January 20, 2009

New Opportunities in Electronics Manufacturing

The world around us is changing fundamentally in many ways as both economics and technology force us to reexamine our business models, the products we build, and the way we build them. From an industry driven by vertically integrated OEM's in the 1980's, cost pressure and the drive to maximize short term return on investment drove it first towards outsourcing and then towards offshoring. The result has been that many OEM's are simply labels today and in that arena the only important metric is price. The Emperor, in many cases, has no clothes. Computers, cameras, cell phones, and 100 other products are simply commodities where the hardware has little or no intrinsic value while branding, software and the chip grab the lion's share of profits. According to the received wisdom, technology and quality are a given.

And yet, without the underlying interconnect technology, it is all meaningless. Without line engineers understanding the complexity and synergies between components and hardware, the software and branding are meaningless and many features would not exist. Without good quality, profits plunge and accountants in many cases simply shift profit centers from manufacturing to repair. One of the dirty little secrets of our industry is the massive cost of repairs. All over the world, thousands of technicians are fixing what should have been engineered and built right in the first place. The recent business model is one of outsourced design, manufacturing, logistics, and to an extent, common sense. Engineers, technicians, and software architects are the enablers and are a core business asset in electronics manufacturing.

One of the results of outsourcing is that one loses the ability to understand new technologies on a basic level if they are not on the factory floor. From understanding comes opportunity. In response to IP and product piracy and the hypercompetitive marketplace in technology, many smart companies now involve only their closest partners in their research and development programs. If you are not a part of the group, you may never see new enabling technologies. This is what has happened to North America and Europe on a dangerous scale.

Today, in many cases, management, government, the military, and even the scientific community do not understand the enabling technologies that can help spur a new economic renaissance. While focusing on nanotechnology, or biotech or energy on a micro scale, we have lost the ability to make it simpler, more efficient, and lower cost. This is a mistake that has been repeated to the point that it has almost become a maxim. Whether it is televisions or VCR's or cellular phones, the business model in many cases has been technology development in Europe or North America, and then exporting manufacturing to lower cost regions. Today, the West stands on the brink of disaster with one of the fundamental pillars of a sound economy, manufacturing, dilapidated, moribund, and unable to comprehend its fate. We need a healthy manufacturing sector to survive and the interconnect is at the center of that capability.

High Density Interconnect (HDI) – Rev 2.0

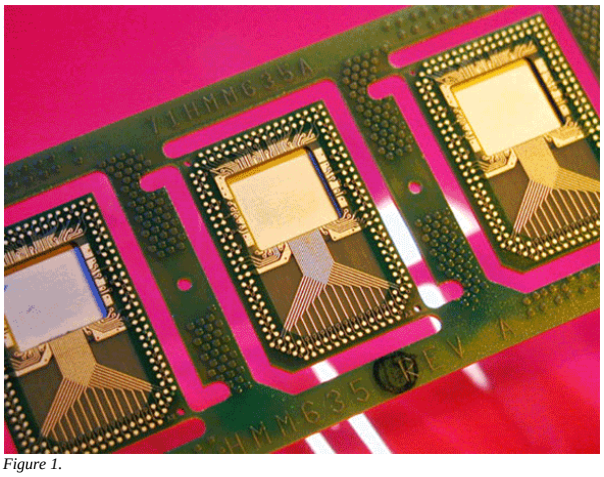

Figure 1.

Source: THIS NEEDS CAPTION

Interconnect technology is not standing still. There have been amazing developments that will help us create the future. But we have to understand these opportunities and commit to seeing the course through. In the early 1990's high density interconnect was invented in North America and Europe. It started with the microvia and sequential build up. There is an extensive body of work on process and technology, and many Western companies were very successful in scaling production for a wide range of applications including telecommunications, workstations, desktop and notebook computers, and handsets. 50+ large factories in North America built HDI very profitably and in high volumes. Today, there are only a few left. Poor business decisions, offshore competition, and a lack of understanding and vision all helped drive much of this offshore. Eventually, people simply forgot. In 2008, one of the major drilling machine manufacturers counted approximately 150 laser drills, a critical tool for HDI, in North America. Globally, their census of the installed base is 3,600+ units, primarily in Asia. A number of Asian manufacturers have 150+ units in a single factory.

Global HDI (Build Up) Production & Forecast

	1999	2005	2006	2011	CAGR 2006/11
Americas	$150	$187	$202	$270	7.0%
Europe	$187	$359	$352	$370	1.0%
Japan	$1,739	$1,365	$1,520	$1,947	4.0%
SEA	$203	$3,306	$3,619	$5,324	8.1%

Figure 2.

