Precision Coating Deposition Techniques for Conformal Coating Applications

Stuart Erickson
Ultrasonic Systems, Inc.

ABSTRACT

Precise control of coating deposition is critical to the application of conformal coatings to selected areas of printed circuit board assemblies. The coating must be applied in a defined pattern and film thickness to ensure that there is adequate coating present on areas to be coated such as soldered connections and no coating on other areas such as electrical connectors. In many cases, the areas to be coated are immediately adjacent to areas where coating cannot be applied (no-coat areas). Automated coating application techniques are increasingly being utilized to replace the less controllable hand spray and dipping techniques for conformal coating application. Typical coating applicators include air-atomized spray, film coating and needle dispensing.

In recent years, automated systems have been developed for the application of coatings with the goal of eliminating the masking and de-masking process. These systems typically consist of a coating applicator for large areas, a coating applicator for small areas, a motion and positioning mechanism for the coating applicators and a system controller.

Typically spray valves or film coating applicators are used for coating the large areas on the substrate quickly to minimize the time required for coating application. However, typical large area coating applicators deposit the coating pattern with irregular edges. The coating cannot be applied close to the no-coat areas with these applicators due to the irregular edge of the coating pattern. In order to eliminate masking another applicator is required to coat the smaller areas immediately adjacent to the no-coat areas. Needle dispensing valves are typically used for coating the smaller areas.

These types of applicators have been effective in certain circumstances but do not produce a uniform coating and do not completely eliminate the requirement for masking.

Limitations of dispensing applicators include imprecise flow rate control, difficulty producing short coating line segments, heavy coating deposition at the start and end of a coating segment and susceptibility to uneven or warped substrate surfaces. The coating flow rate from a dispensing valve is set with a manual screw to adjust the stroke of a piston that is connected to a needle. The distance that the needle moves from the seat controls the effective orifice size at the nozzle tip and thus the flow rate of the coating. This manual adjustment is subjective and will necessarily produce different results each time the valve is adjusted.

The needle and seat arrangement of dispensing valves produces discontinuities as the flow starts and stops. This flow behavior coupled with the head motion profile tends to produce heavy spots at the start and end of a coating segment and makes it difficult to create a short coating segment. Programming techniques can somewhat overcome this effect, but the process can be tedious and difficult to repeat.

To apply coatings to very small areas or in straight lines with a dispensing valve, an external dispensing needle is required. To achieve optimal results, the outlet of the needle must be very close to the substrate, typically within 1 mm. If the substrate is uneven or slightly warped coating skips may result due to the changing distance between the needle and substrate. Additionally, the needle has a tendency to contact previously applied coating and pull it along with it causing skips and smears. The needle is also subject to being damaged if it comes into contact with the substrate.

An automated method for the precise application of conformal coatings has been developed that utilizes the combination of a dual mode “nozzle-less” ultrasonic spray head, a precision digital dispensing head and a precision X-Y-Z-θ-$\varnothing$ motion control platform. The ultrasonic spray head uses ultrasonic energy to break the liquid into small drops to form the spray, but the liquid does not pass through the ultrasonic device. The liquid is applied externally, to a solid surface, vibrating at an ultrasonic frequency (> 20 kHz). Directed air streams are used to expand or focus the ultrasonically produced spray, providing two distinct spray patterns: 1) narrow mode with a pattern width of approximately 5 mm at a distance of 25 mm between the tip of the head and the substrate and 2) wide mode with a pattern width in the range of 3 to 25 mm, proportional to the distance between the tip of the head and the substrate. The digital dispensing head uses a micro flow solenoid valve and a streaming nozzle that produces a pattern width of 1 mm from a distance of 5 mm to 15 mm between the nozzle and the substrate.

This paper considers a particular advancement in precision application of conformal coating using the combination of *Ultra-Spray* technology with integrated fluid delivery applicator, the Micro-Line digital dispensing head and precision X-Y-Z-θ-∅ motion control platform.

Key words: spray coating, conformal coating, ultrasonic spray, printed circuit board assemblies, selective coating.

ULTRA-SPRAY HEAD WITH INTEGRATED LIQUID DELIVERY SYSTEM

This spray head with integrated liquid delivery system consists of an ultrasonic transducer with a spray forming tip, an ultrasonic generator, a precision liquid delivery system, a liquid applicator and air directors.

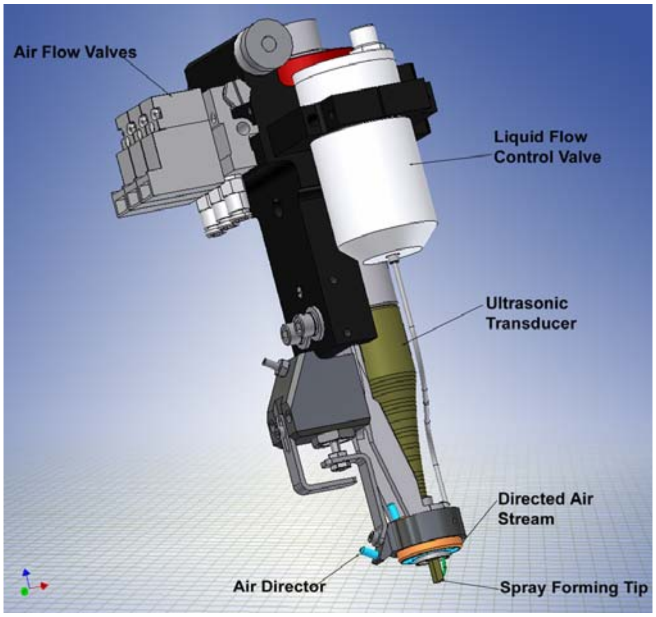


Figure 1 - The key components of the dual-mode ultrasonic spray head are indicated.

The ultrasonic transducer contains a spray-forming tip that vibrates at an ultrasonic frequency (>20 kHz). The transducer is resonant at an ultrasonic frequency that is optimal for atomizing coatings and is driven by an ultrasonic generator with a corresponding frequency. The amplitude of vibration for the spray-forming tip is also set with the ultrasonic generator. The amplitude is adjusted for the coating material and maximum flow rate. Some coating materials require a greater amplitude or more ultrasonic energy to properly atomize and some materials require less. The ultrasonic frequency and amplitude are analogous to a loudspeaker producing a single note. The frequency is the pitch of the note and the amplitude is the volume of the note. In general for conformal coatings an ultrasonic frequency of 35 kHz is optimal and the amplitude is adjusted to accommodate the coating material and required flow rate range.

The coating liquid is delivered to the spray-forming tip on the ultrasonic transducer with an external liquid applicator. The liquid is stored in a pressurized reservoir is fed to the liquid applicator through a rapidly pulsing micro solenoid valve. The pulsing solenoid valve meters the flow precisely to the spray-forming tip. A drive circuit operates the valve to set the liquid flow rate. The ultrasonic vibrations of the spray-forming tip break up the liquid into small drops and propel them from the tip in the form of a spray. The spray produced with ultrasonic energy alone has a very low velocity and does not form a well-defined pattern.

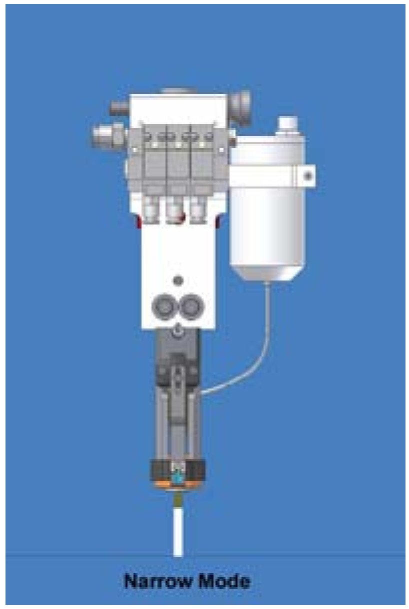


Figure2 - The operation of narrow spray mode is illustrated. The narrow spray mode is activated by directing the air stream through the "air-ring" to entrain the ultrasonically produced spray, producing a narrow coating deposition.

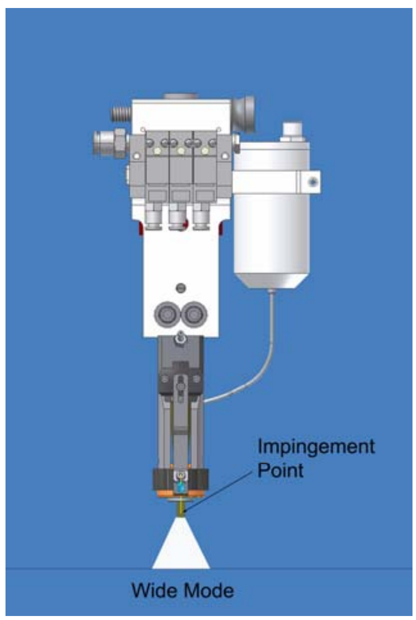


Figure 3 - The operation of wide spray mode is illustrated. The wide spray mode is activated by directing the air stream through the air director onto the surface of the spray-forming tip producing a flat rectangular coating deposition.

Air directors are used to produce air streams to shape and accelerate the ultrasonically produced spray. Two distinct spray patterns are produced with the directed air streams: narrow mode and wide mode. The narrow mode is produced with an "air ring" which entrains the spray and produces a conical pattern approximately 5 mm wide. The 5 mm narrow mode spray pattern is produced when the spray head tip is approximately 25 to 35 mm above the substrate. The edges of the coating pattern in narrow mode are very sharp on the order of +/- 1 mm. The wide mode is produced by impinging a jet of air on the face of the spray-forming tip opposite to the liquid delivery side. The wide mode pattern is a flat, rectangular pattern from 3 mm to 25 mm wide. The width of the spray pattern is proportional to the height of the spray-forming tip above the substrate. At a height of approximately 5 mm, the pattern width is about 3 mm and at a height of about 25 mm the pattern width is about 25 mm. The edges of the spray pattern tend to "feather" as the height is increased and are very sharp at closer heights.

All process parameters for the system are set electronically including liquid flow rate, air pressure, spray mode (wide or narrow), head height and head speed. The ability to set the liquid flow rate electronically eliminates the subjectivity and lack of repeatability associated with the needle in seat arrangement of spray and dispensing valves. Additionally, the ability to set all process parameters electronically enables complete software control of the spray pattern and the amount of coating applied for each individual coating segment. The head is capable of applying a very accurate 5 mm pattern width from 25 to 35 mm above the substrate. This allows coating between tall components without applying the coating to the sides of the components. The head can also switch from narrow mode and wide mode to coat larger areas quickly and simultaneously increase the flow rate to maintain the desired coating thickness independent of the pattern width.

MICRO LINE DIGITAL DISPENSING HEAD

This digital dispensing head consists of a pulsing micro solenoid valve a drive circuit and a streaming nozzle.

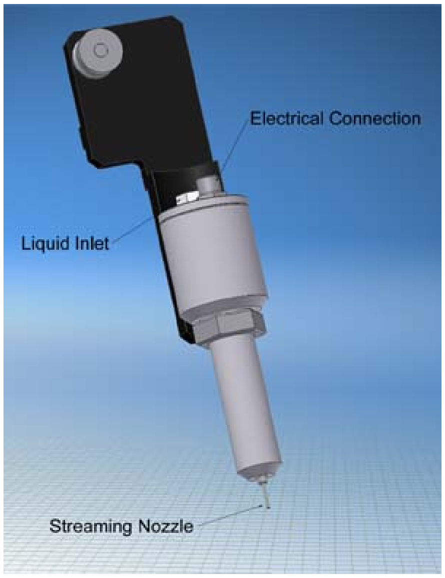


Figure 4 - The key components of the digital dispensing head are illustrated.

The streaming nozzle consists of a stainless steel tube approximately 25 mm long with a very small orifice in the end, approximately 0.2 mm in diameter. When liquid is fed through the nozzle it produces a micro stream that is stable up to a distance of approximately 15 mm from the nozzle tip.

The coating liquid is delivered to the streaming nozzle from a pressurized reservoir through a rapidly pulsing micro solenoid valve. The valve used in the digital dispensing head is similar to the valve used in the ultrasonic spray head and utilizes a similar drive circuit. For any particular conformal coating there is a minimum pressure and flow rate that must be achieved so that the nozzle will produce a stable stream.

The head is capable of applying coating patterns to very small areas in the form of very small dots and narrow lines from a width of 1 mm to about 3 mm. The distance between the nozzle tip and the substrate can be from 1 mm to 15 mm.

All process parameters for the digital dispensing head are set electronically including flow rate, nozzle height and head speed.

COMBINATION OF SPRAY HEADS

The unique combination provides unprecedented coating capability and flexibility. The dual mode ultrasonic head is used to coat the larger areas of a circuit board assembly quickly and efficiently and the smaller system is used to coat the smaller areas down to 1 mm^2.

Both heads can apply coatings with the same low viscosity formula. Therefore they can both be fed from a common coating liquid supply. This avoids the need to have a separate liquid delivery system for the spray valve and dispensing valve that is typical of conventional spray and dispensing techniques in which it is necessary to use a higher viscosity coating mixture for the dispensing valve to minimize coating flow out for the dispensed areas. Additionally, it is very difficult to achieve a uniform coating thickness between the sprayed and dispensed areas using conventional technology.

The combination of the dual mode ultrasonic head and digital dispensing valve enables a much more uniform coating thickness to be achieved between the sprayed areas and dispensed areas. This is due to the use of the same coating to solvent mixture for both heads and the ability of the system to precisely dispense small amounts of coating to selected areas of the substrate.

MOTION AND POSITIONING PLATFORM

The dual system is mounted on a precision X-Y-Z-θ motion and positioning system. A toggle mechanism adjusts the relative Z-height with respect to the ultrasonic spray head. When the ultrasonic head is activated, it is in the "up position", which prevents potential interference with components on the board during spraying operations. When the system is activated, it is toggled to the "down position" so that it is at a lower Z-height relative to the ultrasonic spray head. This prevents potential interference between the tip of the ultrasonic head and components on the board during dispensing operations. The system can also be tilted to allow coatings to be dispensed on the sides or under certain components. Both heads can also be rotated about Z-axis to change the orientation of the ultrasonic head or the tilt direction of the valve. Alternatively, the ultrasonic head can be fitted with a 90-degree rotate mechanism to quickly change the orientation of the head. This is useful in applications that require a short cycle time. The ultrasonic head can then be oriented such that it can operate in wide mode in both the X and Y directions without the need to rotate both heads.

The system is controlled with a Windows XP based operating system utilizing an integrated PCI motion controller. A graphical user interface (GUI) is used to set all operating parameters and create process programs.
The GUI employs a graphical image of the Prism system with "hot spots" for each subsystem. The system operator uses a trackball to highlight each hot spot and bring up a window to setup or configure each subsystem. Hotspot windows include the X-Y-Z-θ-∅ system, the coating head setup, conveyor setup, and program recipe.

The X-Y-Z-θ-∅ system window allows the heads to be moved manually with the trackball anywhere throughout the range of motion within the system.

The coating head setup window allows all parameters of each coating head to be manually activated. This is primarily used for the initial setup of each coating head and to ensure that the coating heads are functioning properly.

The conveyor window is used to set the operating parameters of the conveyor for automatic (SMEMA mode) operation as well as to test the various conveyor functions.

