WHITE ELECTRONIC DESIGNS

ALPHA PARTICAL
Application Note

ALPHA PARTICAL CONSIDERATIONS IN FLIP CHIP TECHNOLOGY

1) What are alpha particles?

High energy particles are emitted during radioactive decay of heavier elements like lead. The problem was discovered in the early 1970's at IBM. Because of chip geometries in the early years of semiconductors, it wasn't too much of an issue until the last 5-6 years. Alpha emission is measured as alpha counts/hour/sq cm. A typical alpha count from solders used in electronics is 1.0 to 20, sometimes higher. Low alpha is 0.01 to 0.05 a/hr/cm^2. Ultra low alpha count is 0.00X and below. The key question is how low does it need to be? Allowable FIT for a given application defines low alpha goals.

2) Products with a concern about alpha emissions.

High order ASICS, gate arrays, PLDs, processors like SPARC and others, typically where the chip geometries are below .25micron. Memory arrays in ASICS are of particular concern. But also important is the application of the chip and that markets tolerance of SER and FIT. For example, a SPARC chip may go in an ATM or a video game. An error on an ATM deposit is not viewed kindly. But if Mario doesn't jump the dragon one time, it's not too critical.

3) How to achieve low alpha?

Non-lead solders are a first approach most companies look at. But in the industry, other metals will exhibit the emissions because of impurities created during the smelting or atomization process of preparing various alloys. Because the metallurgy companies blend the metals in the same vats, cross contamination occurs and you can get high alpha emissions in "non-lead" alloys. Vendor purity control is difficult and dedicated vats are expensive.

Within this category, there are several non-lead alloys that are gaining popularity because of their reflow profiles. Included are alloys of copper-antimony-silver-tin. Another is copper-tin-silver-indium. Tin-silver is also popular. These and others have the advantage of lower reflow temps than high lead solders. But care must be taken with issues of voiding (from larger grain sizes in the compounds), electromigration, thermal migration, dendritic growth and rigidity; all of which impact reliability.

4) A second approach to low alpha is reduced alpha leads.

They retain the advantage of long term reliability, reduced electromigration/thermal migration, etc, but are more costly. They are developed using antiquity leads or through laser isotope separation. Alpha emissions go down over time as the radioactivity decay progresses. Uranium - Polonium - Lead210 - Lead 206 etc.) If you use "old" lead that was already melted once it will have lower alpha activity. This comes from old ship anchors and armor dredged up from the bottom of the oceans. Some mines have inherently low alpha emission leads. Finally, lead can be vaporized and a laser beams at the right frequency is shot through the vapor. This pushes the alpha particles out and the condensed lead can be made to low or ultra low alpha based on the time the laser is on. Alpha content can be reduced to 0.000X a/hr/cm2 via this method.

5) Inherent to any solution will be the bump process.

There are three primary processes, and several secondary processes for bumping. The three key ones are evaporation (practiced by Motorola, IBM, partially by Unitive and IBM licensees), plating (everyone can do it and is usually Nickel or eutectic solder), and printing (K&S and Delco). High lead is commonly used in the evap process. If they can control the lead source they can achieve low alpha. Printing processes requires solder pastes which are somewhat difficult to control because pastes are formulated from atomized powders which can become contaminated during processing. Plating can somewhat control alpha through material selection.

6) Many applications will use error detection and correction.

Mil and Space applications have been using EDAC for space radiation control for some time. This technology is in work stations, bank computers, medical equipment, and other SER sensitive applications with a lot of processors and memory intensive cards.

7) If there is room on the die, designers can position the bumps away from sensitive areas in the chip.

This limits bump I/O and tightens pitch of the bumps, but if alpha is a prime concern, it is a viable solution. Alpha emissions are “line-of- sight” only. Therefore most of the concern is the flat area of bump directly above the UBM structure. If the chip is designed with bumping in mind to begin with, sensitive nodes can be kept away from the bump pad. Also, the particle will usually only penetrate 30-50 microns. Depth of the sensitive node makes a difference.

Another approach for alpha protection is to “enhance” the UBM structure to make it more particle resistant. I haven’t heard this is successful, since UBMs tend to be very thin. But there may be something evolved to help protect the chip below the bump.

8) How to measure alpha emissions?

Probably the toughest aspect of the technology. Commercially available detectors are limited to around 0.004 a/hr/cm2. But measuring alpha emissions must take place about 4 months after final reflow. This is the rough time it takes for the emissions to reach their peak (more half life stuff). By that time, a bumped die is usually in a system and measuring alpha emissions is nearly impossible. A company called Spectrum Sciences makes the background detectors. The user should request an alpha spec from the bump house. But how they verify it will be interesting. And can they keep the low alpha process isolated from the non-low alpha bumping process? Another issue is the alpha induced SER from bumps versus ambient radiation caused SER. Users will need to separate bump alpha from ambient alpha emissions.

9) A separate issue - is the “green” one.

Lead is environmentally becoming unpopular. Europe has declared some restrictions. In the US I am not aware of any laws restricting lead use, but it is a topic at some conferences.