Source: Prismark Partners

Today, HDI is a mainstream product, but only a small percentage of the circuit boards are built in North America. Markets include hand held devices, HDTV control boards, iPod's and MP 3 players, Bluetooth devices, high end notebooks, GPS systems, automotive engine controls, cameras, digital watches, hard drives, and many other products. HDI is an enabling technology for smaller, lighter and faster electronics for military, aerospace, and medical applications. The technology drivers are miniaturization, packaging, high frequency, I/O density, and in most cases, cost. Almost every single ink jet printer cartridge in the world contains HDI. HDI circuit boards are in fact an extremely cost effective technology and are being built in the hundreds of millions of units per year.

Demand in North America for bare board HDI technology is already in the billions of dollars, but the vast majority is imported. Recent data indicates that North American production of HDI boards was approximately $200 Million, while known orders from a limited range of customers willing to share their data totaled over $1.1 Billion. Imports of products containing HDI boards are in the many billions of dollars. Most of this is in high volume products.

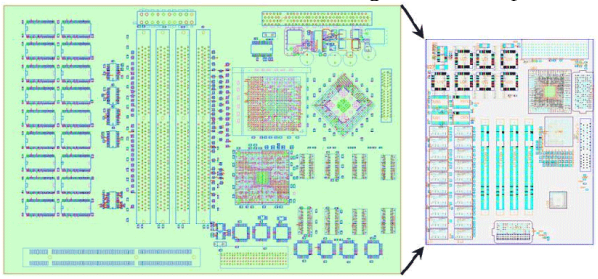

Figure 3. 16-layer 10" x 7.8" PTH Substrate reduced to 5"x6" 8-layer substrate using Type III HDI process

Source: Happy Holden Mentor Graphics

However, HDI has not yet made the transition into many applications where the North American interconnect fabrication base feels they can compete successfully. The scale and cost of some technologies can appear to be daunting. The infrastructure that existed in the 1990's is now smaller. Today, these solutions are available on the open market. The hard work has already been done. One of the critical reasons for success in Asia was that the entire interconnect supply chain worked together to achieve common goals. Designers, OEM's, fabricators and assemblers worked together to develop more efficient and lower cost solutions and understand how to use the technology effectively.

HDI Applications

- Video Graphics Cards
- High End Notebook Computers
- Bluetooth
- Automotive GPS
- HDTV
- Engine Controls
- Medical
- Aerospace
- Military

Figure 4.

HDI is an enabling technology. It reduces costs and footprint and can improve product performance significantly. Weight and size are two of the greatest considerations in OEM product development today. HDI can answer these design challenges. But in selling HDI, the overall benefit to the application is critical. HDI can enable new applications and allow the product designer to add features and portability or make a product more robust. Board designers and fabricators must understand their customers products and goals to see how the technology will help create breakthroughs and cost reductions.

Embedded Active & Passive Components

Coupled with the explosion in HDI usage is the potential for embedded component technology. Embedded capacitance and resistance within the printed circuit board has been available for many years but had limited acceptance in North America. A major change in OEM philosophy towards embedded components occurred several years ago when the handheld manufacturers began a major push to reduce costs and increase functionality in a very limited footprint. Prototypes were manufactured in North America, but production went almost immediately to Asia. Yields climbed rapidly as designs were optimized. In some cases, the functionality was placed on the chip. However, the seeds of a new idea had been planted. Today, embedded component technology has been growing rapidly along a similar path as HDI at the outset.

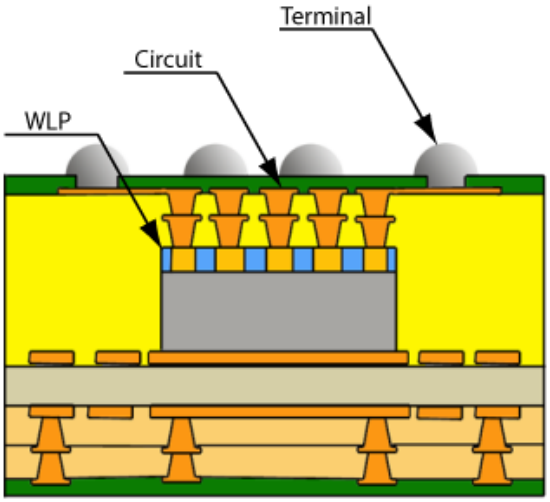

Figure 5. Embedded semiconductor technology: wafer-level package

Source: CMK

Manufacturing printed circuit boards containing embedded active and passive component requires a high level of precision and absolute quality control. Once embedded, components typically cannot be repaired. It has to be done right the first time. While the original efforts in North America emphasized design rules and special materials, the Japanese approach uses either modified SMT components or die attached devices. Chip sets including CPU + memory are attached to the organic substrate using copper posts, microvias, and copper plating. In some processes for passive devices, thin film resistors are used while others simply use low profile 0402, 0603, and 1005 resistors and capacitors.