The program recipe window is used to develop a coating recipe for a specific circuit board assembly. "Teaching" the coat areas with simple point and click operation creates the program recipe.

Creating a Coating Recipe

A program recipe is created by teaching the coat areas by a point and click operation using a laser pointer that is located between the coating heads on the mounting mechanism. Coating commands include Line, Multi-Line, Dot, Move, Arc / Circle, Fill, Step and Repeat and Rotate. Each command creates a line or lines in the coating program recipe.

Line – a line is created by moving the laser pointer to start and end points for the line on the board assembly and clicking the mouse button at each point.

Multi-Line – the multi-line command is used to generate multiple line segments that are connected so that the motion of the coating head is continuous from line to line. This is used to reduce cycle time and to produce smooth transitions between line segments.

Dot – a dot is created by moving the laser pointer to the location on the board assembly for the dot and clicking the mouse button.

Move – the move operates similar to the line command, but does not generate a coat command. The head is moved from the start point to the end point without applying coating.

Arc / Circle – the arc / circle command creates an arc or circle on the board assembly by clicking on three points on the arc or circle to be created.

Fill – the fill command creates a series of coat commands for a rectangular area on the board assembly. The fill command is very powerful since it can generate both coat and no-coat areas within a defined rectangular area on the board assembly. It can be used to quickly produce a coating program to coat a large section of a board assembly.

Basic Fill - the basic fill instruction creates a series of coat commands to coat a rectangular area on the circuit board assembly. The operator defines the width of the spray pattern and the direction of the coating segments, and then clicks on the two corners of the rectangular area to be coated. The fill command then generates the series of coat commands to coat the selected area based upon the above user-defined parameters.

Fill with Continuous Motion - the fill with continuous motion is created in the same manner as the basic fill instruction. When the continuous motion box is checked, the coating head moves continuously in a "serpentine" pattern when executing the fill routine. This creates a smoother coating pattern and reduces the cycle time for coating the selected area.

Fill with No-coat Areas - the fill with no-coat areas enables selected areas within the fill pattern not to be coated. The basic fill area is selected with the same procedure as the basic fill command. However, multiple areas within the fill area can be selected as no-coat areas. The result is a series of coat commands and no coat commands that cover the selected fill area.

Step and Repeat – the step and repeat function enables a section of a coating recipe to be copied and recreated at a different location. This is ideal for board assemblies with multiple identical coating areas or multiple board assemblies mounted n a fixture or pallet.

Rotate – the rotate function allows a section of the coating recipe to be copied and rotated. This is ideal for boards mounted on a fixture or pallet and arranged in different orientations.

Off-Line Recipe Creation

The coating recipe can also be generated "offline" by using a portable GUI that is installed on another computer.

An image of the board to be coated is imported into the GUI. The image can be a photograph of the board of a drawing of the board. The image is scaled to set the dimensions in the recipe to correspond to the actual board dimensions. The coating recipe is produced using the above commands by pointing and clicking on the board image with the computer mouse.

Coat Command Structure

The coating recipe consists of a series of "coat commands". Each coat command contains the following information:

- Start Point
- End Point
- Coating Height
- Coating Flow Rate
- Air pressure
- Head Select
- Wide Mode or Narrow Mode
- Rotation angle
- Tilt Position
- Etc.

The coating recipe is stored in the computer in the form of an editable "spread sheet". The recipe can be easily edited offline to change data or the order of the coat commands.

PERFORMANCE CHARACTERISTICS

The coating patterns, produced with the dual mode ultrasonic head and Micro Line digital dispensing valve, are characterized below.

Dual Mode Ultrasonic Spray Head

The dual mode ultrasonic spray head operates in narrow mode and wide mode.

- Narrow Mode – the spray head produces a 5 mm wide coating deposition at a coating height of 25 to 35 mm between the spray head tip and the substrate. As shown in the figure, the edges of the coating pattern are well defined on the order of ± 1 mm. The narrow mode is primarily used to coat areas of the circuit assembly in which tall components prevent the head from being positioned close to the board.

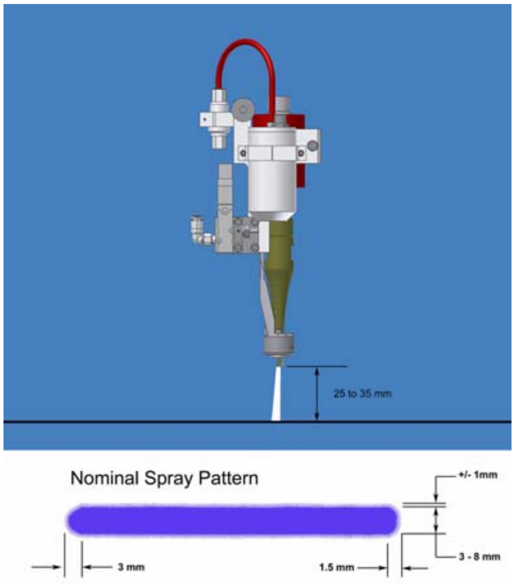


Figure 5 - The nominal spray pattern produced for the narrow spray mode is illustrated.

- Wide Mode – the spray head produces a pattern width proportional to the coating height. The coating pattern produced at a 5 mm height between the tip of the spray head and the substrate is approximately 3 mm. The coating pattern width increases as the coating height increases. However, the edges of the coating pattern have more variation and have a “feathered appearance.

Digital Dispensing Valve
The coating patterns produced with the digital dispensing valve are characterized below.

The system produces a 1 to 3 mm coating pattern from a height of 5 to 15 mm between the nozzle tip and the substrate. The width of the coating pattern is proportional to the coating flow rate and head speed. A narrower pattern is produced using a lower flow rate and faster head speed.

Examples of Challenging Coating Applications
A few examples of challenging “real world” coating applications are described below.

- Miniature Connectors – the requirement is to apply coating to only the leads of miniature connectors without coating flowing into the connector. The challenge is to apply only enough coating to protect the leads of the connector; excess coating will flow into the connector making it unusable. The Micro Line digital dispensing valve is used to successfully apply coating only to the connector leads.

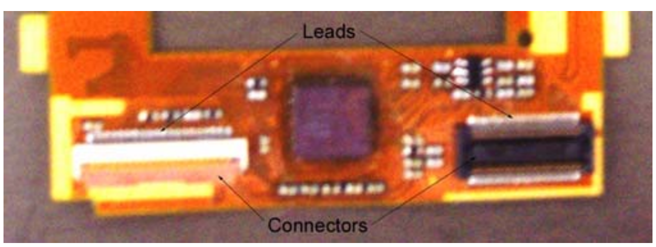


Figure 6 - An example of miniature connectors is shown. In this case the soldered leads require coating and the coating must not flow or wick into the leads of the connectors. The digital dispensing head is capable of applying the coating only to the soldered connectors.

- Water-Based Coatings – water-based coatings present coating application challenges since they must be applied in a thin film of 50 to 150 microns to facilitate proper curing. If these coatings are applied in too thick of a film, cracking may occur during the curing process. The cracking is caused by the top layer of the film curing first and forming a skin inhibiting evaporation of the water solvent carrier in the lower layers of the coating film. The dual mode ultrasonic head is capable of spraying the new water-based coating formulations and applying a coating at the required coating thickness for optimal curing.

- Complex Assemblies – some circuit board assemblies have complex layouts with very small areas to be coated, such as areas between connectors or areas near a ground plane or connection. The system can apply coatings to very small areas without coating flow-out or overspray.

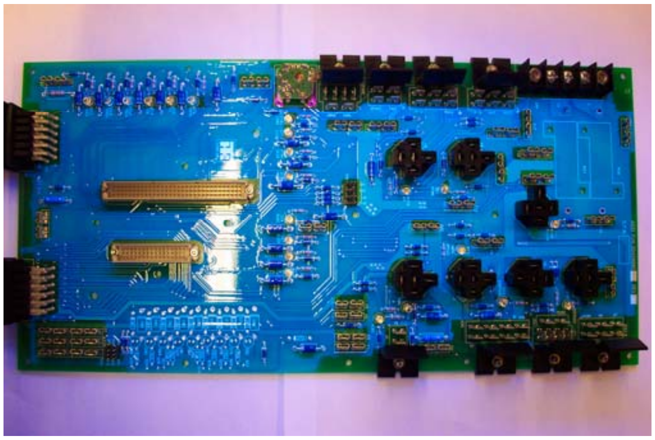


Figure7 - A coated board assembly with many very small keep out areas is shown. This assembly was coating using a combination of the dual mode ultrasonic head and digital dispensing head with no masking required,

- Combination Assembly (large and small coat areas) – many board assemblies have a combination of larger and smaller areas to be coated. However, the coating must be of uniform thickness for all areas of the assembly.

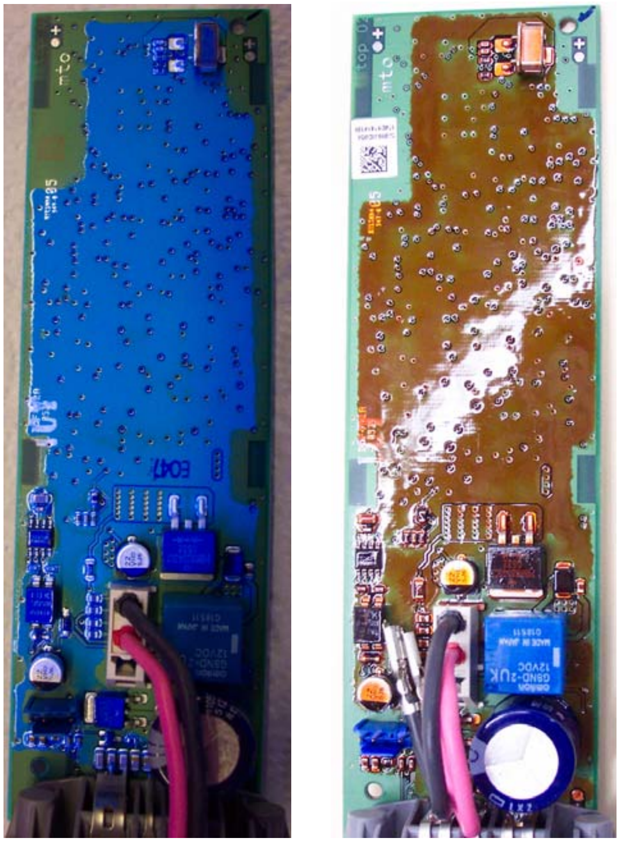


Figure 8 - The board on the left is coated board using a combination of the dual mode ultrasonic head and digital dispensing valve without using masking. The board on the right was coated using masking.

CONCLUSION

As circuit board assemblies become smaller, more complex and are placed in more hostile environments, the requirement for protective coatings increases. Correspondingly, more precise methods for the application of the protective coatings are required. The combination of the dual mode ultrasonic spray head, digital dispensing valve and precision X-Y-Z-θ-∅ head motion and positioning platform is a significant improvement over conventional spray and dispensing techniques.

Asian Experiences & Trends

J. S. Erickson
DuPont Electronic Technologies
Research Triangle Park, NC.

The miracles of science™

Expert-

Someone that has made lots of mistakes

but been around long enough to learn from them.

Background

-I've made lots of mistakes

-Worked for DuPont for 30 years- been around long enough (?)

-Had P&L responsibilities +15 years for a number of businesses

-Start-up team for a JV in Europe +20 years ago

-Involved with an early China JV +15 years ago

-Formed a JV in Japan +10 years ago

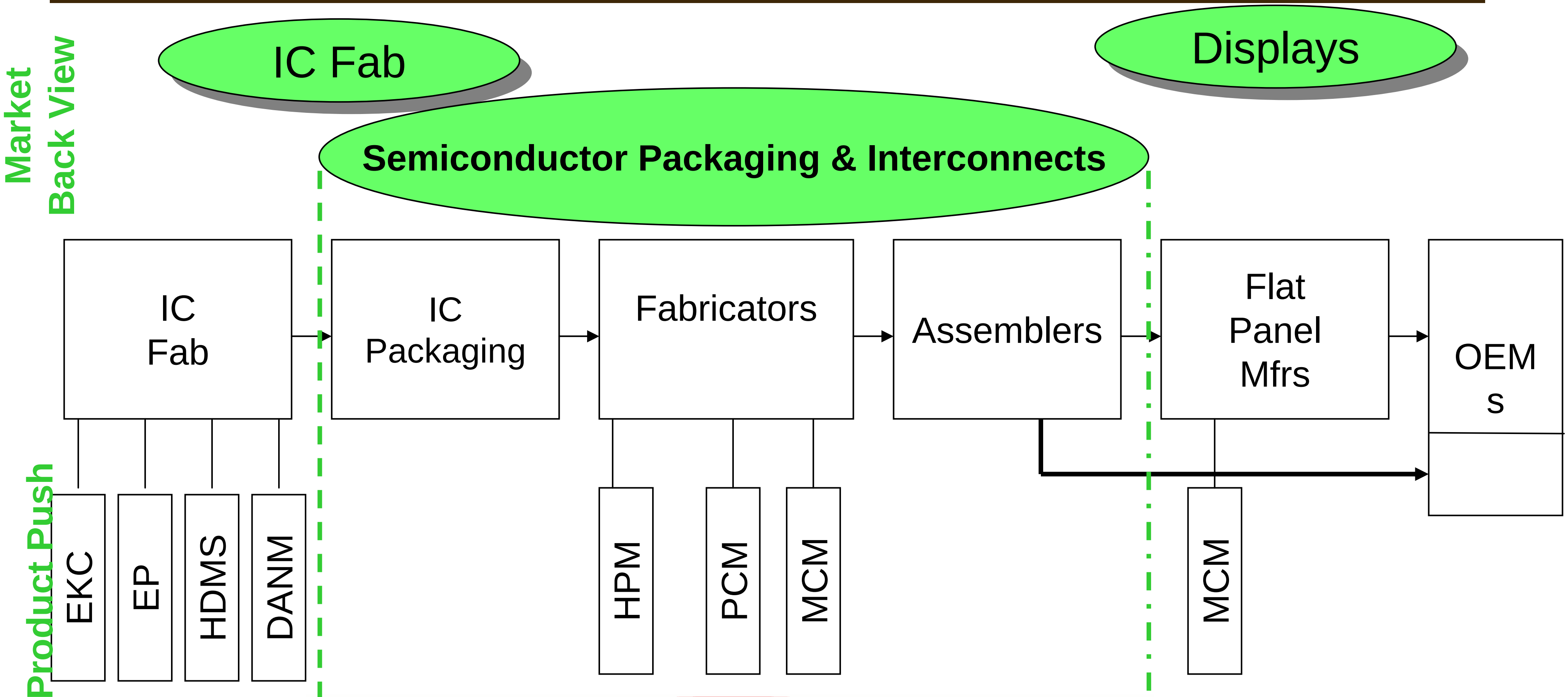
-Formed a JV in Taiwan +5 years ago

-Formed a JV in Korea +2 years ago

-Board Member/Managed 2 other JV in Japan

- Large JV in Japan +25 years old
- Marketing Company

Improve "Market Back Focus" created "Domains"



"Big" DuPont

Back to the future

-**Start-up team for a JV in Europe +20 years ago- Sold to third party**

-**Involved with an early China JV +10 years ago – DuPont acquired 100%**

-**Formed a JV in Japan +8 years ago - Doing very well**

-**Formed a JV in Taiwan +5 years ago - DuPont acquired 100%**

Formed a JV in Korea +2 years ago - Early

-**Board Member/Managed 2 other JV in Japan**

- Large JV in Japan +25 years old - **Very successful but lots of effort**
- Marketing Company

DuPont's view on JV's

-Last alternative - track record internally and externally is not good

-Very structured approach –high hurdle

-Evaluate every other alternative

-Form a cross function team with corporate M&A and Legal

-Internal JV Training Seminar

-Heavy due diligence

-Must have "divorce clauses" negotiated

-Must be assured the JV will meet DuPont Core Principles

Experience with a Chinese JV

-**We had to have a partnership to go in – 2 partners**

-**We build a world class facility – 3 Questions!**

-**Choice the technology we put in carefully- finishing only**

-**Did the A+B strategy to protect our technology**

-**Today the company is a solid success**

- Business is not close to the original marketing plan
- Hire solid local people – all in functions
- Good Asian support base
- Started with a large shell with minimum equipment – highly flexible
- Establish both a solid domestic and export business

-**Why did we buy the partners out – “expectations were not the same”**

How do culture differences play (my view)?

