Area Array Packaging - Then and Now

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High volume packaging was presumably launched during WWII when ceramic modules were mass-produced for proximity bomb fuses. Alumina (Al_2O_3) was found to be a highly robust substrate and is still widely used today. The war-era packages used screen-printed conductors that were fixed by firing at high temperatures that was required by the inorganic ceramic chemistry. Components, such as miniature vacuum tubes, were hand soldered. Some progress had been made with printing resistors and the mixed technology led to the term "hybrid circuits" and ceramic hybrid technology. The 2nd-level connection from the module also required hand soldering using an insulated wire interface. Most early ordnance systems didn't use a PCB, so there was little motivation to develop a different assembly method. It would take at least another decade before a more efficient means of connecting the package to the system was developed. But a paradigm shift in active device technology would force changes in device connection methods in a few more decades. The solid-state breakthrough that has just celebrated its 60th birthday - the invention of the transistor - would revolutionize packaging. Solid-state would ultimately lead to much more demanding package requirements, especially after the integrated circuit was developed.

The leadless ceramic chip carrier (LCCC), also known as a ceramic flat pack, was an early package design that allowed a direct connection to the printed circuit board, or surface mounting. This was well before plastic packaging made the scene. The LCCC interconnect was a land grid array (LGA), simply a set of solderable pads, that allowed the ceramic package to be directly connected to a PCB. The pads could be formed using ceramic-metal ink (cermet), or by direct metallization. The common cermet pads were composed of silver-palladium that was readily solderable. Although leads were added to make perimeter packages, including DIP (dual in-line package) and PGAs (Pin Grid Arrays), the leadless format remained popular. By the 1960's, wire bonding had become the preferred chip-connection process although IBM was having good success with flip chip assembly to ceramic packages for mainframe computers.

FIG. 1 - LCCC

The idea of adding metal connection spheres appeared almost 50 years ago, even though metal bumps and balls are considered modern. The first documentation of adding metal balls to the package is probably IBM's SLT (Solid Logic Technology) that was introduced in the early 1960's; probably 1963, at least that was the public announcement date. The balls were made of copper and were soldered onto highly passivated transistors to make a 3 I/O Ball Grid Array (BGA) shown in Figure 2. The ball attachment solder had a high melting point that allowed the SLT package to be soldered to package substrate or to a printed circuit board (PCB) that was typically made of low-expansion ceramic (no underfills at this point in time). A few years later, IBM moved from copper spheres to solder alloy that was vacuum deposited and the package was called C^4 (not C4 that was easier to type) for controlled collapse chip connection; also known as the DCA (Direct Chip Attach) package. Solder bumps, or balls, were later applied to ceramic substrate - the leadless ceramic chip carrier now became the ceramic ball grid array (CBGA). IBM also used columns to provide a higher standoff for increased reliability; Column Grid Array.

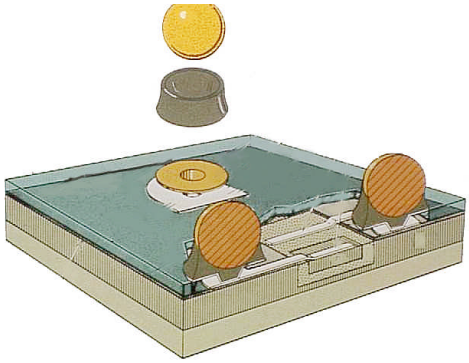

FIG.2 - SLT

While ceramic substrate was desirable for a low CTE (Coefficient of Thermal Expansion) and high-reliability perspective, organic (plastic) could reduce cost, primarily due to the simpler manufacturing steps. Motorola, a licensee of IBM's area array packaging IP, introduced the Plastic Ball Grid Array (PBGA) as the Ompak® (overmolded package). Solder balls were placed on the bottom of the chip carrier substrate to form this classic BGA interconnect. For a short period, development work by Motorola, and others, included conductive adhesive balls, and solder balls formed by stencil printing and fluid jetting. Even the old IBM copper ball idea was resurrected, with the idea of having an assured standoff height and less chance of bridging.

Now its 2008 and packaging is alive and well. In fact, activity is at an all time high. Multichip modules, under a variety of names, are one of the most active areas, and 3D is the big play. But what about low cost single-chip designs? Surface mount area array is still the *de facto* standard. But what about the 2nd-level package-to-PCB interface -- is it still the BGA? Well, not quite. While the completed assembly may look like a BGA, the low-cost package is a QFN - quad flatpack no-lead. Right, it's the BGA without solder balls. The substrate can be plastic for general applications, or ceramic, when required, such as for some MEMS and RF devices. But hold on! Isn't the ceramic QFN really the ancient LCCC? Ironically, the LCCC, one of the earliest packages, is, in essence, the same concept as the newest designs. So, "then" and "now" are the same, and we're right back where we started from.

FIG.3 - QFN Package