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Ultrasonics in Wire Bonding

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Part II of II

High Frequency, continued from Volume III, Issue 6
Bond quality, as well as process productivity, has shown considerable improvement when high frequency is designed into the process. However, direct substitution of HF for a 60 kHz system does not give optimum results. Time, Force, & Ultrasonic power bonding parameters must be optimized.

The success of HF is basically due to the enhanced acoustic absorption or efficient energy transfer to the interface of the materials involved.

Phonon Interaction, Acoustical Energy
Acoustic energy is a function of Phonon interaction or generation. Phonons are a result of thermal energy or thermal radiation analogous to Photons, which are electro-magnetic radiation. Phonons travel at the speed of sound. Photons, of course, travel at the speed of light.

In a simplistic manner, Phonons are generated as temperature increases in a material - i.e., the crystal lattice vibrates more and more resulting in more collisions causing even more heating in the material. Any material imperfections in general result in more collisions.

An increase in temperature in a material results in thermal energy absorption at imperfections (dislocations, impurities, etc.). This easily observed when a metal (a nail, for example) is bent back and forth until fractured and the fracture becomes hot to touch. Heat or thermal energy is generated; Phonon interaction is occurring.

In the same way, when acoustic energy is applied to a material, heat is generated and absorbed at imperfections; therefore, ultrasonic energy transfer is essentially equivalent to application of a given amount of thermal energy. There is, then, and equivalency of temperature (thermal) to Watts/cm² (acoustic).

Dislocation Movement, Mechanical & Chemical Activity
Since Phonon generation is heating and results in a mechanism for dislocation movement, the slip activated deformation occurs with ultimate material softening, increased chemical reactivity, and general metallurgical disturbance.

A typical example of such phenomenon for mechanical stressed aluminum indicated that a stress of 1,000 kg/mm² results in 100% elongation with 35 Watts/cm² at room temperature. With only heating-thermal energy - 400ºC is required for the same result. It becomes obvious, then, that acoustic energy transfer results in a heating mechanism which can be utilized in interfacial activity at the bond.

It is observed that the higher the frequency, the more Phonon generation, and although detectable heating is not observed, reactivity as evaluated in the Au-Al bond is enhanced. This can best be seen in designed experiments with shear testing (and Intermetallic coverage on the surfaces); though no hard quantitative data exists, dislocation movement by acoustic or thermal enhancement results in heat generation. Acoustic energy transfer, however, is preferential at the imperfection while thermal energy encompasses the entire material.

Theoretical studies imply that dislocation movement may give rise to Phonon heating at such sites in the order of 1,000ºC for 10^{-12} seconds. This localized heating weakens the general area and allows for softening of the bonding metals and better chemical reactivity. It has been observed microscopically that 200 kHz+ for a few seconds can result in complete melting of the bond if additional thermal energy greater than 150ºC is used.

Summary
In summary, high frequency, acoustic energy transfer carried out with dedicated power controls, transducer, and properly designed capillaries can result in a more quality enhanced bonding process.

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