-**First corporate cultures differences are large!**

-**Taiwanese/Chinese**

- Very financially driven
- Don’t care too much about the “divorce clause”

-**Korean**

- Very aggressive negotiators
- Don’t want the “divorce clause”

-**Japanese**

- still to this day have a longer term view and are very detailed
- “divorce clause” concept is accepted

Ideal Flow

-Date a while – Marketing Agreements, JDA, etc

-Acquire if possible

-Build solid understanding and relationship

-Determine if the “cultures” can align (more corporate cultures)

-Clear and “aligned” expectations

-Solid “divorce clauses” and “conflict resolution” clauses

Trends

1. Geographical – China

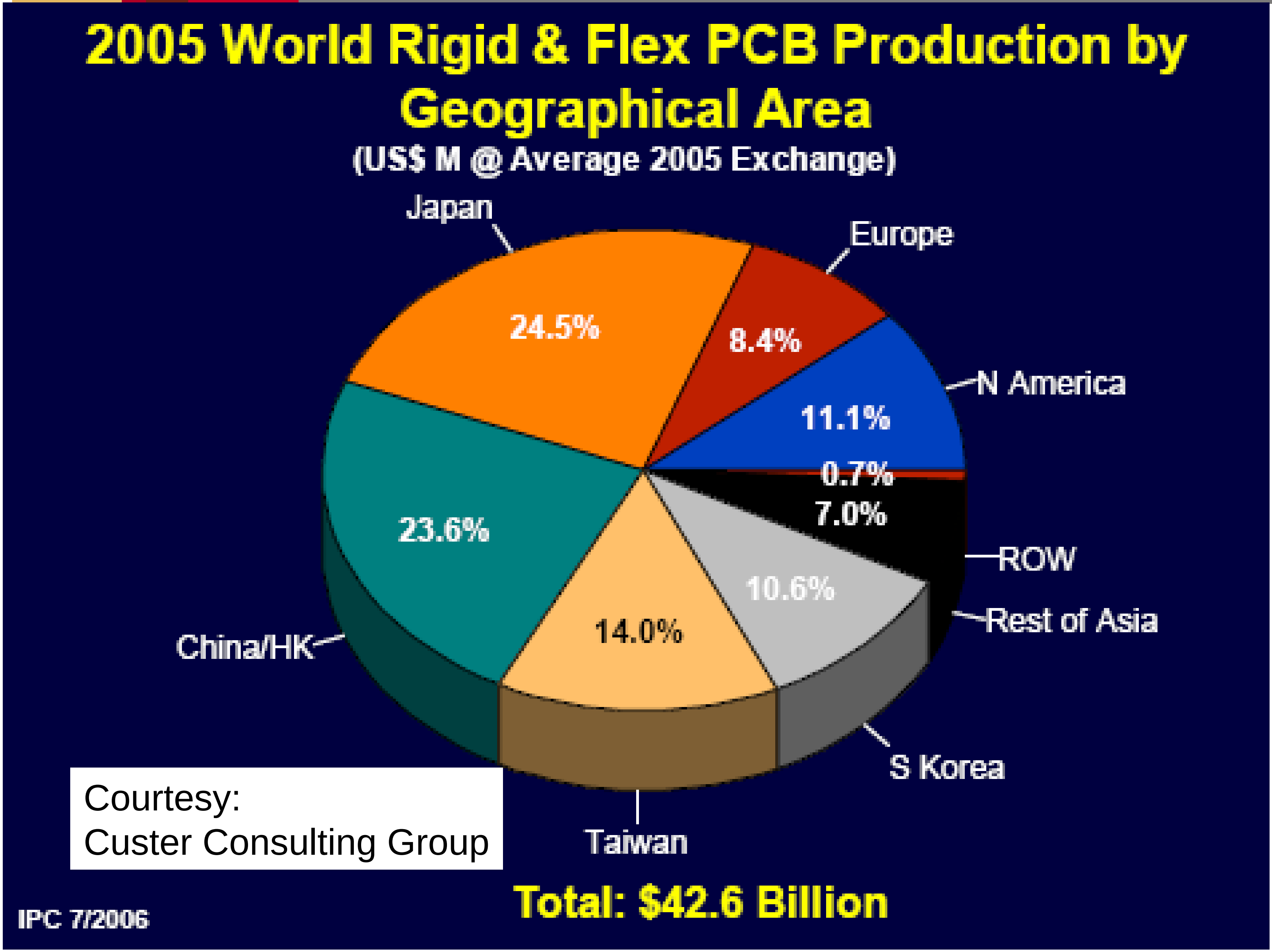
Beijing
- Software Development
- IC Design
- Telecom Expertise

Shanghai
- IC Manufacturing
- IC Foundries
- ODM Manufacturing
- EMS Manufacturing

Fujian
- General Manufacturing

Taiwan
- Software Development
- IC Design
- IC Foundries
- IC Manufacturing
- ODM Production

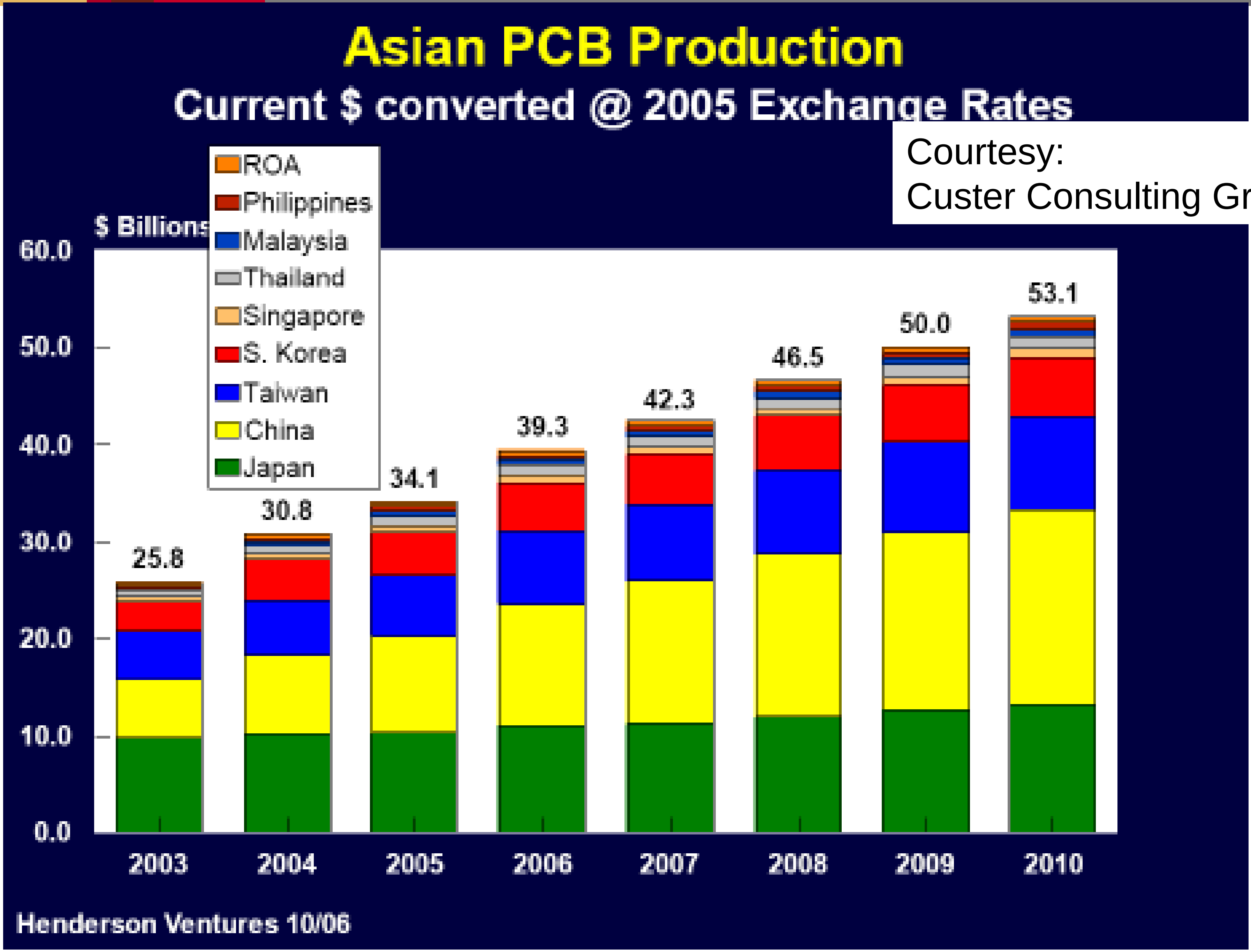
Guangdong
- EMS Production
- ODM Production
- Other PCB Assembly and System Builds



2005 World Rigid & Flex PCB Production by Geographical Area
(US$ M @ Average 2005 Exchange)
Japan
Europe
N America
ROW
Rest of Asia
S Korea
Taiwan
China/HK
24.5%
8.4%
11.1%
0.7%
7.0%
10.6%
14.0%
23.6%
Courtesy:
Custer Consulting Group
IPC 7/2006
Total: $42.6 Billion

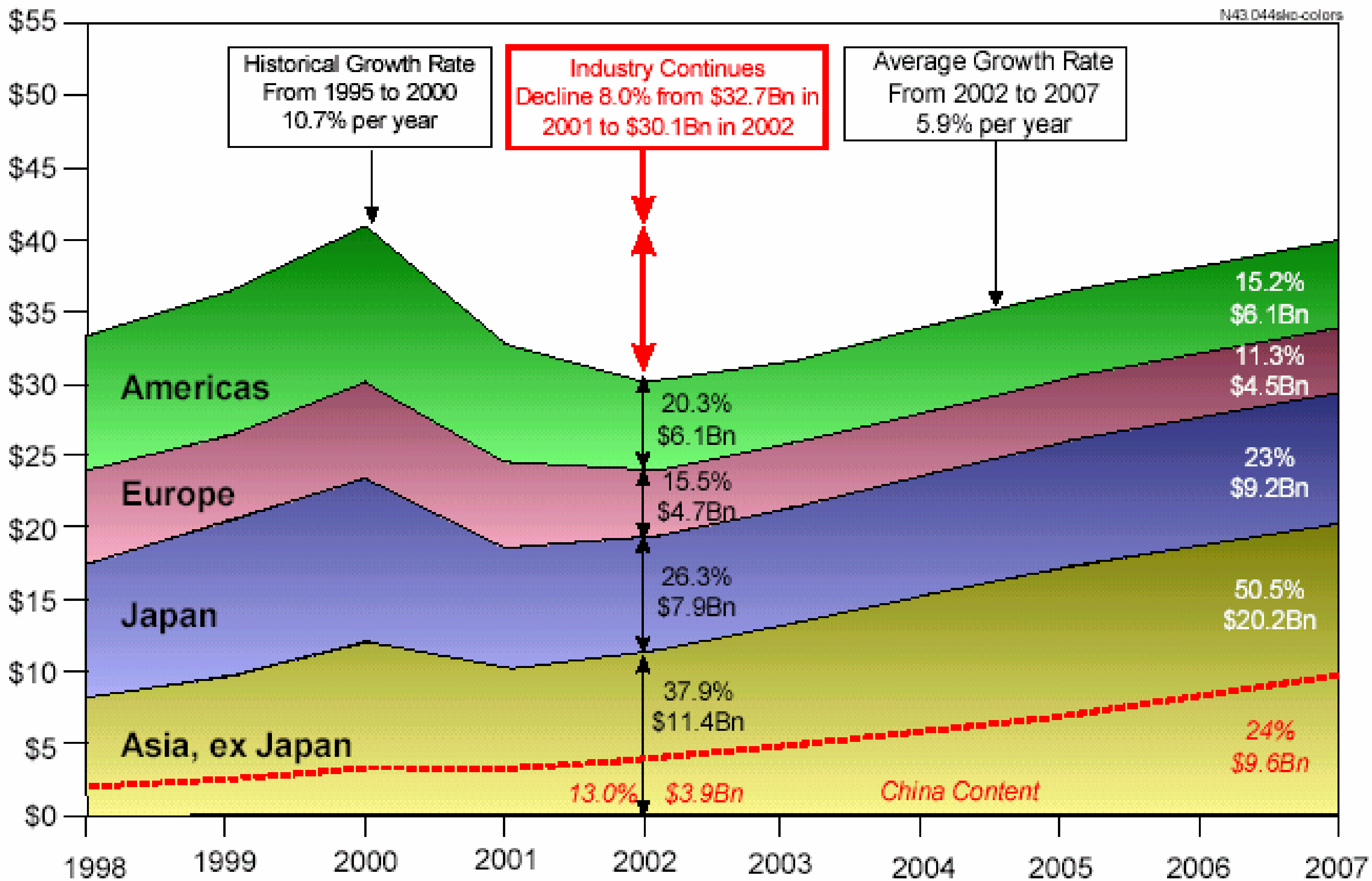
Trends - China

1. My believe is in 2006 China became the #1 producer- bulk of the commodity boards, majority of multi-layers and lion share of “standard flex”.