The technical benefits include reduced I/O count, reduced component count, significantly improved interconnect reliability for severe environments, vibration resistance, improved high frequency transmission, reduced footprint, and simplified routing. Heat dissipation can be enhanced by mounting directly on copper lands. Panel thickness can also be reduced considerably. It is in most cases simply a better product.

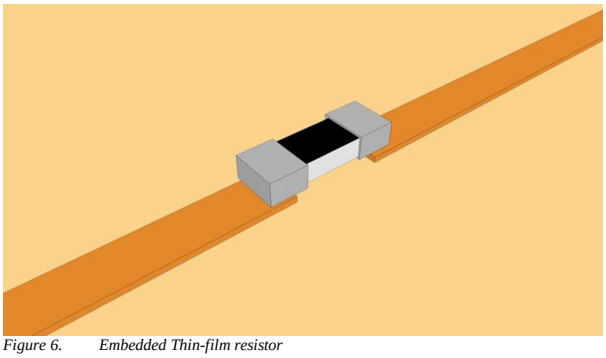

Figure 6. Embedded Thin-film resistor

Source: CMK

Current applications include stacked memory, memory cards, BGA's, modules, portable electronic devices, sensors, fuel cells, and automotive devices. Usage in military and aerospace applications is growing as well because of the combination of advantages offered. One of the highest volume applications to date has been runner's watches which include GPS, distance, speed, and pace information. In automotive and energy transmission applications, supercapacitors capable of discharging 50 amps at 4 Volts are a game changer. 1" square and 100 microns thick, the advantages of embedding these components in very high volume will further drive this technology opportunity.

For the printed circuit manufacturer, embedded components are a game changer. First, the quality requirements require world class performance. Failure to maintain quality results in a much higher cost per loss per unit. However, this discipline then flows throughout the factory, improving overall yields. Yield improvements drop directly to the bottom line and also result in enhanced customer satisfaction and retention. By making the printed circuit board an active device, the overall price per panel usually increases as well, allowing the fabricator to increase revenues and margins without a huge expansion ion plant square footage. Partnership with OEM's also creates closer relationships and opportunities for further product development.

For the OEM, one of the most significant advantages in using embedded components is intellectual property protection. Hardware can be concealed and key design elements protected. Reverse engineering becomes more difficult by orders of magnitude, and security or encryption devices can eventually be embedded as well. In a world that runs on time to market, this simple benefit could be measured in the millions of dollars.

The real advantage in the long run, though, is that radically new designs can be envisioned and enabled. The United States Army Land Warrior Project envisioned biometrics, communications, medical capabilities and weapons systems integrated into a whole that projected the capabilities of the individual soldier far beyond today into the realm of science fiction. Much of the requisite technology already exists but must be miniaturized, simplified, and made more cost effective. Information gathering and telematics will require simplified and rugged packaging solutions, and the opportunities in medical electronics alone are amazing. As 3G and 4G wireless technologies roll out, HDI/Embedded will be integral to enable new features and applications. Apple Computer, RIM, Nokia, Motorola and others have shown what can be done when video, wireless, and other features are integrated in new and amazing ways. Just imagine the synergies and opportunities across the spectrum of industrial, consumer, and technical product capabilities when the means of technology change fundamentally.

Meso-MEMS/Microfluidic Printed Circuit Applications

The latest initiatives in interconnect technology involve the incorporation of functions previously placed on a chip in some cases or completely new architectures based on those technologies. Microelectromechanical Systems (MEMS) have been in volume use for a number of years, primarily at the semiconductor level. The applications today include accelerometers used in airbags, MEMS gyroscopes used to detect yaw, car tire pressure sensors and many other applications. The DLP chip used in flat panel televisions and many other applications consists of hundreds of thousands of micro mirrors that switch on and off. Microfluidic MEMS such as pumps, valves, heating elements, and channels enable technologies such as the ink jet printers used in our industry as well as the 100+ million printer cartridges sold per year. SEMI calculated the global market for MEMS in 2006 at over $40 Billion.

