PTB >> Optoelectronic Contract Manufacturing Starts Before Design — Not After

During the 1980s, electronics companies began a two-fold move toward outsourced manufacturing and away from a vertical manufacturing infrastructure to focus on their core competencies. This is evident in the rise of fabless design companies, the rise in electronic packaging companies, and the success of companies focused on system-level assembly. The rise of this new type of manufacturing environment has led to a very nimble, highly complex infrastructure with international capabilities.

A primary driver for this movement was the enormous growth of the personal computer business that began in the mid 1980s and continued unabated through the 1990s. The product focus for outsourced electronics manufacturing falls into three categories: silicon die, packaged components, and assembled boards that were combined in the final product enclosure or box.

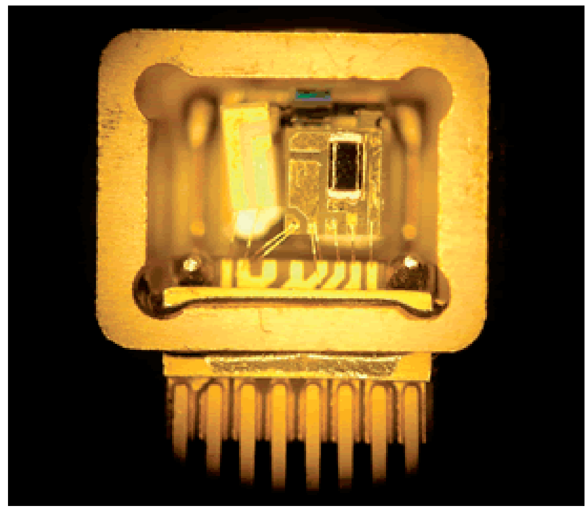

Figure 1. The 3D nature of optoelectronic packages makes these systems different from electronics, which are predominantly 2D.

By the time the telecommunications bubble began in earnest in the mid to late 1990s, this easily scalable infrastructure was in place for the manufacturing explosion that was to occur. The telecommunications bubble, in particular, fed rapid growth in the electronics contract manufacturing market. Unfortunately, optoelectronics could not handle the ramp-up nearly as well.

Optoelectronics:

Unique Physical Considerations

By the 1980s, the three primary product categories mentioned above were largely two-dimensional. While some components were three-dimensional and mounted to boards, all electrical signals were still carried in two-dimensional traces.

The nature of most of these products was such that the “guts” of the systems were contained within the two-dimensional space that made up the logic space of the semiconductor. Other than that, the remaining parts of the system existed to support and transfer the information that was created within the semiconductor devices. However, in the relatively nascent world of optics — which, from a manufacturing perspective, was primarily driven by the telecom industry — the support nature of the various components was wildly different.

When a new electronic component is added to a device the rules are straightforward. However, when a system or product introduces the use of photonics — whether in the visible or infrared — the optics part of the system must take priority throughout the device; all other design considerations — including electrical, mechanical, and thermal — must wrap themselves around the optics of the system if it is to function properly.

The key reason for this is the high frequency of light and what this means to signal propagation. Low-frequency electrical signals can follow virtually any kind of metal trace; these can be straight or winding. Higher frequency electrical signals will interact with their surrounding medium, and this additional complexity must be taken into account during the design phase of the project. In other words, components can be placed almost anywhere on an electronic because the signal will follow a convenient metal path that may have numerous twists and turns.

Optical systems propagate light via free space or through fibers. Free space requires a series of bulk optical elements; the optics cannot move or change (by thermal expansion/contraction) without adversely affecting the signal. Systems that use optical media, such as optical fibers or waveguides to propagate light, depend on the media's ability to create total internal reflection to capture the light and transmit it with minimal loss. Unlike metal traces, however, fibers are severely limited in their ability to bend or twist, and there still remains the issue of coupling the light in and out of the waveguide.

Signal propagation challenges lead to manufacturing challenges. While electronic circuits have placement tolerances of a micron or so, optoelectronic assemblies regularly have tolerances as low as a tenth of a micron. This leads to an enormously more complicated set of assembly issues. High-speed placement tools exist that can place die or components to ±5-10 μm, but high-speed placement tools that can place a component to within 0.1 μm and hold the tolerance after the joining operation do not exist.

When thermal expansion and contraction are added to the mix of challenges facing the manufacture of optical circuits, it becomes readily apparent that the design and manufacturing of the device must be viewed holistically.

Different Driving Forces

In addition to the dimensional differences between electronic and optoelectronic components and circuitry, the product space driving the use of electronics or photonics also creates manufacturing distinctions.

The digital semiconductor industry, for example, was driven by Very Large Scale Integration (VLSI), allowing multiple components to be interconnected on a single monolithic structure at a very low cost per connection. Moore's Law indicated that the cost would be driven down as the complexity was driven up, thus yielding a very low cost per interconnect. The cost of interconnecting the chip to the board is several orders of magnitude higher, while board-to-board and system-to system-costs climb even higher by orders of magnitude.

This level of integration has yet to take effect in high-frequency photonics and RF devices, which are mostly concerned with transmission of data versus manipulating the data. Functionality is built at the board level, creating pressure for cost reduction at the packaging and interconnect level.

Before the Bubble

Unlike electronics, by the 1990s optoelectronics for data transmission did not have a large-scale manufacturing base. Instead, many of the products that were needed for the expansion of the Internet and telecom infrastructure were still in development. Standards for the various markets (long haul, metro/access, etc.) were non-existent.

Figure 2. Avo Photonics' specialty packaging manufacturing line for volume production.

New products were taken from the laboratories, where they were designed as tabletop assemblies for performance only, and installed in the field. Systems were not designed to accommodate an automated or semi-automated manufacturing platform. There were numerous examples of products that were in essence designed for hand assembly because their specifications would have led to disastrous yields for an automated assembly platform. Manual assembly meant each unit could be customized for the part specs, but this type of manufacturing does not have the scalability required of contract manufacturing operations.

VCs Demand Change

Another attribute of companies and manufacturing during the telecom bubble was that many venture-backed companies were financed to be vertically integrated. In some measure this was done to protect the particular recipe for manufacturing the product and protect intellectual property.

Venture companies are no longer financing companies to support their own manufacturing, forcing the telecom industry to change from vertical to horizontal manufacturing infrastructures. This is both good and bad for companies looking to succeed in this new world. Telecom companies unfortunately don't have large enough volumes for many products to transition directly into the electronic contract manufacturing structure. Nor are there simple, scalable rules for package design that companies can work with and then use to feed their products to these contract manufacturing companies.

Relative to optoelectronics, electronic contract manufacturing is much more straightforward. Looking back at the mistakes made during the bubble for ramping up product volumes, it is clear that the three-dimensional aspect and the expanded thermal and mechanical considerations of optical devices require a contract manufacturer for optoelectronics devices to have the experience and ability to create the device holistically. Designing to a single design consideration and ignoring the downstream manufacturing platform during product design has and will lead to disastrous consequences.

While optoelectronic contract manufacturing was not prepared for scalability during the bubble, it is now possible to design products appropriate for the transition into volume manufacturing. Unfortunately, an optoelectronic product and its subcomponents are completely interdependent. This means that, unlike the electronic product space, the design rules are not separable.

Therefore, the products must be designed for the manufacturing platform.

Manufacturing equipment and the component design must keep the optical elements as the primary consideration and the other design elements as supporting the photonic functionality. This is best accomplished by performing the entire product design and analysis under one roof in order that the appropriate tradeoffs between the competing design considerations can be made with an eye toward the best and most reliable product possible.

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