Courtesy:
Custer Consulting Group

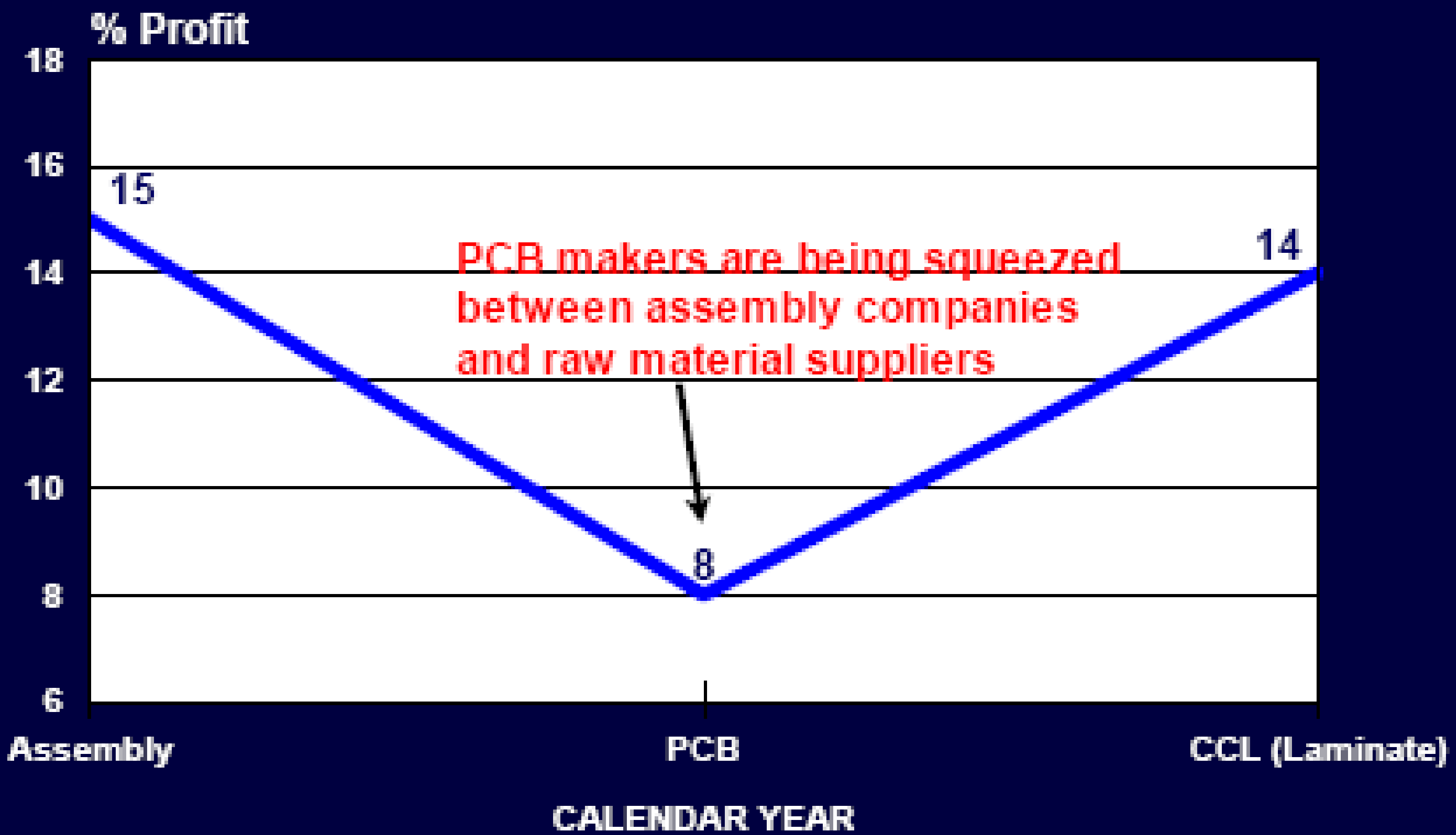
RECENT HISTORY AND OUTLOOK FOR THE GLOBAL PRINTED CIRCUIT INDUSTRY



Courtesy: Prismark Partners

China PCB "Food Chain" Profit 2004

Courtesy:
Custer Consulting Group



CPCA6/2005

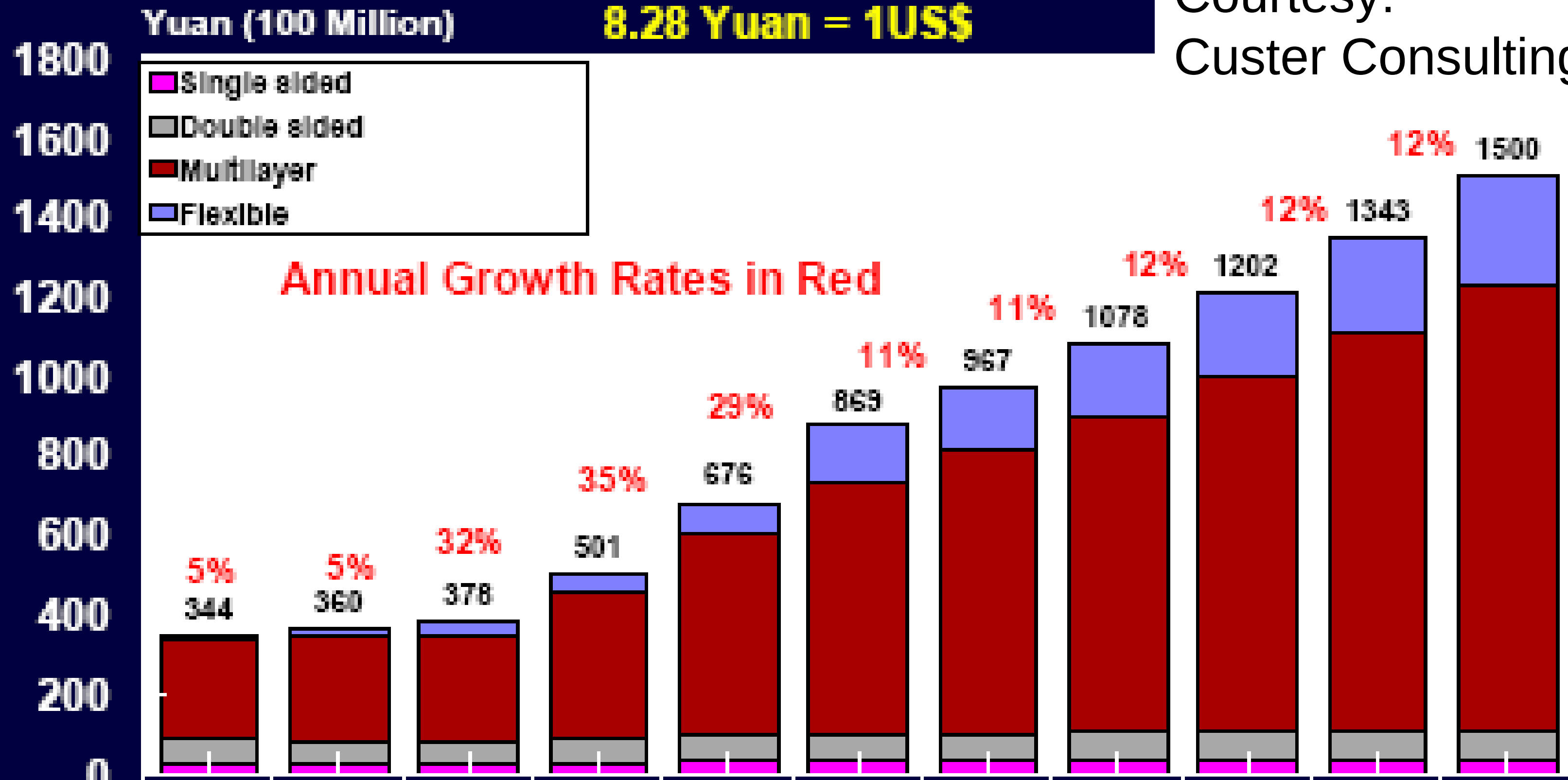
Trends - China

1. My believe is in 2006 China became the #1 producer- bulk of the commodity boards, majority of multi-layers and lion share of “standard flex”.

2. **China has had a stronger backward integration into materials then recognized– Nanya PCB is a good example.**

Chinese PCB Industry Production

Courtesy:
Custer Consulting Group



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Flexible	10	18	30	51	82	136	156	180	207	238	273
Multilayer	252	265	271	366	502	637	713	799	895	1002	1122
Double sided	59	56	57	61	67	69	71	72	74	75	77
Single sided	22	21	20	22	25	26	27	27	27	27	28

CPCA 6/05

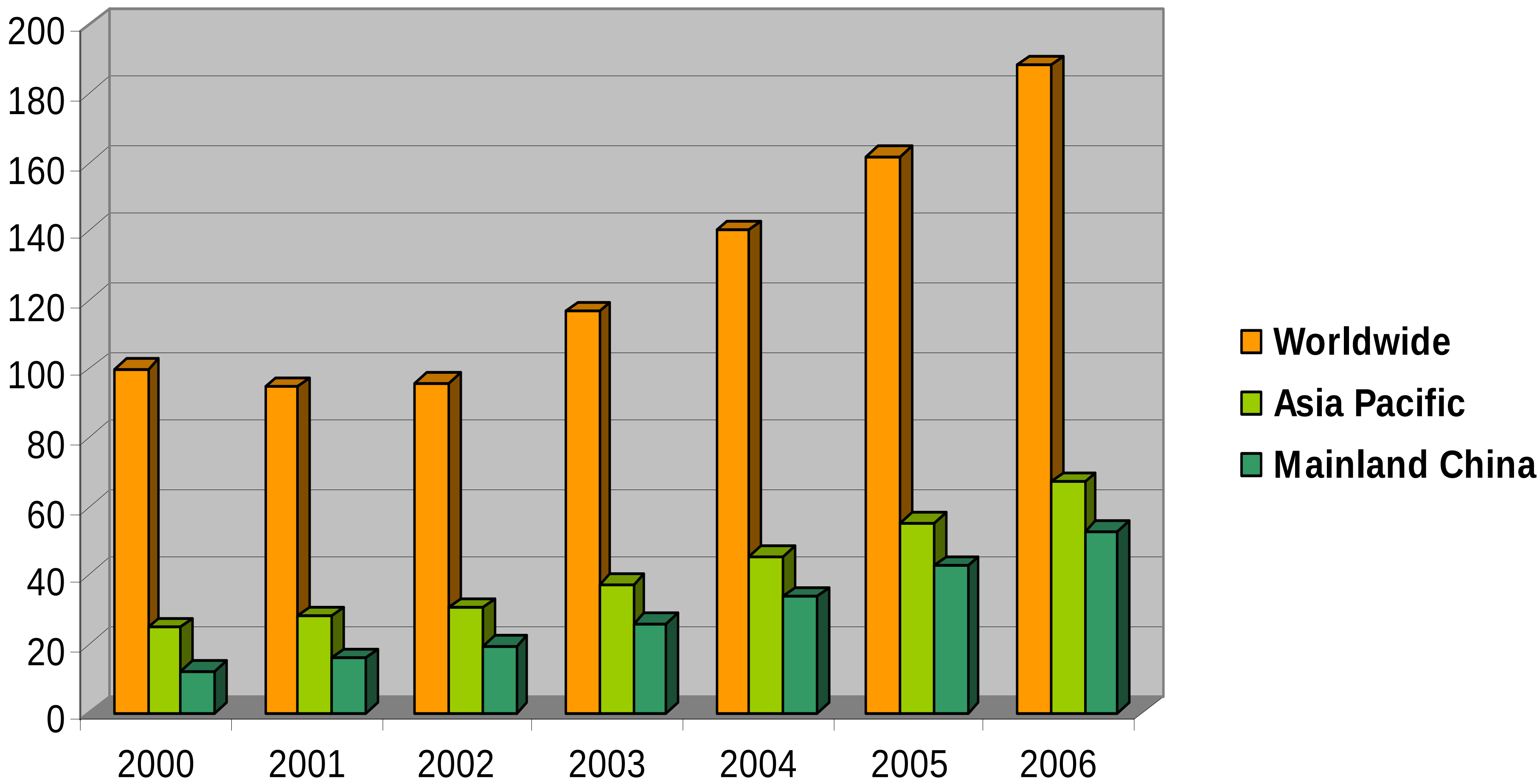
Trends - China

1. My believe is in 2006 China became the #1 producer- bulk of the commodity boards, majority of multi-layers and lion share of “standard flex”.
2. China has had a stronger backward integration into materials then recognized– Nan Ya good example.
3. **China will have a couple years continued strong growth and then flatten shift to other higher growth lower cost countries.**

Source:

iSuppli Corp.

Worldwide, Asia-Pacific and China EMS Production Historic Trends



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WHERE DOES A RATIONAL ELECTRONICS INDUSTRY GO FOR MANUFACTURING?

	China	Brazil	Thailand	Philippines	Turkey	Russia	Vietnam	India
A plentiful supply of low cost motivated labor	✔ (red)	✔ (red)	✔	✔	✔	✔	✔	✔ (red)
An agglomeration of skills to form a critical mass	✔ (red)	□	✔	✔	O	O	□	□
A large and growing market with distribution access	✔ (red)	O	O	✔	O	O	O	O
A trade and financial crossroads and fertile ground for entrepreneurs	✔ (red)	O	✔	✔	O	O	□	✔
A political climate that favors growth of an industry, but does not stand in its way	✔ (red)	□	✔	✔	✔	✔	O	□

Legend:

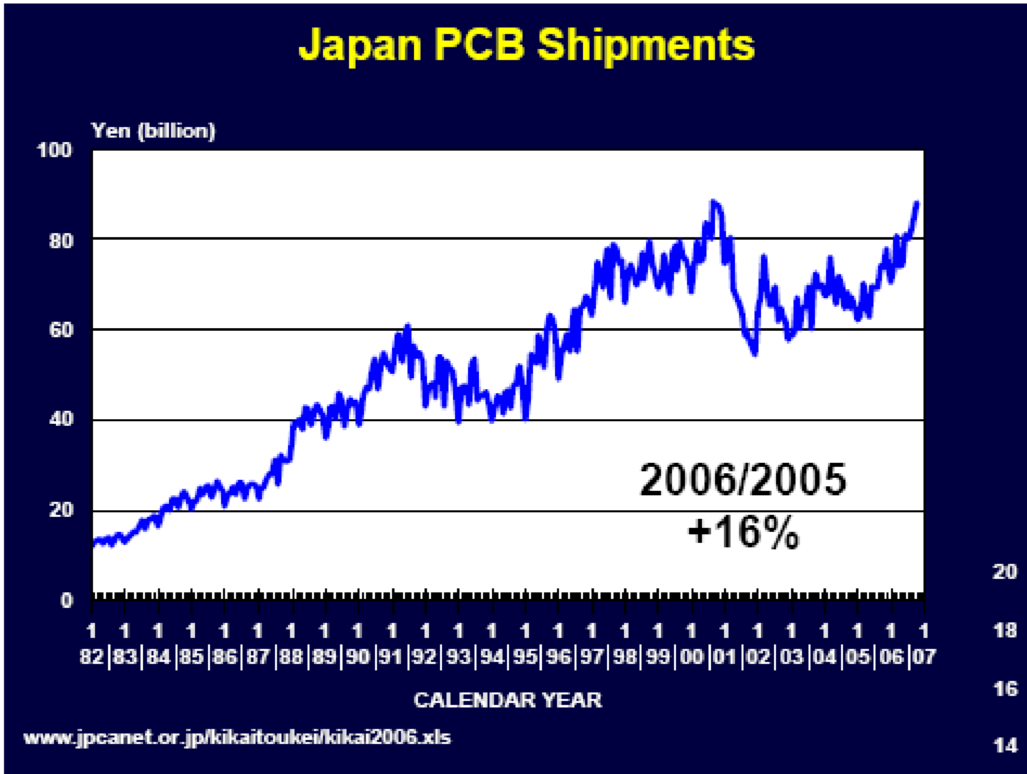
- ✔ (red) Significant Presence
- ✔ Present
- O Partial Presence
- □ Absent

