"What happened here?“

Diagnosis of internal defects from acoustic images 9/25/2000

By Tom Adams

***Acoustic micro imaging (AMI)** employs very high frequency ultrasound to image internal features nondestructively. One of the more important aspects of AMI is the neat separation it makes between well bonded internal interfaces and disbonded or gap-type interfaces:*

•Well bonded interfaces between dissimilar materials reflect a portion of the ultrasound, and are therefore imaged in the middle range of intensities.

•Gaps reflect nearly all of the ultrasound, and are therefore imaged at much higher intensity.

Contents

Variable underfill flow speed [Figure 1]

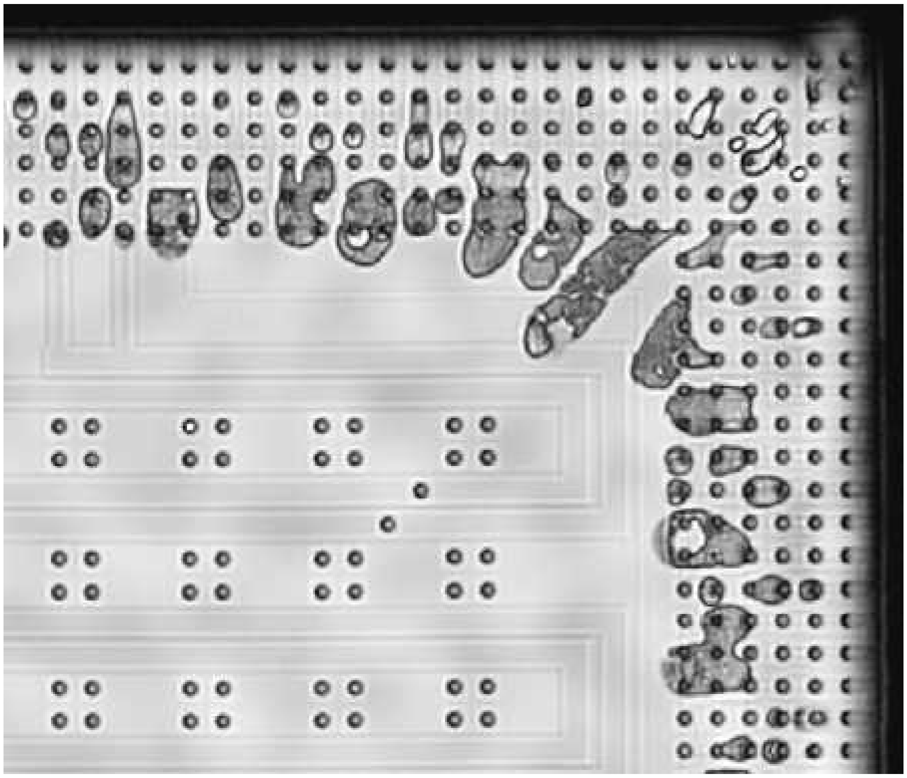
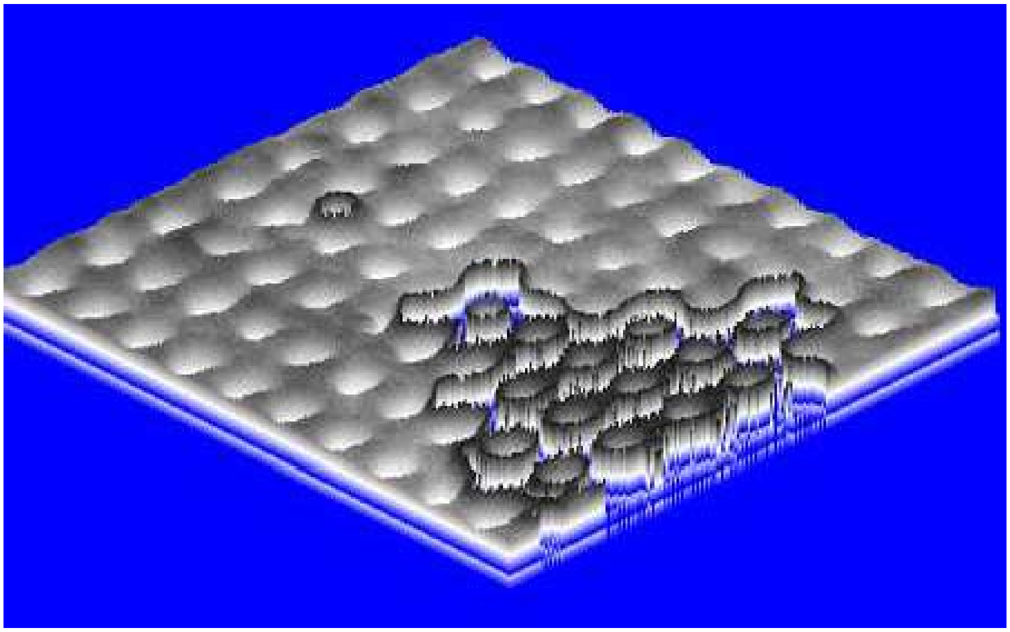


Figure 1 is the acoustic image of one corner of a flip chip package. Higher ultrasonic frequencies yield higher resolution, and here (as is often done with flip chips) the very high frequency of 230 MHz was used.

