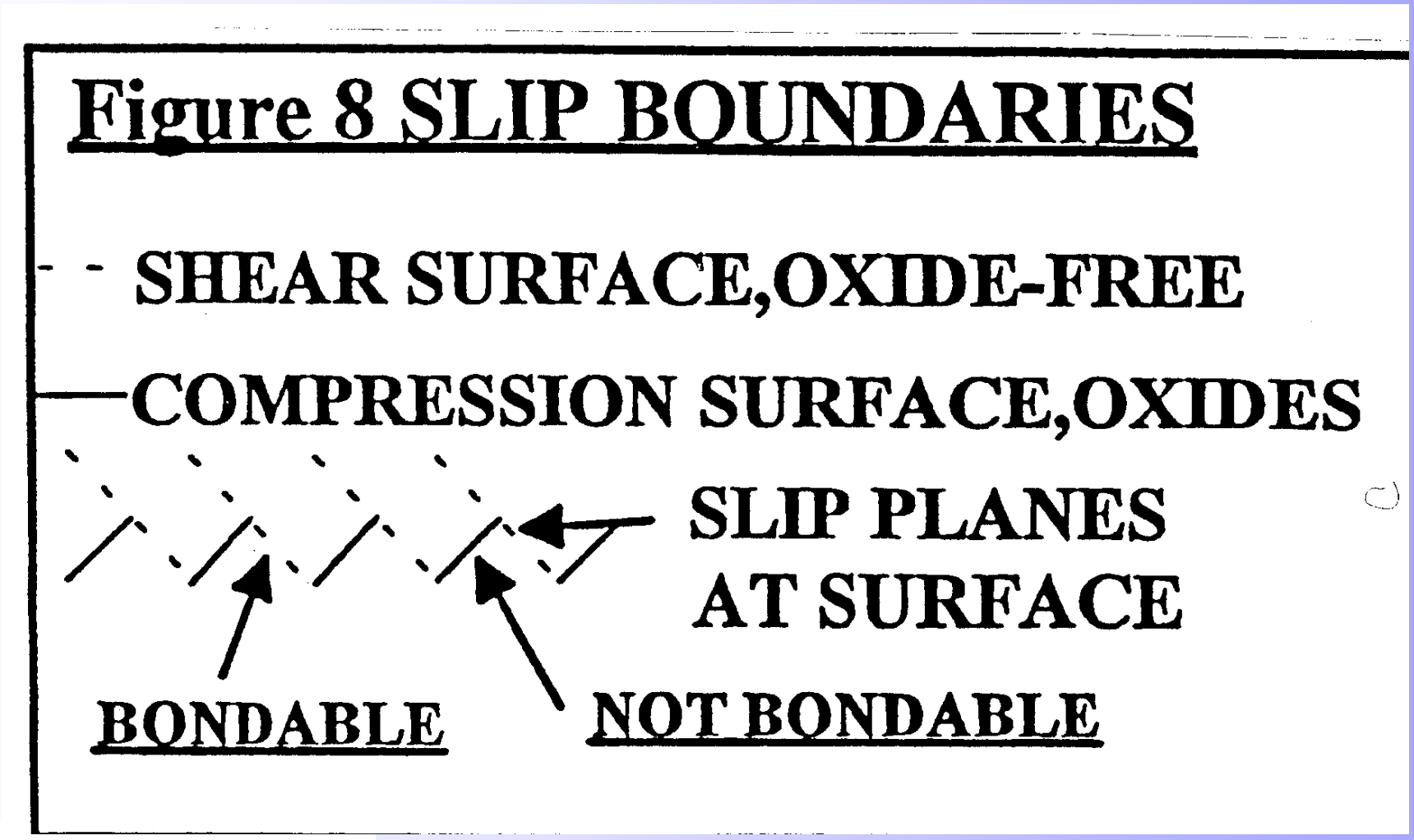
EFFECT OF DEFORMATION

SLIP OCCURS ON PREFERRED PLANES, SINGLE CRYSTAL MODEL



Source: Van Vlack

Slip at a Deformation Interface



Conclusions

- Welding will always be superior to soldering
  - Stronger
  - More reliable
  - Less sensitive to creep and fatigue
- Ultrasonic welds occur faster and at lower temperature than thermo-compression bonds
- Where possible ultrasonic bonding will be the preferred joining method