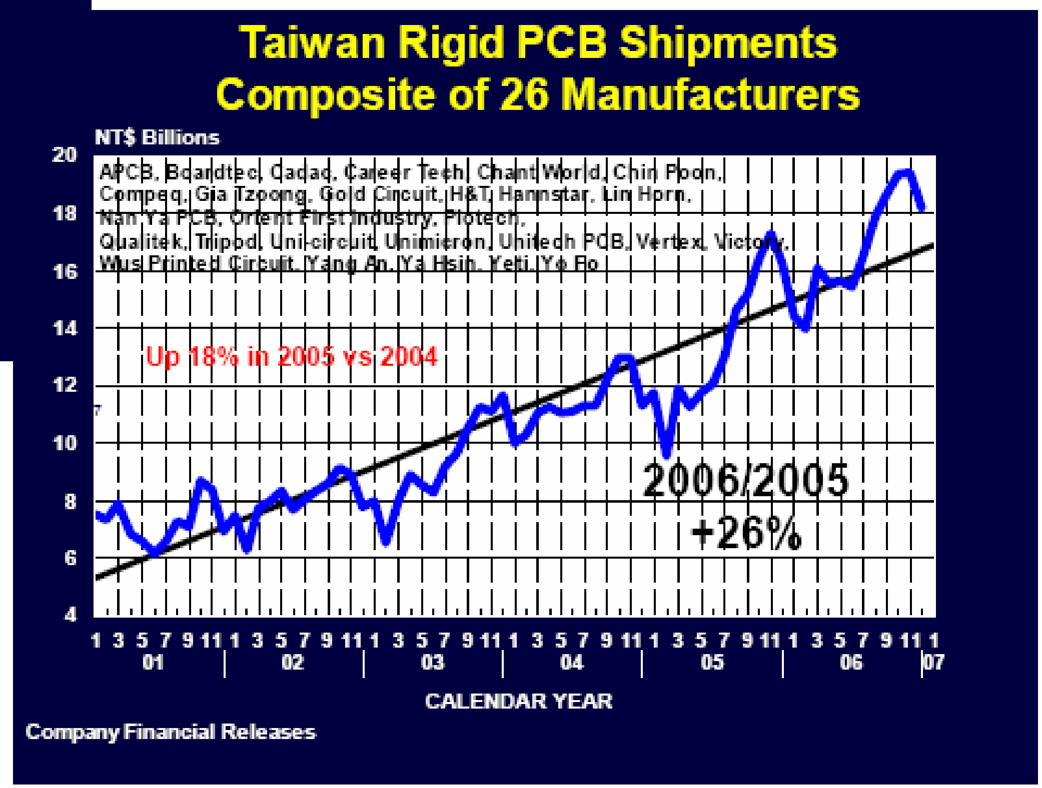
PRISMARK PARTNERS LLC

Courtesy: Prismark Partners

Story of Asia China Only – No!

Story of Asia China Only – No!



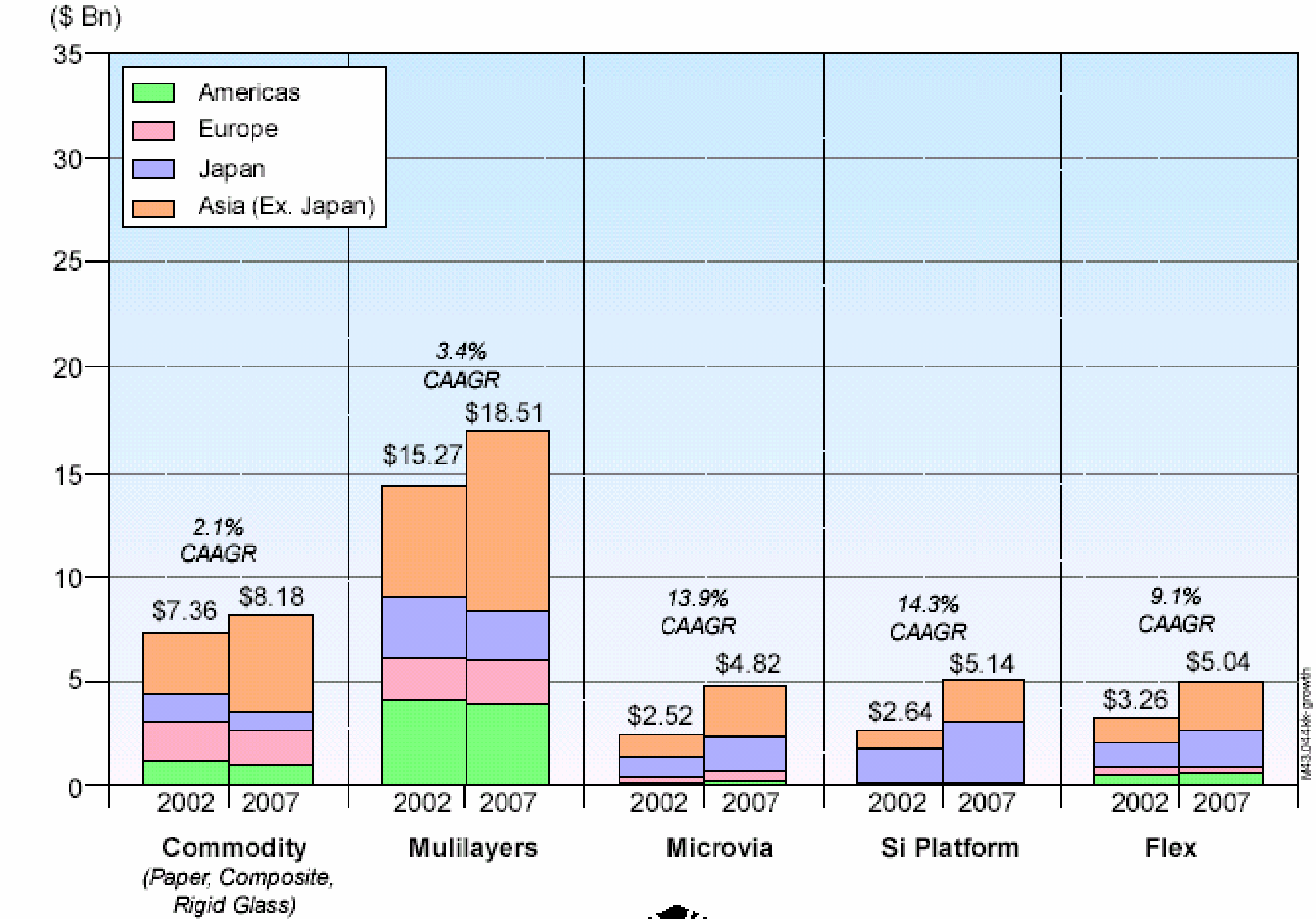


Courtesy:
Custer Consulting Group

Technology Leadership

- Japan continues to be the technology leader
- Taiwanese are very fast followers
- Focus for both has shifted to HDI, IC Packaging and Flex

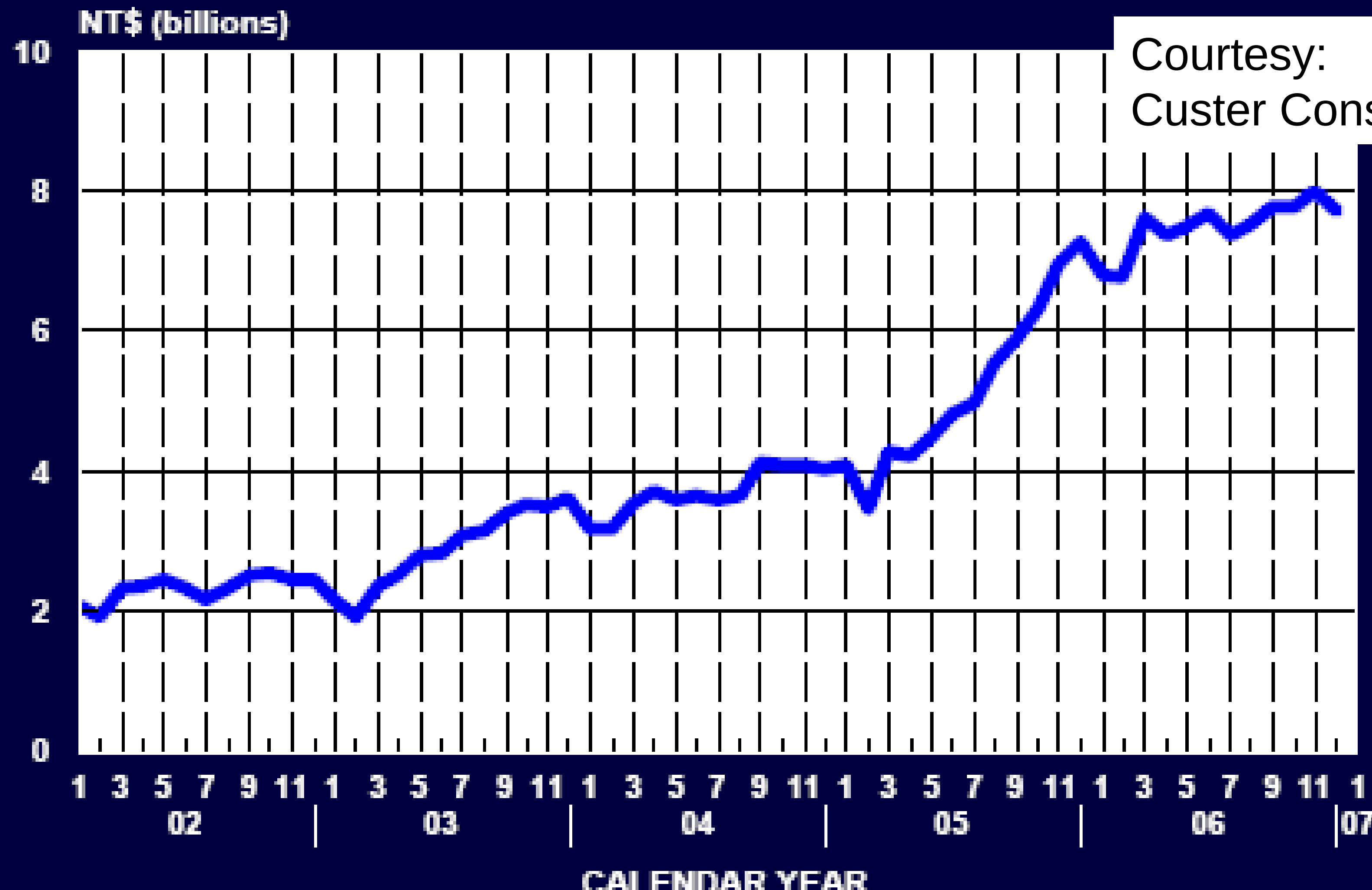
2002/2007 PCB MARKET PROFILES GROWTH



Courtesy: Prismark Partners

Taiwan Flip Chip Substrate Producers
Composite of 4 Manufacturers

Courtesy:
Custer Consulting Group

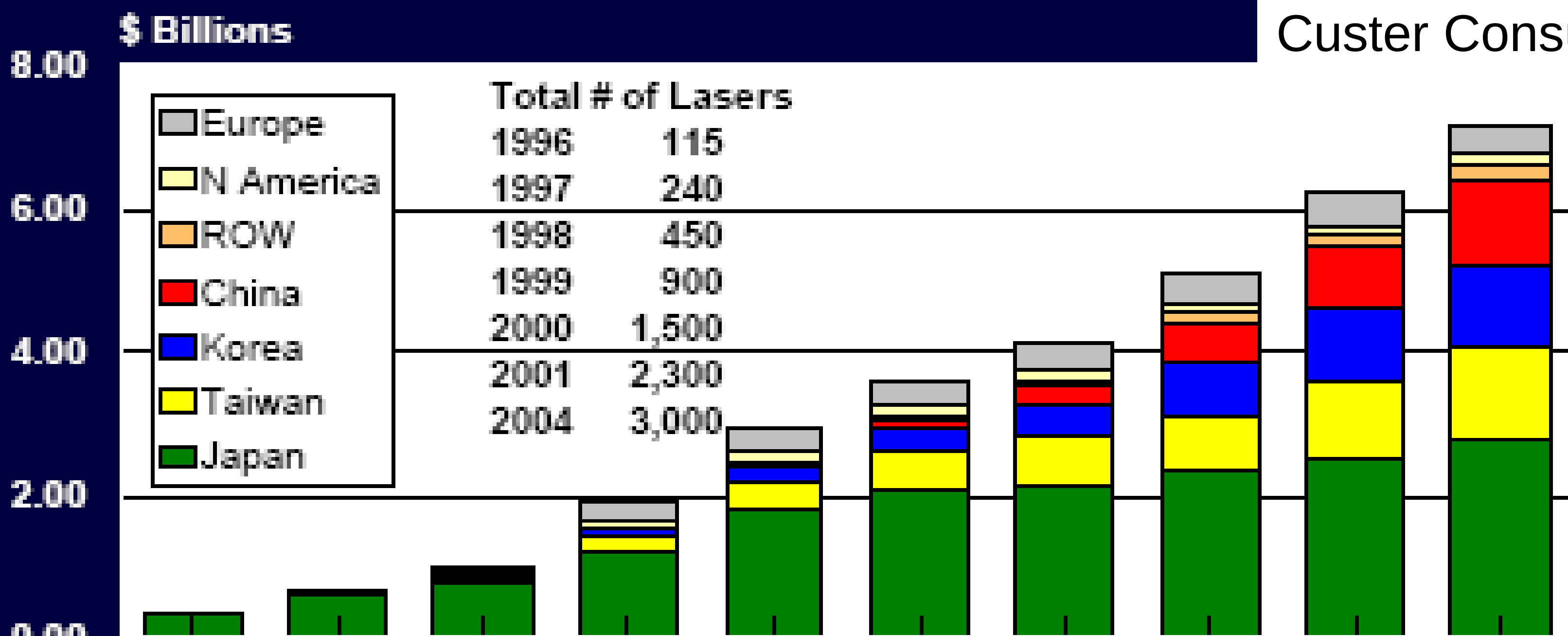


Company Financial Releases
Nanya PCB, Phoenix Precision Technology, Kinsus Interconnect Technology, Unimicron Technology

Increasing I/O count demands area-array packages with microvias and fine line interconnects

WORLD MICROVIA BOARD PRODUCTION

Courtesy:
Custer Consulting Group



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Europe	0.01	0.02	0.08	0.23	0.30	0.37	0.40	0.43	0.47	0.40
N America	0.03	0.04	0.07	0.13	0.18	0.16	0.13	0.13	0.14	0.15
ROW	0.00	0.00	0.00	0.00	0.03	0.08	0.09	0.16	0.18	0.27
China	0.00	0.00	0.00	0.00	0.04	0.12	0.28	0.64	0.88	1.18
Korea	0.00	0.00	0.02	0.11	0.22	0.28	0.45	0.76	1.04	1.14
Taiwan	0.00	0.01	0.04	0.23	0.38	0.55	0.67	0.77	1.08	1.32
Japan	0.32	0.60	0.80	1.20	1.80	2.08	2.14	2.33	2.52	2.77