There are no missing solder bumps, although one bump in a group of four just left of center is much brighter than the others, indicating high reflection (and therefore a gap) where there should be a bond to the die face.

There are also numerous large voids (the irregular gray areas). Their orientation and location give clues to their formation: as the fluid underfill flowed around the solder bumps, it slowed down. In some areas, this slowing allowed pockets of air to be surrounded and pinched off. After the fluid underfill material traveled beyond the densely arranged peripheral solder bumps, void formation stopped.

Insufficient quantity of fluid underfill [Figure 2]



In Figure 2, there is a single small void at left, and a second "gap" area at right that is too large to have been formed by the pinching off of an air bubble. Instead, this area represents an underestimate of the amount of fluid underfill needed to fill the offset between the chip face and the substrate. The design of the dispensing pattern for the fluid underfill may be correct, but there isn't enough material to go around.

BGA with underfill [Figure 3]

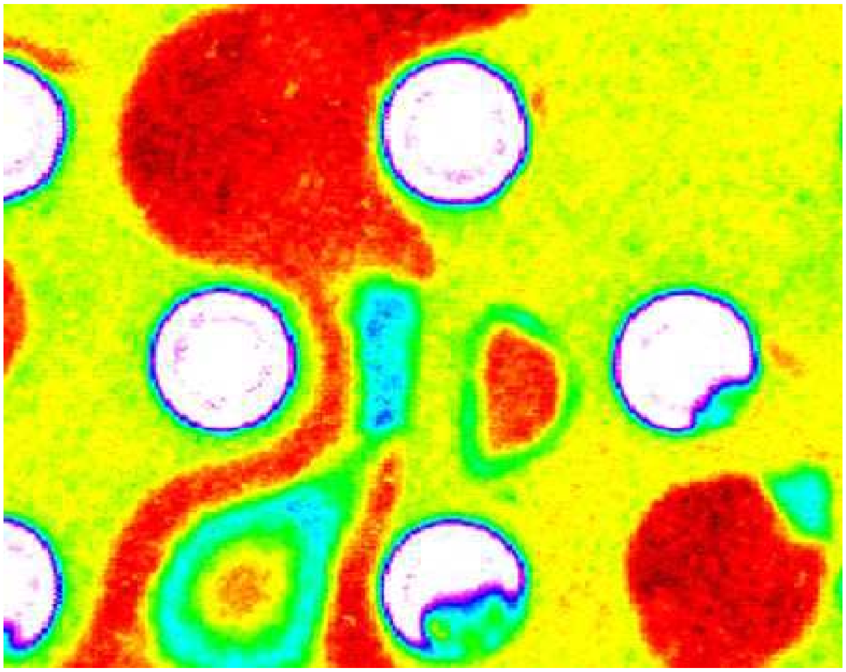
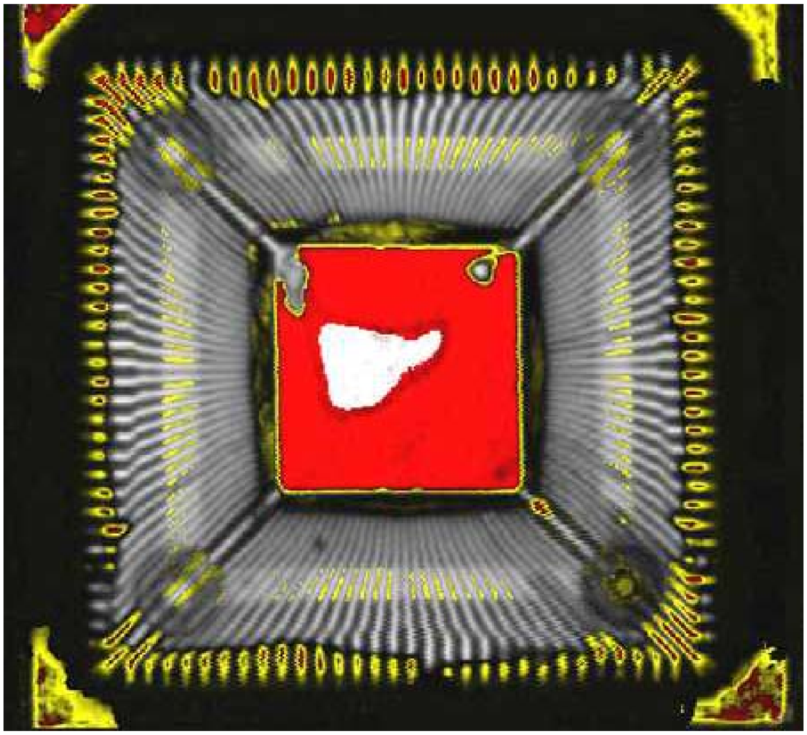