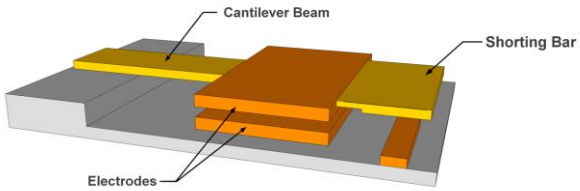

Figure 7. Schematic illustration of a single pole, single throw (SPST) MESO-MEMS RF switch. Applying a voltage between the electrode plates causes the plates to move toward each other. In doing so, the shooting bar is brought down and across the traces, completing the circuit.

Source: Motorola, Inc.

MEMS technology is rapidly migrating to the interconnect for a variety of reasons. Ink jet printer cartridges, one of the first MEMS applications, developed at Hewlett Packard in 1979, use both HDI and MEMS because the technical and economic advantages make the most sense in the application. It is very high technology which must be manufactured at very low cost. Meso MEMS, or those used on printed circuit substrates, originated at Motorola in the early 2000's. The ability to place MEMS on silicon is proven, but the penalty in increased packaging real estate on the chip and hermetic packaging requirements required in many applications becomes cost prohibitive. Printed circuit boards today have crossed the .001" geometry line that semiconductors crossed in 1960, and thus many MEMS applications can be migrated to Meso-MEMS at much lower cost. A Meso - MEMS switch might require from .001" - .005" line/space capability with the advantage of much higher current capacity. Other Meso-MEMS opportunities include Laboratory on a Chip (LOC), RF switches, valves and pumps.

LOC applies single or multiple laboratory processes onto the silicon. This is especially usefully for analytical and medical applications. They offer significant advantages in portability, lower chemical costs, and better process control in chemical and biochemical reactions. Analytical integrity is also enhanced because of the integration of functionality, isolation of samples, and precise volumes and metrics. Point of care applications will blossom as costs are reduced. Meso-MEMS is one tool to do so.

A last niche application for printed circuit substrates is lighting. LED technology has already had a significant impact, from traffic lights to automotive brake lights to display technology. Energy savings of 90%+ and lifetimes orders of magnitude longer than conventional incandescent or fluorescent lighting make LED's a very attractive choice. With close to 20% of North American energy demand consumed by lighting, the energy and economic impact is considerable. Even now, printed circuit substrates are being integrated into LED arrays. The application will accelerate as the availability of printable electroluminescent materials and Organic LED (OLED) materials and solid state lighting opportunities grow. The printed circuit board is an ideal low cost substrate in many applications.

The combination of these technologies results in an active interconnect that goes far beyond the limitations of today's conventions. When combined with electro optical components, RF designs, or other technologies it is obvious that the printed circuit board will undergo a complete re-definition in the 21st century. The interconnect has become the nexus and cortex of technology. Conventional printed circuit boards will continue on for many applications, but the fact is that unless we plan now, the opportunities of the future will elude us. Science fiction describes many of the possibilities and alternatives that await us, but unless the engineers and managers and technicians lay the groundwork, the journey to the stars or towards energy independence or 100 other noble goals may not happen.

There has been a failure in leadership in North America. The visionaries such as Bill Hewlett and David Packard, Bob Galvin, Bob Noyce, Gordon Moore and Andy Grove who invented the opportunities for a high technology economy have been replaced by MBA's, accountants, lawyers and marketing executives.
In government, a fundamental understanding of the importance of the manufacturing process has been lost. While willing to fund basic research and development, government and academia have ignored scaling these inventions up for commercialization, where the jobs and profits to fuel the economic engine reside. Outsourcing and programs as COTS (Commercial Off The Shelf) have scaled back the fundamental understanding of the interrelationship between technology, security, quality, and cost. Without this symbiosis among all of the stakeholders, we are lost.

We are faced now with the most challenging economic environment in a generation. Our industry was fundamentally rocked by outsourcing and offshoring and if allowed to continue in its current state will eventually disappear. Today, the bulk of North American interconnect manufacturing is conventional, low margin product. Plant and equipment investment are historic lows while the technology becomes more and more sophisticated. But we have an historic opportunity. The offshore model was built on extremely high volumes with high operating rates, thin margins, and an abusive relationship between customer and vendor. The trend, however, is towards high mix/low volume and flexible response. Implementing HDI/Embedded will require significant investment and a change in the way the factory floor is run. The benefits, however, will be quickly seen in more stable business relationships, technology partnerships, and significantly improved margins and yields. We are entering a new era, and we must adapt and innovate.

Matthew Holzmann
Christopher Associates Inc.
(714) 979-7500
matt.holzmann@christopherweb.com