H Nakahara, N.T. Information Ltd 8/06

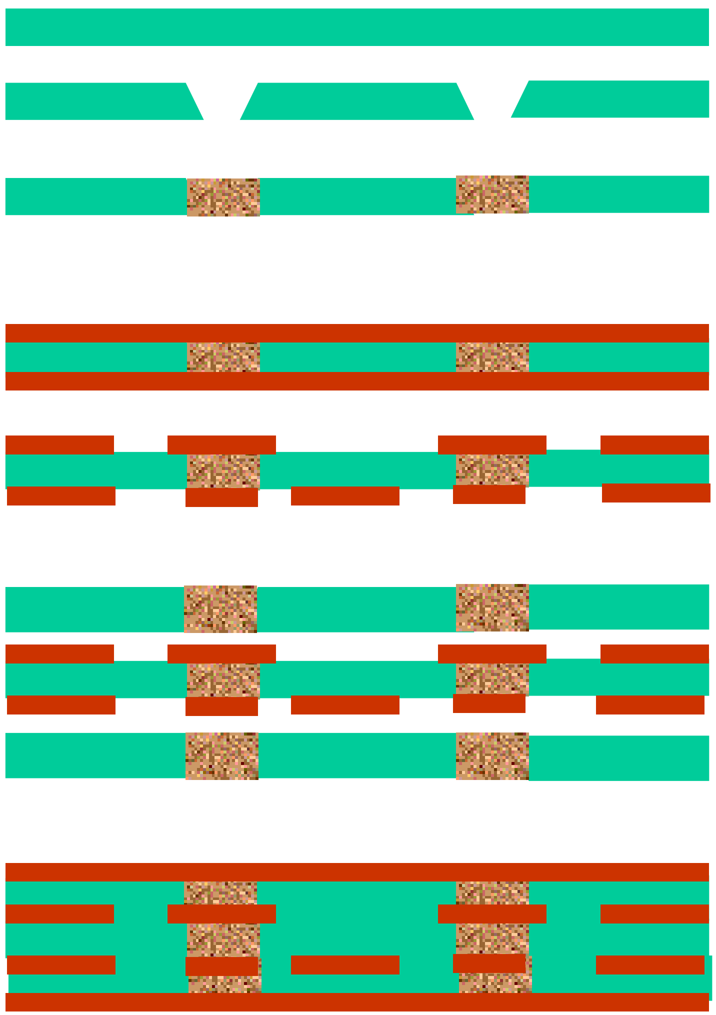
"Core-less" Microvia Boards, "Parallel Processing", Stacked Microvia Designs are enabled by proprietary processes of Japanese companies

Designers like stacked microvia capability:

- routing options, flexibility
- no plated throughhole via stubs affecting signal integrity
- shortest signal path between layers

- Matsushita's ALIVH process is used widely in Japanese cell phone boards
- Other core-less processes are making inroads
- Processes are pioneered by vertically integrated OEMs and consortia. Materials are often proprietary developments
- z-axis interconnects may be conductive pastes printed into laser-drilled holes, screen printed silver bumps, etched bumps or plated bumps
- The following slides give examples of these processes

ALIVH (Any Layer Interstitial Via Hole) Process Schematic



1.Aramid prepreg

2. CO_2 laser drill prepreg

3. Fill holes with conductive (copper/epoxy) paste

4. Laminate with copper foil

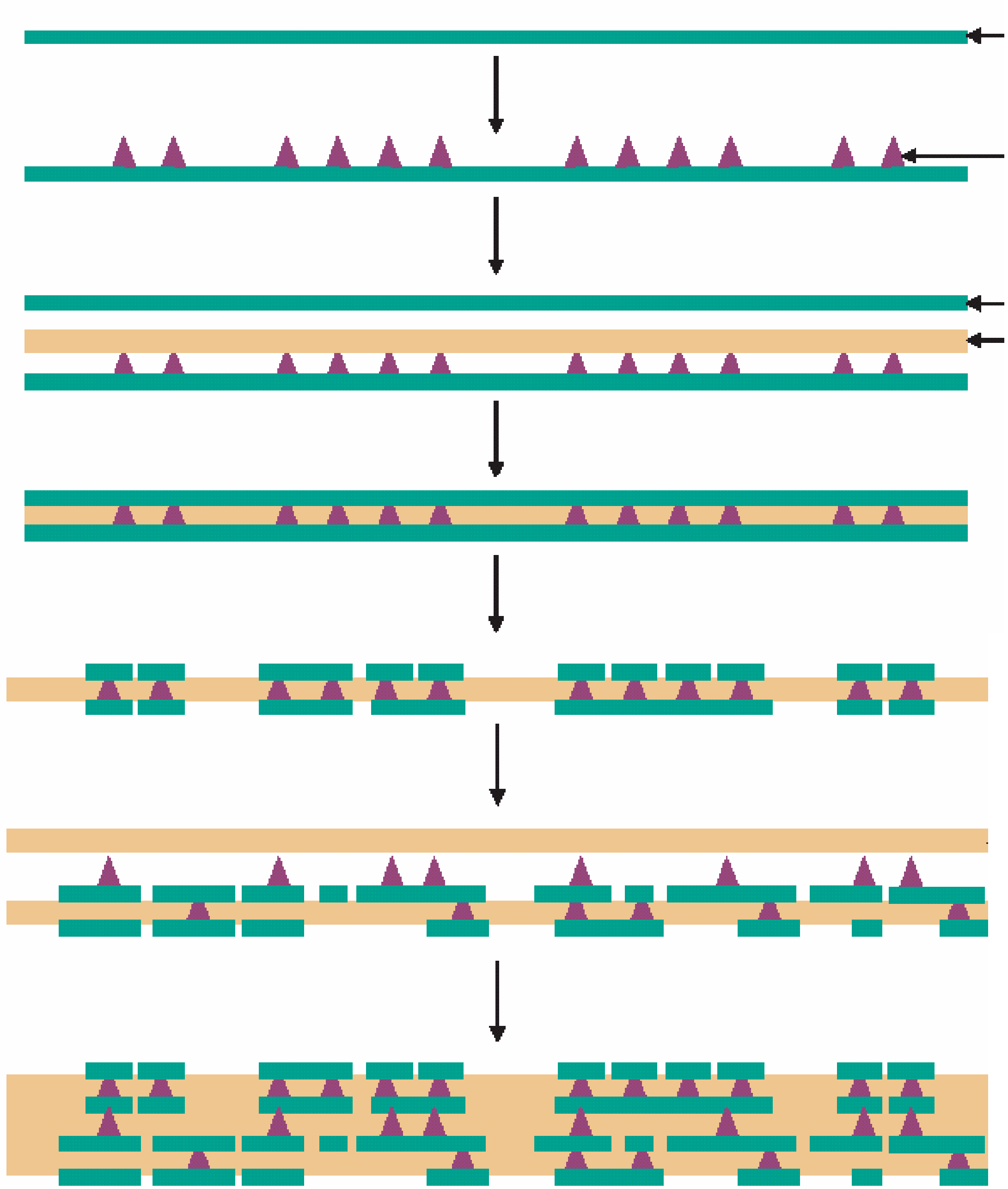
5. Circuitize

6. Form next two prepreg layers following steps 1-3.

7. Laminate with copper foil

8. Circuitize, build up next layers etc

Toshiba's B²it Process



Copper Foil

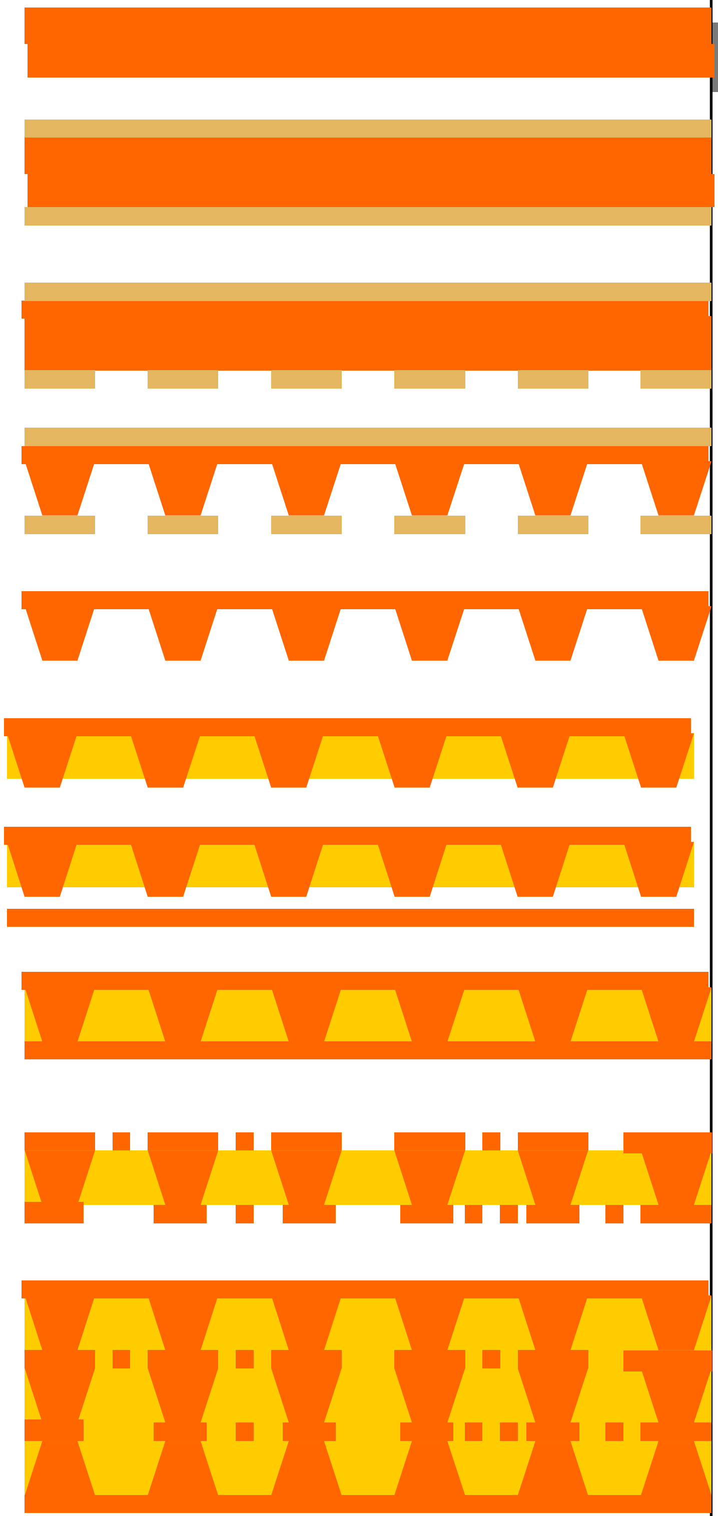
Screen print metal (silver) bumps

Lay-up dielectric, copper foil

Pierce dielectric, connect to top copper foil

Print & Etch

Repeat bump screen printing, lay-up, lamination



1.Copper or Copper Alloy Base

2. Apply Photoresist

3. Expose, Develop Resist Pattern

4. Etch Bumps

5. Strip Resist

6. Laminate Dielectric (Insulator)

7. Lay-up Copper Foil

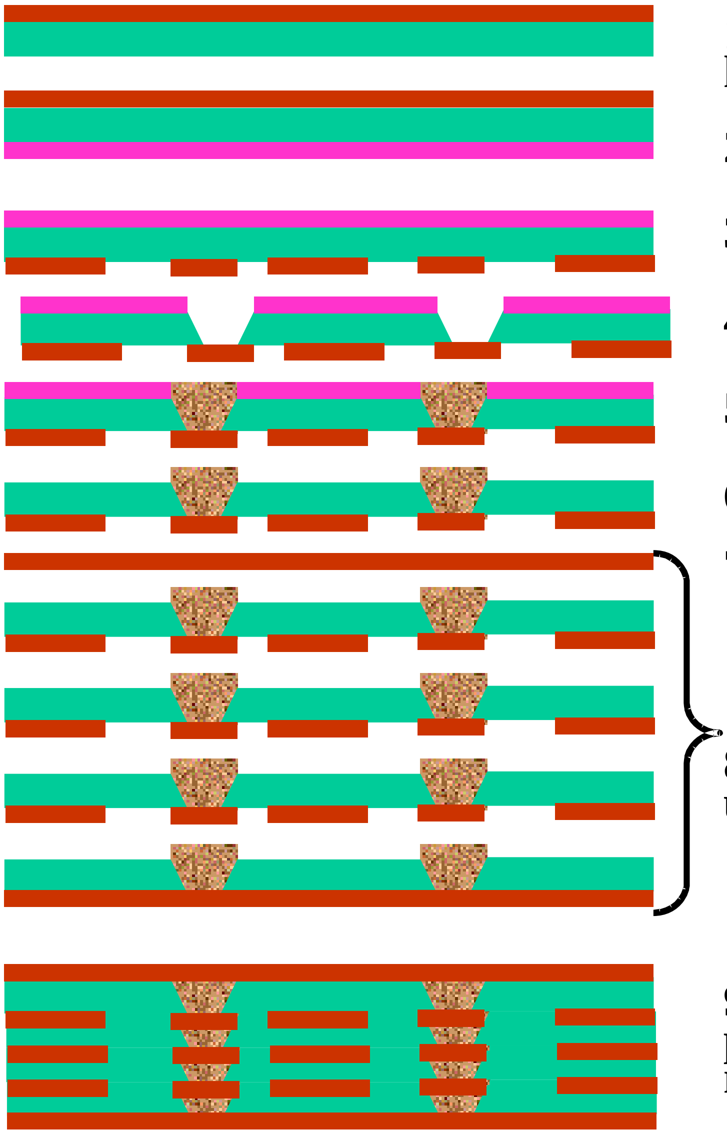
8. Press (Hot)

9. Circuitize (Resist Apply, Expose, Develop, Etch, Strip)

NMBI (Neo Manhattan Bump Interconnection) Process Flow (North Corp., Japan)

10. Repeat Steps 1-8

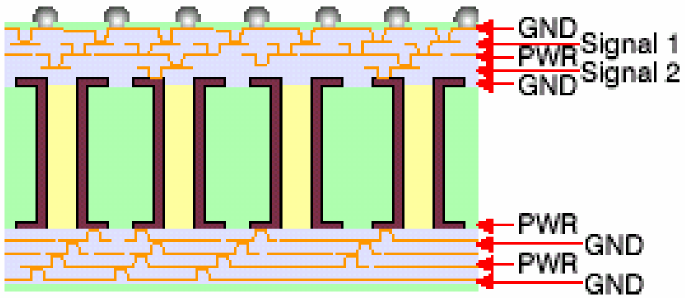
PALAP (Patterned Prepreg Lay Up Process by Denso
(Consortium: Denso, Wako Corp., Airex, Kyosha, Noda Screen, O.K. Print)