Figure 3 is a magnified view gated acoustically to use only the return echoes from the interface between the solder bumps and the substrate. This BGA displays multiple anomalies. First, the expected bright circular reflection is missing from two of the solder bumps, which are only partly bonded to the substrate. One likely cause is surface contamination during reflow.

In addition, the dispersal of filler particles in the underfill material is uneven (yellow and green areas). The red areas are voids - areas with no underfill material at all.

PQFP with peripheral leadframe delaminations [Figure 4]



Imaged from the bottom side, this PQFP shows two defect types. First, most of the die is disbonded (red) from its paddle. Only the white area is bonded. Surface contamination of the die paddle is one possible cause of disbonding.

Second, nearly all of the lead fingers are delaminated (red, yellow) from the molding compound, but only at their outer limits. A delamination here opens a pathway for environmental contaminants. One cause of such a peripheral pattern of delaminations is mishandling during trim and form - but that cause can be discounted here because the PQFPs are still in strip form and not yet singulated. Portions of the strip are visible as triangular features at the top and bottom of the image.

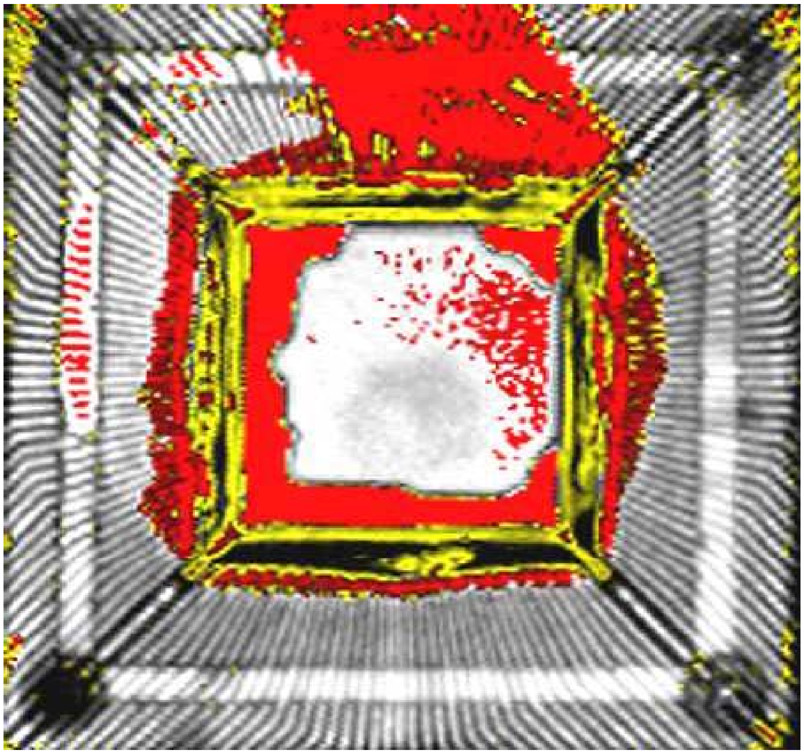
Other causes of this delamination pattern include oxidation from bonding temperatures, and warping of the leadframe when processes do not permit adequate stress relief.

Lead finger delamination related to tinning [Figure 5]

This PLCC suffers from two defects. First, the dark red area around the die is a large delamination of the paddle from the molding compound.

More interesting, though, is the delamination of every lead finger at its inner end. This is where the lead fingers are tinned to improve wire bonding, but the tinning material needs to be compatible with the molding compound material. Some tinning materials - usually gold and other noble metals - don't form good bonds with some molding compounds. The pattern of delaminations suggests that such a mechanism may be operating here.

PQFP with multiple defects [Figure 6]



This PQFP was imaged acoustically from the topside and with rather wide gating which encompasses depth from just above the die face downward to the die paddle. The red areas in this image actually define three separate and possibly unrelated internal defects:

•The red area surrounding the die, and extending to the top of the image, is a large "popcorn" crack. Popcorn cracks often occur during reflow when excess moisture in the molding compound is heated and expands.

•The solid red area around the periphery of the die indicates partial disbond of the die from the die paddle. One possible cause: surface contamination. The gray-white area is the well-bonded area of the die attach.

•The smaller red spots within the well-bonded area are small delaminations between the die face and the molding compound above it. They are visible here because of the unusually wide gating of the return echoes.