

# 3D Packaging Helps Create Small, Powerful, and Out of this World Consumer Devices



**W**ith each new generation of miniature mobile phones or pocket-sized

MP3 players that hits stores, consumers may wonder how can something so small do so much? The wonder, however, only lasts a moment as consumers quickly adapt to the conveniences of the current generation of portable devices and, instead, begin to expect more.

But before taking it for granted that mobile phones can surf the Internet and show a photo ID of callers or that wrist watches can make phone calls with a simple voice command and tell time in five countries, it's important to understand the technology behind these little marvels. It is a fast-evolving niche in the semiconductor market known as stacked or 3D packaging.

Once reserved for high-end and military purposes, 3D packaging has come a long way in the years since Sharp Electronics first attempted it. It serves as a key component for many manufacturers in keeping up with the smaller, lighter, but more powerful trend in the consumer products market.

## Who's Stacking Now

**Companies that have made a foray into 3D-packaging technology include:**

- **3D Plus**
- **Altera**
- **Amkor Technology**
- **ChipPac**
- **Dense-Pak**
- **Epson/Seiko Epson**
- **Fujitsu Microelectronics**
- **IBM**
- **Intel**
- **Mitsubishi Electronics**
- **NEC**
- **Sharp Electronics**
- **Tessera**
- **Toshiba**
- **Vertical Circuits**

*(Information provided by Electronic Trend Publications)*

### **Mobile Phones Downsizing while Driving Growth in 3D Packaging**

The rampant use of mobile phones has been a clear driver behind the growth of the stacked-packaging market. Just consider the evolution of the mobile-phone market.

According to figures provided by Sharp in its white paper, "Packaging Trends for Mobile Application," production volumes in 1999 greatly exceeded expectations to reach 280 million units. The number of mobile-phone subscribers could grow to 1 billion units by 2003.

Beyond the growth in mobile phone use is the need by consumers for their phones to do so much more than simply call someone. Such phones need to provide a range of data-communication functions, including e-mail and instant messaging. The catch is that with increased demand for constant communication,

consumers also want convenience with phones that fit nicely inside a purse, briefcase, or pocket.

"Over the past few decades, electronic equipment development has been driven by miniaturization based on the semiconductor wafer process, a trend that will continue in the future," says Morihiro Kada, general manager of IC Packaging Development for Sharp Corp. in Japan.

Sharp realized the trend in the mid-1990s. As such, it innovated stacking technology by being the first to stack Thin Small Outline Packages (TSOPs), which was the prevailing technology at the time. Sharp's goal: shrink the size of TSOPs to fit more memory into a smaller area on the motherboard, allowing a device to accommodate more functions.

Later, as Chip Scale Packages (CSPs) came into their own and began replacing TSOPs, Sharp experimented with stacking two die (SRAM and Flash) within a single CSP.

"The CSPs have undoubtedly made mobile phones smaller and lighter," Kada says. "Mobile phones contain many components like the CSP, which is a semiconductor package. However, I am convinced that CSPs have lead the way toward lighter and more compact mobile phones and contributed to their worldwide dissemination."

Sharp's biggest challenge in working with CSPs to stack SRAM and Flash has been preventing wires from touching each other, which also is known as wire wash. But market analysts say Sharp has worked hard to make sure each electrical I/O is isolated from the others to avoid wire wash.

"Sharp has done a lot of revolutionary work in making stacked packaging a reality and is still con-

sidered the market leader," says Sandra Winkler, a senior analyst for Electronic Trend Publications in San Jose, CA, who has covered the packaging industry for the last decade. "Stacking die within a single CSP was simply a more difficult and newer technology when Sharp began working with it. But Sharp has done a good job of getting it to work and is considered the pioneer in this area."

### **To Stack or not to Stack**

Despite apparent advantages to stacked packaging, companies that specialize in this niche can meet with some resistance to the technology. The major concern: reliability of memory. After die are wirebonded and packaged, it's hard to take the package apart if in testing it is discovered that one of the die is faulty.