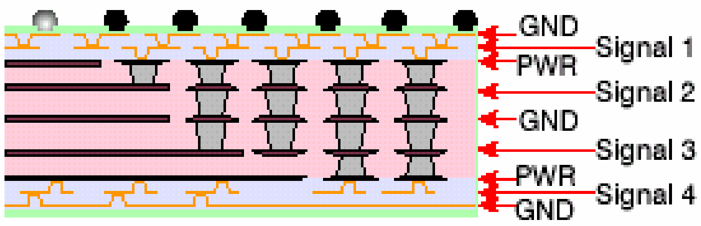


1. Copper foil laminated to PEEK (polyether-ether ketone) thermoplastic resin (from Mitsubishi) or LCP
2. Laminate plastic film to resin
3. Circuitize copper layer
4. Laser drill from the resin (film) side
5. Screen conductive paste into holes
6. Peel off plastic film
7. Repeat Steps 1 through 6 several times
8. Stack innerlayers, cap off with copper foil and unstructured cap layer.
9. Hot press at 200-240°C to producemultilayer. Metal paste sinters, leaving only metal. Diffusion between paste metal and copper layer creates strong bond.
10. Structure outerlayer copper (not shown here)

Kyocera HDBU® (Source: Prismark Partners)

STRUCTURE AND DESIGN RULE OF KYOCERA HDBU®





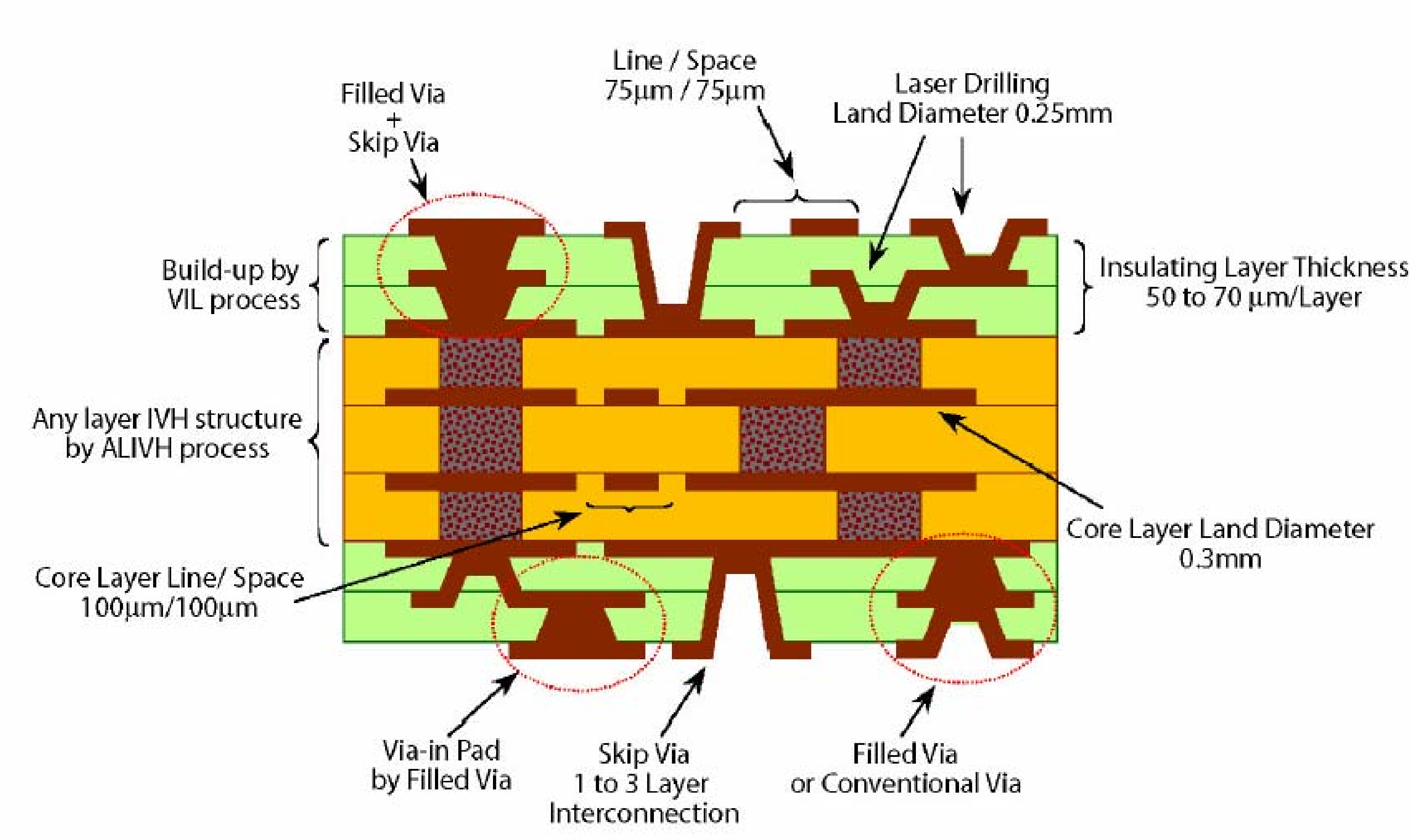
Note: Good Z routing capability for full area array FC pad.

Typical Structure		Current HDBU®	Next Generation Super-HDBU®
Build Up	Line/Space	30/30	30/30
	Via Land	50/100	50/100
	Via Pitch	155	155
Core	Line/Space	100/100	50/50
	Via/Land	300/550 Through Hole	100/200 Stacked Via
	Via Pitch	650 Through Hole	250 Stacked Via

Source: Kyocera

The S-HDBU technology is the first package-based technology under qualification that uses a stacked via core. Kyocera has developed a ceramic type process using LCP (liquid crystal polymer) with a PPE resin and ceramic powder for the dielectric layers. The material properties of PPE and LCP offer excellent electrical characteristics.

ALIVH-VIL Technology (Source: Matsushita Electronic Components, Ltd.)



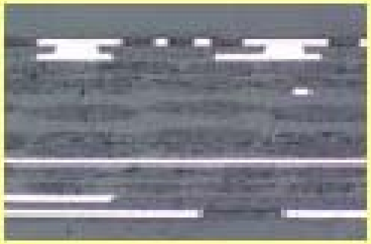
AGSP Process (licensed by Daiwa Co., Ltd.)

Copper bumps are etched in a thick foil, and then dielectric layer (epoxy) is curtain coated on top to provide dielectric. The board is then processed through an automatic belt sanding machine to expose the Cu bumps.

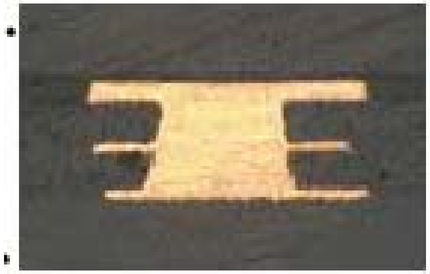
Features/Benefits:

- Bumps (bulk copper) offer low electric resistance and high thermal conductivity.
- Land to via joining is achieved by copper plating.
- By selecting an etching mask with different hole sizes, bumps of different diameters can be formed on the same layer.
- The process yields very flat land surfaces without an extra via filling step.
- The process is suitable for stacking vias.

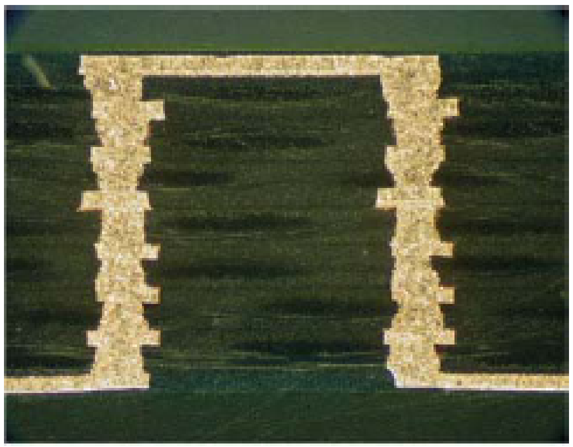
Etching bump of ϕ100μm, 250μm pitch

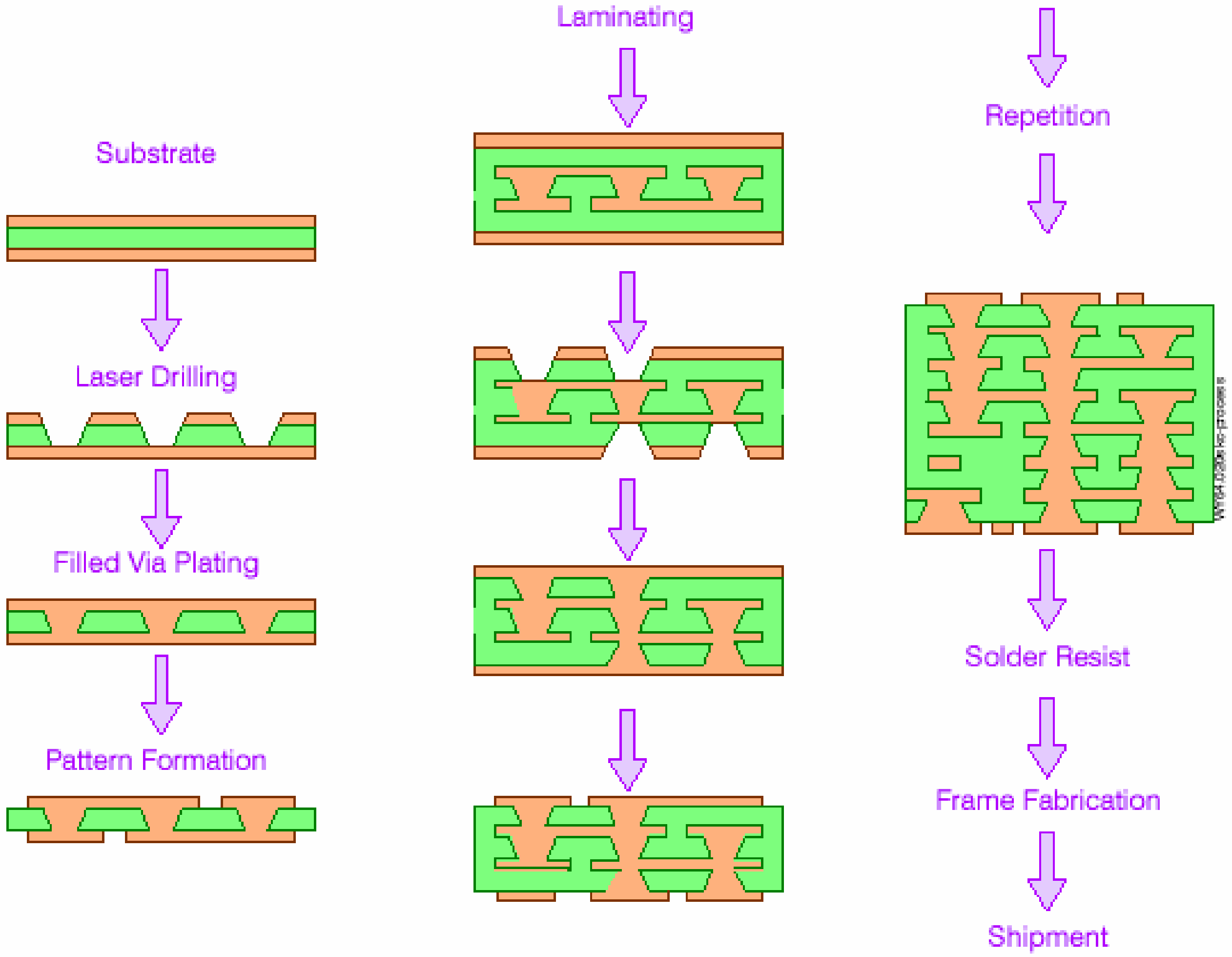


Cross sectional view of AGSP



IBIDEN FVSS MANUFACTURING PROCESS AND STRUCTURE





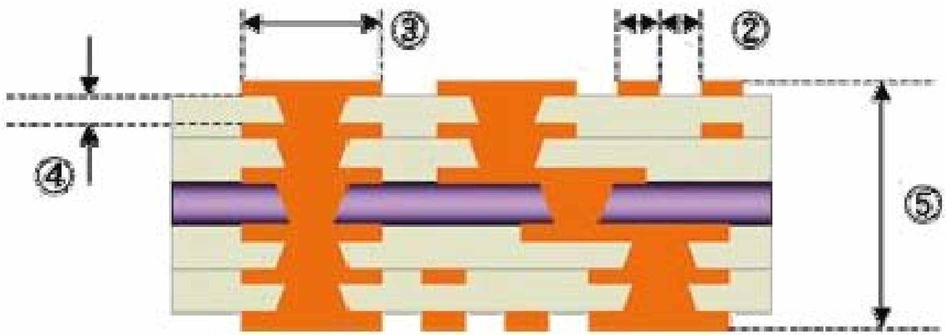
FVSS = Free Via
Stacked-up Structure

PRISMARK
PARTNERS LLC

IBIDEN FVSS ROADMAP

	2003	2004	2005	2006-2007
Line/Space (μm)	75/75	50/75	50/50	35/35
Via/Land (μm)	100/250	70/150	50/100	
CSP Pitch (mm)	0.5	0.4	0.4	0.3
Others			Embedded L, C, R	Embedded IC

IBIDEN FVSS SPECIFICATION

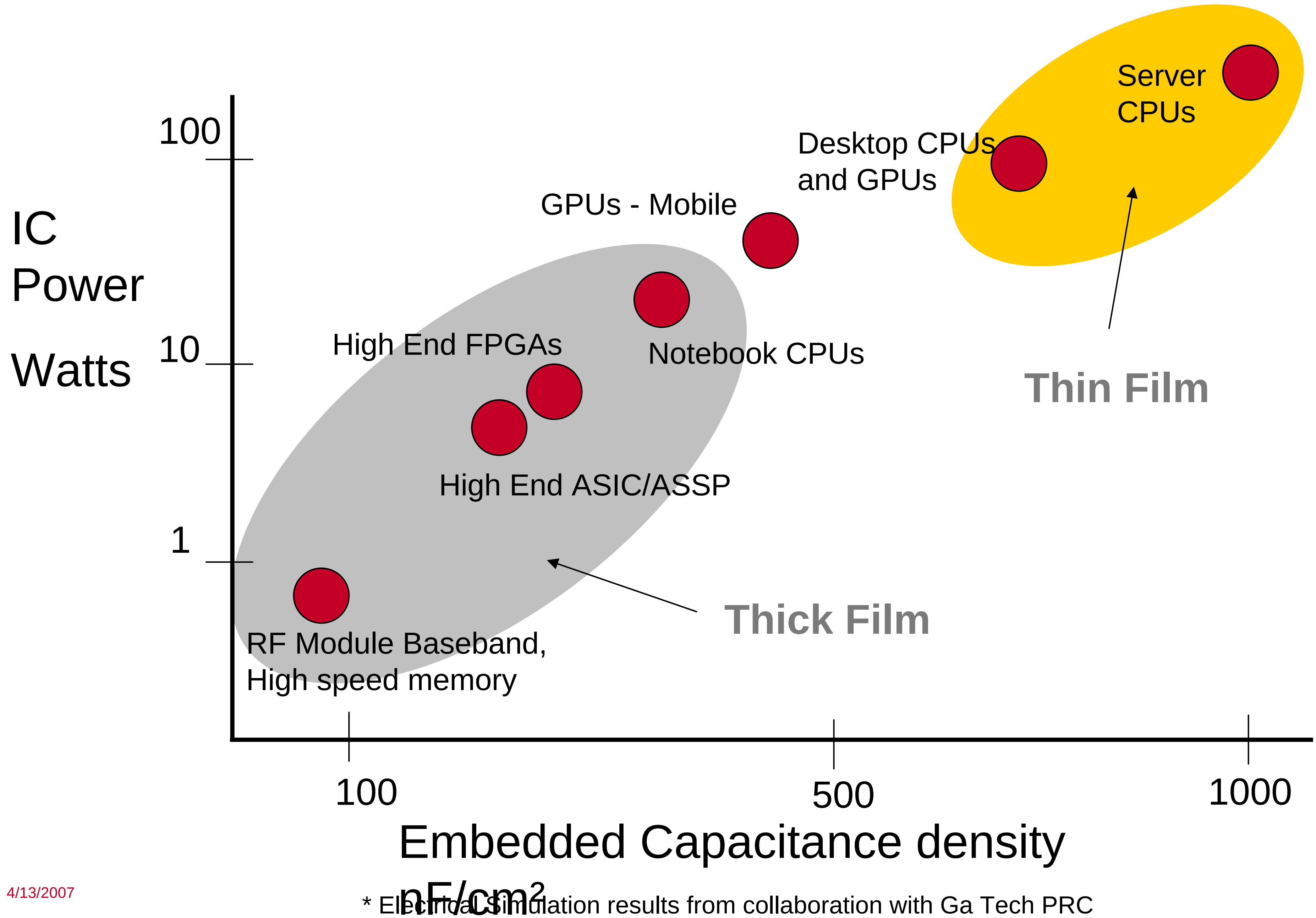


Item	Spec
1. Layer Count	>6 layers
2. Line/Space	75/75 (50/50) μm
3. Land ϕ	150 – 275μm
4. HDI Dielectric Thickness	60 – 80μm
5. Board Thickness	>0.5mm

Ibiden opening 2nd plant in Beijing
to supply FVSS technology cell phone boards to Nokia

Embedded devices will take hold over the next couple of years. Today the volume is mainly planar capacitors, with some PTF resistors. Quickly scale up with discrete buried passives and actives.

