



# Green PCB and Substrate for Sustainability—A brief overview

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**20 February, 2009**

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# Outline



线路板科技開發中心  
Printed Circuit Board Technology Center

- 1. Environmental Policy in Europe**
- 2. Environmental Research for Green PCB Material**
- 3. Environmental Policy in China**
- 4. Environmental Research for Green PCB Processes**
- 5. Conclusions and PolyU PCB Technology Centre's Research in Green Manufacturing**



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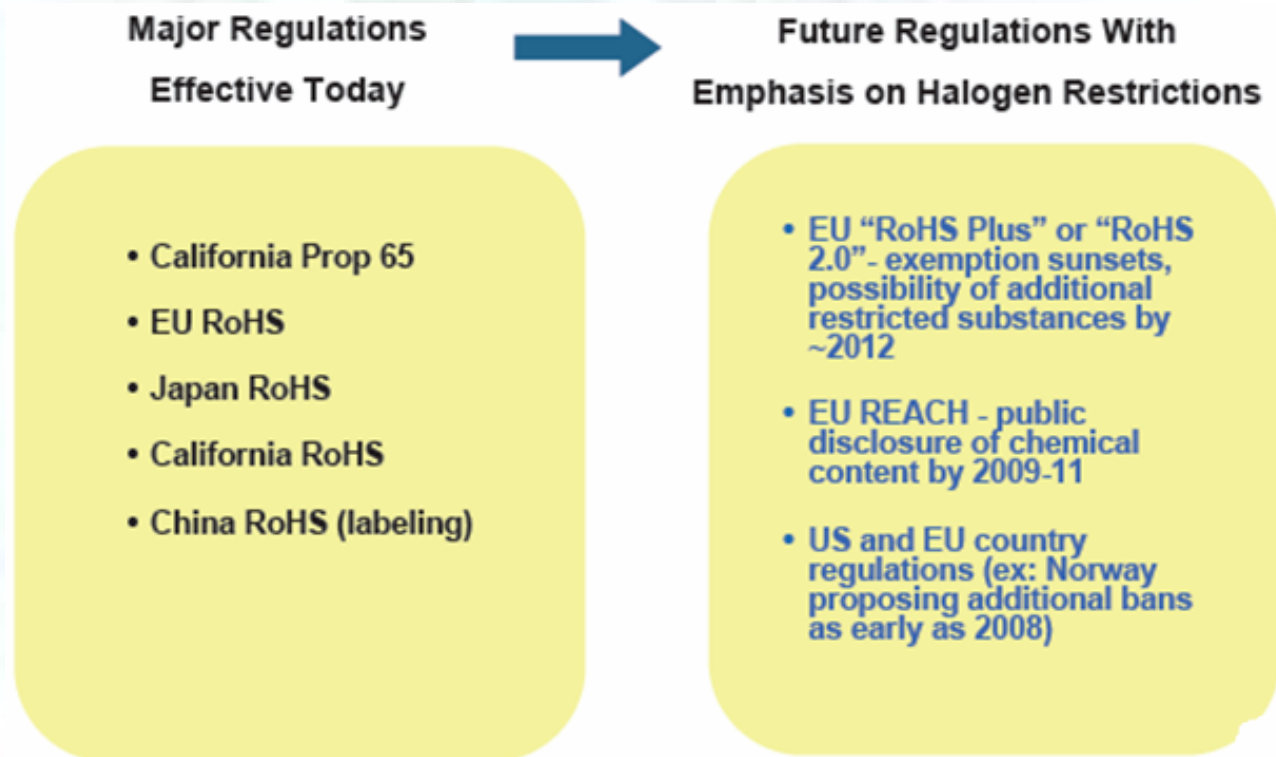
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Systems Engineering

# 1. Environmental Policy in Europe Regulation Update

- Materials Regulations are increasing





# 1. Environmental Policy in Europe

## 1.1 EU RoHS Directive Update

- Highlight of the proposal for EU RoHS Directives – Dec 2008
  - Revised RoHS directive would cover new categories (8 and 9):
    - **Medical Devices (effective from Jan 1, 2014), and**
    - **Monitoring and Control Instruments (effective from Jan 1, 2017)**
  - there is no new substance was added to the RoHS restriction list on the proposal

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# 1. Environmental Policy in Europe

## 1.1 RoHS Directive Update

- Other examples of high priority hazardous substances of interest :
  - Arsenic
  - Beryllium
  - Antimony
  - Phthalates
  - PVC

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# 1. Environmental Policy in Europe