One company that is making great strides in 3D-packaging reliability is Amkor Technology, which is based in Chandler, AZ. Amkor supplies outsourced packaging and services to test semiconductor interconnects. Amkor focuses on furthering stacking technology.

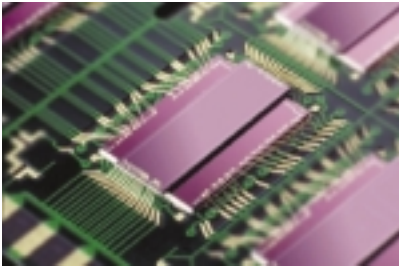
"Testing is certainly a concern," says Jon Woodyard, Amkor's product manager for 3D Packaging. "But with stacked-packaging technology today, companies can individually test the memory and know it works before it is packaged."

Woodyard says that Amkor boasts an assembly yield of 99.9 percent on its stacked-packaging process. "Most often, companies are taking Flash memory with a 90-percent yield and packaging it with SRAM that has a 99.1-percent yield so it's clear that the overall package will offer a good yield," Woodyard adds.

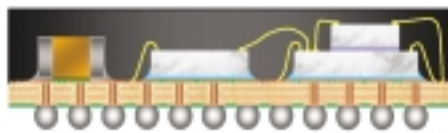
But when you consider many companies would release a product with a package yield of 50 percent

## Trends in 3D Applications

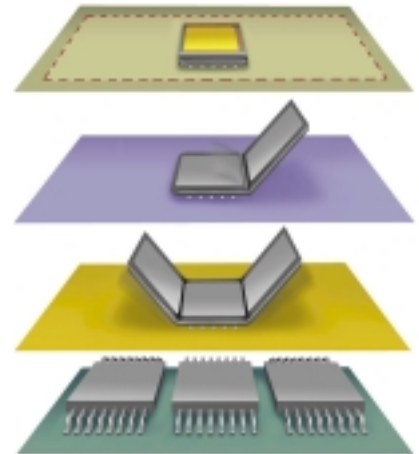
### Die Stacking within a Package



### Passive Integration and Die Stacking within a Package



**Figure 1.** Sharp led the way in stacking packaging in the 1990s by figuring out how to stack die in a package. (Image courtesy of Amkor Technology, Inc.)



**Figure 2.** There are many ways to stack and package die, including stacking two odd-shaped die together and stacking three die in less space than most technologies can stack two die, known as folding, which Tessera recently introduced. (Image courtesy of Tessera)

## Stacked packages save board real estate, so that the PCB (printed circuit board) can be smaller, thus the final product can be smaller.

to make sure they are first to market, experts say concerns over stacking reliability don't add up.


"Stacked packages offer many advantages," Winkler says. "They save board real estate, so that the PCB (printed circuit board) can be smaller, thus the final product can be smaller. Stacked packages also minimize the amount of I/O entering and exiting a chip because some I/O can be shared among the die. Sharing die I/O then minimizes the traces on the PCB, making PCB design simpler."

Cost remains another concern. The cost of stacking versus side-by-side packaging often depends on overall costs of the system. In general, stacking TSOPs can run a little more, while CSPs run less, than side-by-side packaging.

"Total system cost must be taken into account," Winkler says. "However, because a stacked package requires less board real estate, the PCB can be smaller; thus it costs less money, which saves system costs."

### 3D Packaging Market Future

After Sharp delivered 3D-packaging technology, 26 companies followed suit, including Amkor. Other innovators include Tessera in San Jose, CA, which in 2001 introduced a folding 3D technology for licensing that claims to stack three die in less space than most technologies can stack two die. Companies such as 3D Plus and Dense-Pak also are making noise in this space by stacking multichip modules (MCMs) for specific, high-end applications.

Even with the downturn in the economy, Winkler says the opportunity for 3D-packaging growth remains strong. "Right now, the cell-phone industry is tapering off," she says. "But there's still opportunity for handheld devices. Ultimately, chip scale is driven by the fact that consumers want smaller and lighter. Stacked packaging offers an answer for space-constrained products." 

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