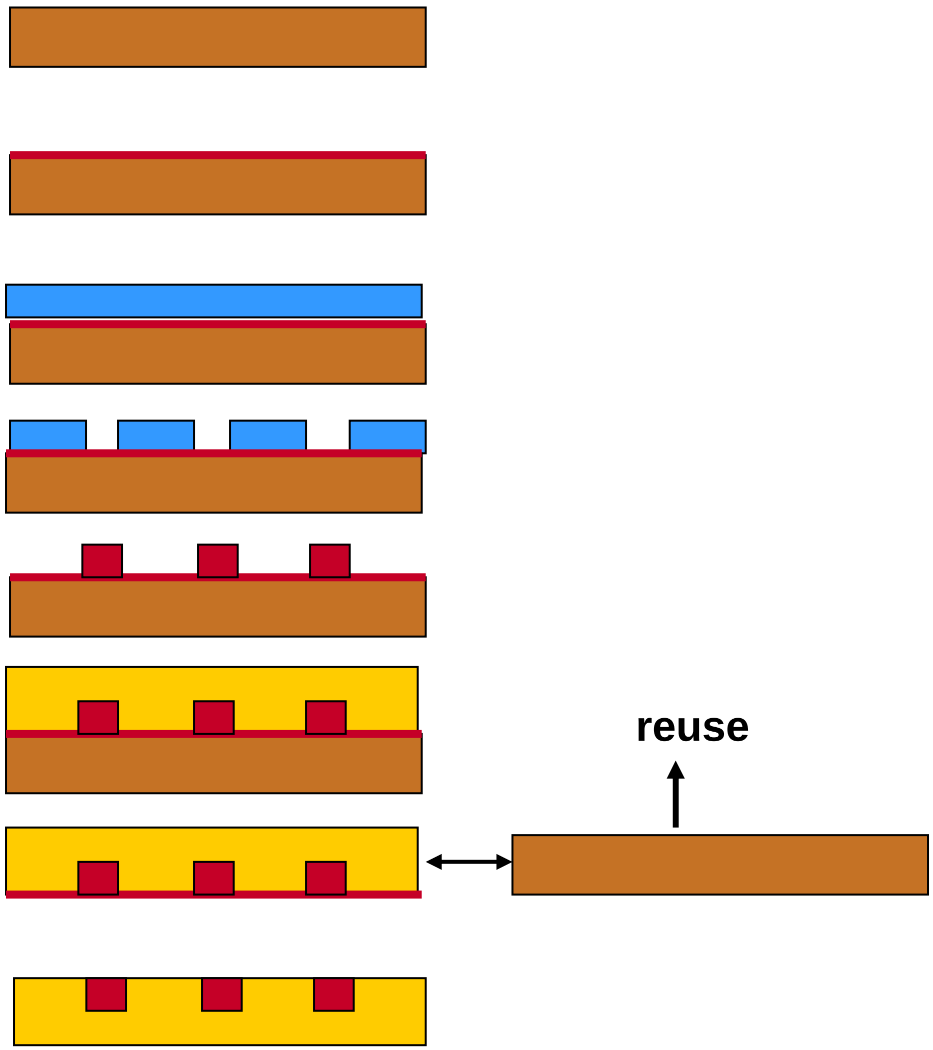
Effective Mid Frequency (0.2-2Ghz) Decoupling*



* Electrical Simulation results from collaboration with Ga Tech PRC

Substrate manufacturers developing dual-damascene-type recessed circuits for fine line, very planar multilayer packages

Illustration of transfer lamination (Source: R. Watanabe, Samsung Electro Mechanics)



1. Base layer (board or film)
2. Base surface treatment/ seed layer formation
3. Photoresist application
4. Exposure/development
5. Pattern plate/ resist stripping
6. Apply dielectric
7. Base layer separation
8. Seed layer etching/ flip

CMK's New Technique?

CMK Creates Method for Making Ultrasmooth Printed Wiring Boards

Tuesday, June 28, 2005

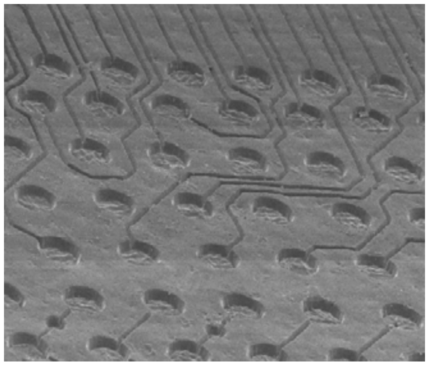
TOKYO (Nikkei)--CMK Corp. (6958), Japan's largest manufacturer of printed wiring boards, has developed a way to fabricate boards that are so smooth that surface irregularities are kept below 0.1 micron.

……………...In CMK's new technique, the circuit wiring is fabricated on a base of film or metal foil and then covered by the insulator. Additional layers can be stacked, but in the end, the base is peeled off and the board flipped over so the wiring on the bottom is now on the top. When this is done, the surface irregularities can be limited to around 1.2 microns. With polishing, the irregularities can be smoothed out to less than 0.1 micron.

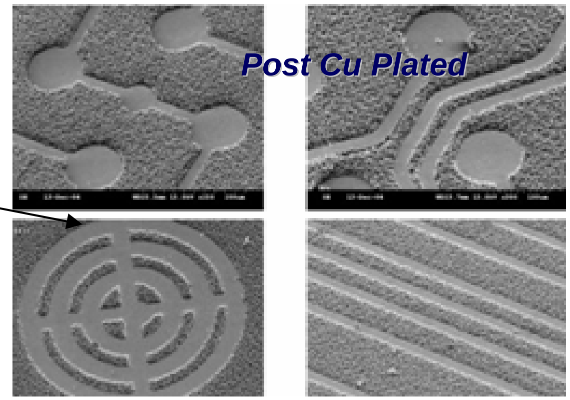
Amkor's Embedded Circuits Approach

(use of laser to form grooves for circuit traces and holes for vias. Seed entire surface and hole surface with e-less copper, electroplate up, preferentially in grooves and holes, remove unwanted copper from the surface in a planarization step)

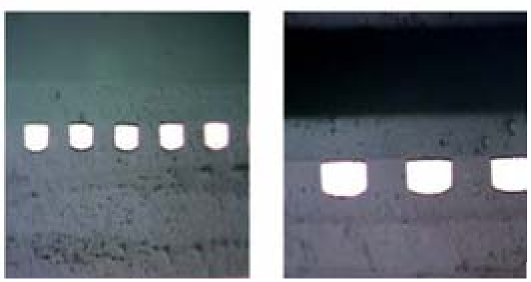
Disruptive Technologies, – Amkor Patented Embedded Circuits



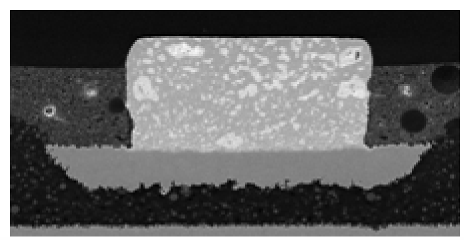
FC Lyr-1 Ablation Pattern

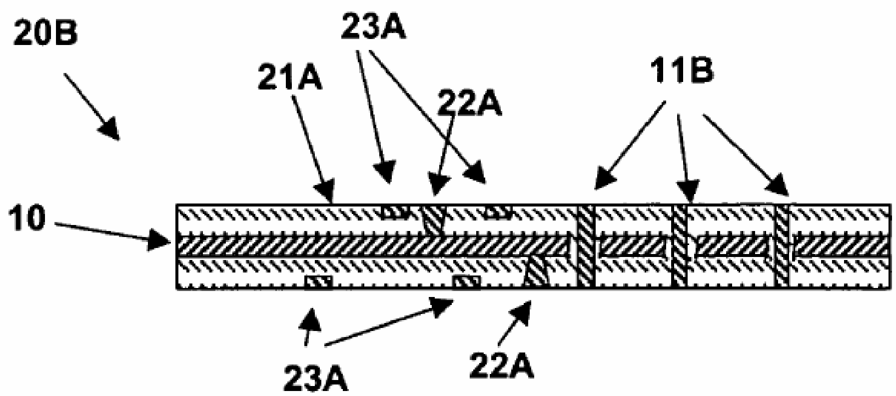


Multiple Patents Granted by USPTO already …
… more coming



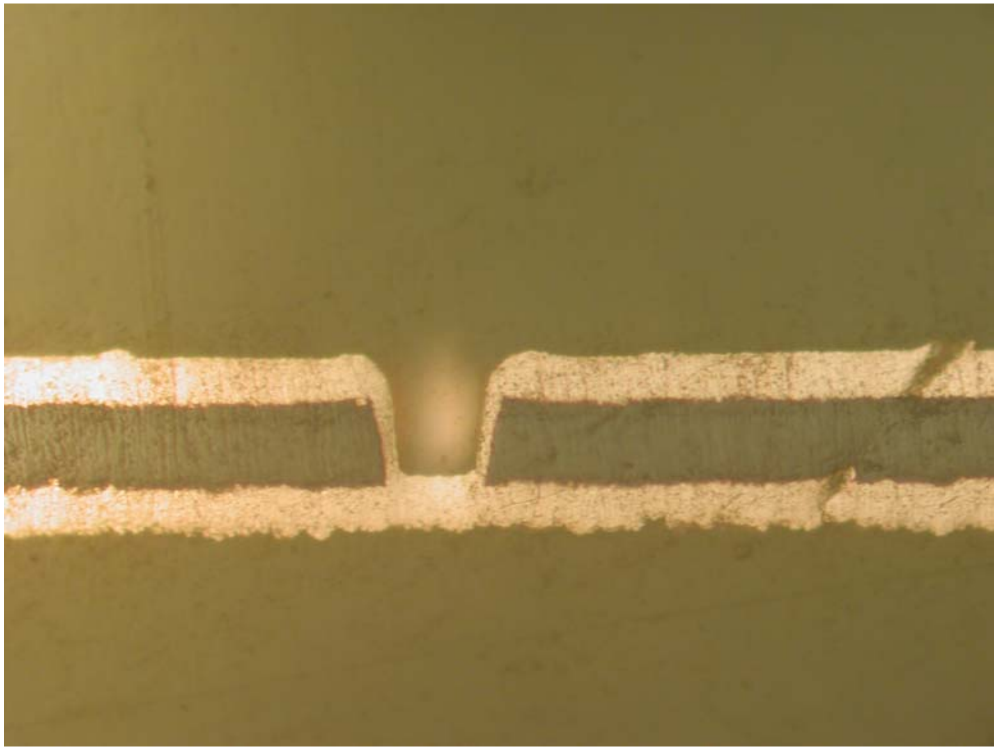
Lyr-1 Trace Cross Sectional Views (12μm)



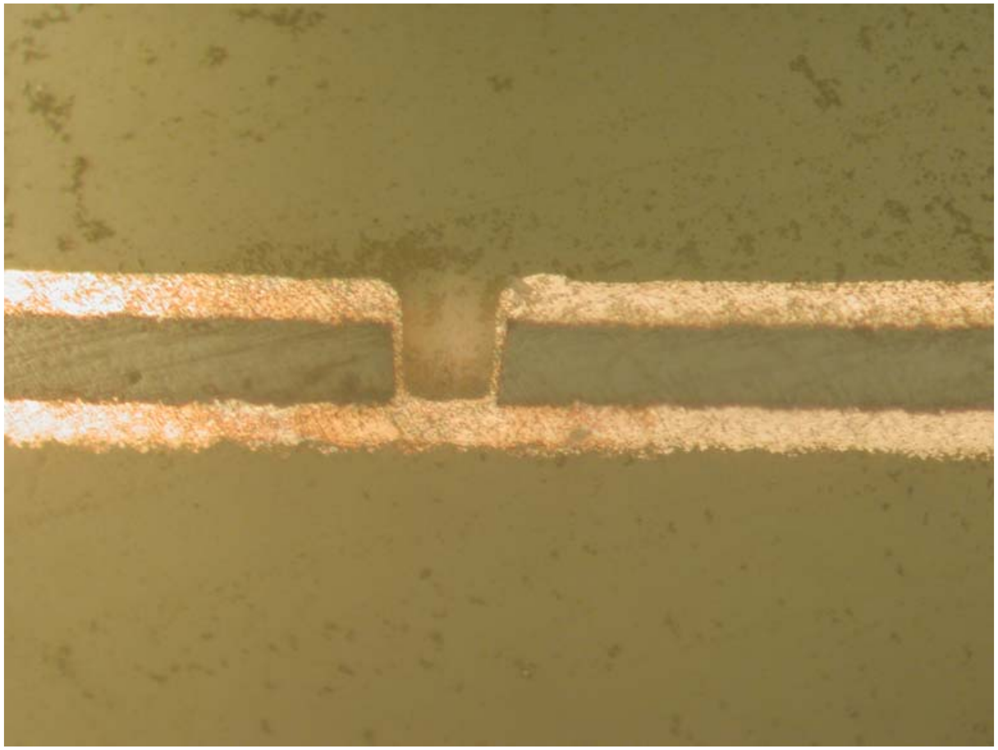


DuPont's Digital Circuitry Development

50 um DC blind via



Block No.1



Block No.3

Other critical technology developments

-**IC Design beyond I/O's – Low K, Power**

-**Wafer level packaging**

- Silcon through vias

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