Find Defects in IC Packages

Matthias Hutter - September 01, 1999
The die-attach material used in an IC serves three functions: It physically attaches a die to a die paddle or to a substrate, it conducts heat away from a die, and it absorbs some internal stresses. Yet the die-attach material in an IC that passes production tests may contain undetected defects such as voids and delaminations (Fig. 1), and these may eventually cause the chip to overheat or break. Using a combination of imaging techniques, manufacturers can uncover defects before shipping products to customers.

Delaminations show up during manufacturing as thin spaces that often occur across a wide area between the die-attach material and the die, or between the die-attach material and the IC's lead frame. In addition, thermal shock or mismatches in the coefficients of thermal expansion of materials can also cause delaminations, which means delaminations tend to “grow” during thermal cycling. Delaminations may also occur within epoxy-based die-attach materials. These internal delaminations result from the failure to thoroughly mix die-attach chemicals during production.

A delamination acts like a high thermal resistance that reduces the ability of an IC package to act like a heat sink, so a delaminated die can overheat. A large or growing delamination worsens this effect and the die may eventually overheat to the point that it fails. When a delamination extends across the entire die-attach surface, the die may remain held in place only by the fragile lead wires, which will break when stressed.

A second type of opening, called a void, appears as a large gap in the die-attach material. Voids may originate as bubbles trapped in die-attach materials or they may result from outpassing of the die-attach material. Also, the lack of sufficient die-attach material applied during manufacturing can create voids. Voids tend to act as the nucleus for horizontal cracks.

The stresses that result from different coefficients of thermal expansion increases at distances further from the center of die. Thus, the highest stresses occur at the corner of the die, and defects near the corners of a die are more likely to result in device failure. Conversely, a small defect near the center of the die-attach material may never expand into a lethal defect. Due to the potential lethality of these openings in the die-attach material, MIL-STD-883, Method 2030, spells out the sizes of defects that manufacturers can tolerate near corners.

Looking for Defects
To prevent die-attach defects from leading to field failures, IC manufacturers test samples of die-attach materials from each manufacturing lot, looking for voids and delaminations. By carefully examining any defects, these manufacturers can determine their causes and can act to prevent them in the future.

For example, delaminations can occur when surface contamination prevents the die-attach material from “wetting” surfaces. An IC manufacturer might correct this by cleaning surfaces more thoroughly to remove contamination. Or, the manufacturer might have to select a different die-attach material that offers better adhesion properties.

Uncovering the defects, however, can prove difficult. I have found that using a combination of x-ray imaging and acoustic imaging essentially discloses all of an IC’s internal structural defects. X-ray images quickly reveal thick or deep defects that offer high contrast. Acoustic, or ultrasound, images show very thin gap-type defects. (The value of using both techniques was described in recent symposiums 1, 2)

To determine how well each imaging method works, I studied the bonds between 6-mm 68-pin SOICs and copper substrates using an echographic tin-silver solder. To be sure I looked at only die-attach defects, I used preliminary acoustic imaging to eliminate samples containing defects in either the die or the substrate.

I took an image of a device using x-rays and then took an image using an acoustic-microscopic imaging system using ultrasound at 100 MHz. The x-rays needed to have sufficient energy to penetrate the metal substrate, yet could not be so powerful that they “swamped” the small change in density as they passed through a void. Small light areas in an x-ray image represent voids in the die-attach material (Fig. 2). The thickness of a void determines its contrast in an x-ray image. Trapped bubbles that extend from the substrate to the die show the highest contrast with surrounding materials. Smaller voids appear as lower-contrast spots.

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