## 1.2 REACH Update

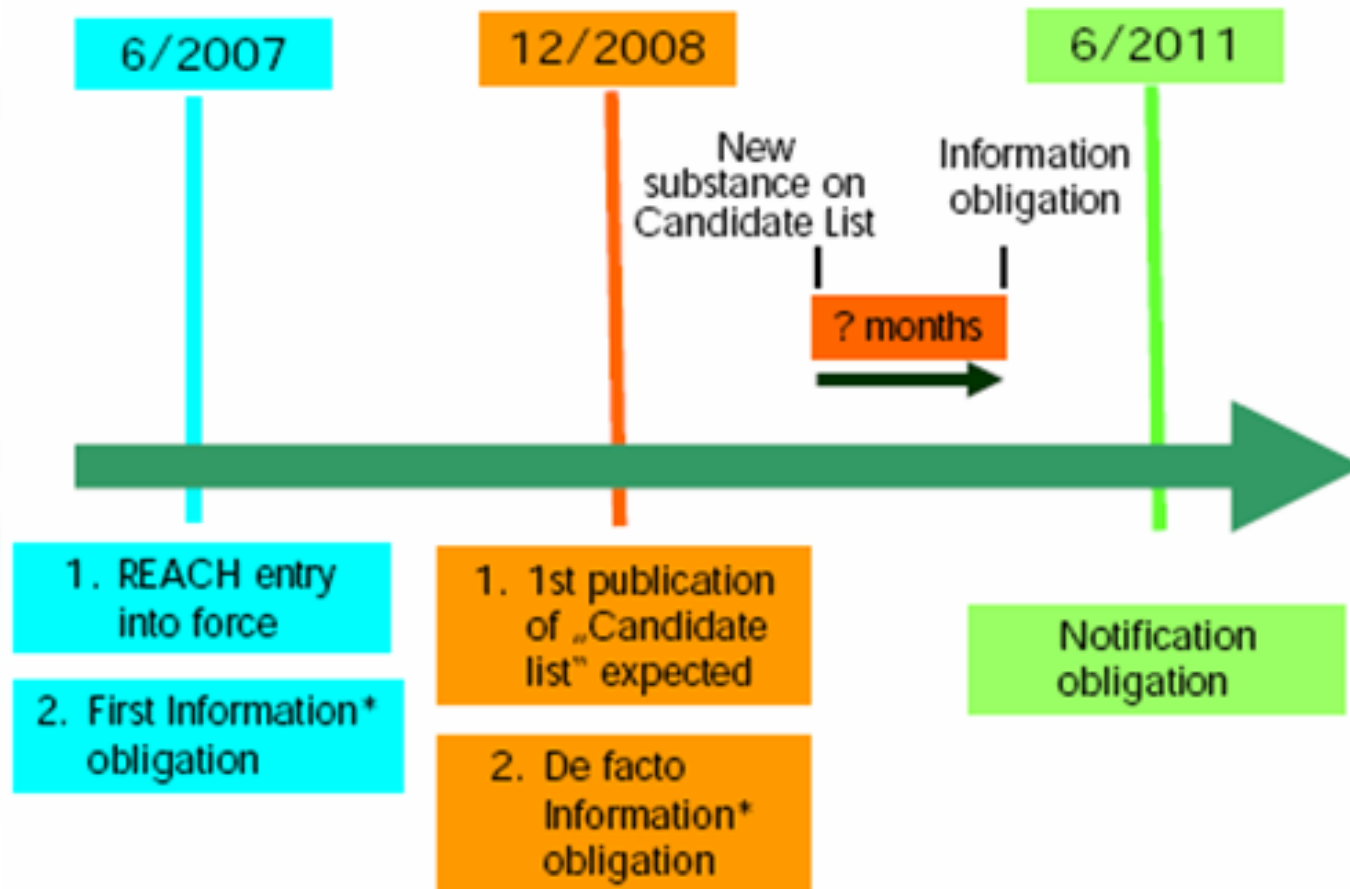
- REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) is a new European Union (EU) chemicals regulation that entered into force on 1 June 2007, with phased deadlines to 2018
- Call for progressive substitution of the most dangerous substances when suitable alternatives have been identified.

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# 1. Environmental Policy in Europe

## 1.2 REACH Timeline



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# 1. Environmental Policy in Europe

## 1.2 Impact from REACH

- Halogen additive may be identified as potential dangerous substances
- Plus, there is an potential need to replace halogen in electrical appliances or devices





## 2. Environmental Research for Green PCB Material

### 2.1 Elimination of Halogenated Flame Retardants

#### 2.1.1 Flame Retardants in PCB Material

#### 2.1.2 Characteristics of Halogen-Free Laminates

#### 2.1.3 Processing Challenges of Halogen-Free Laminates

#### 2.1.4 Future Activities in Halogen-Free Laminate

### 2.2 Reduction of Toxic Solvents

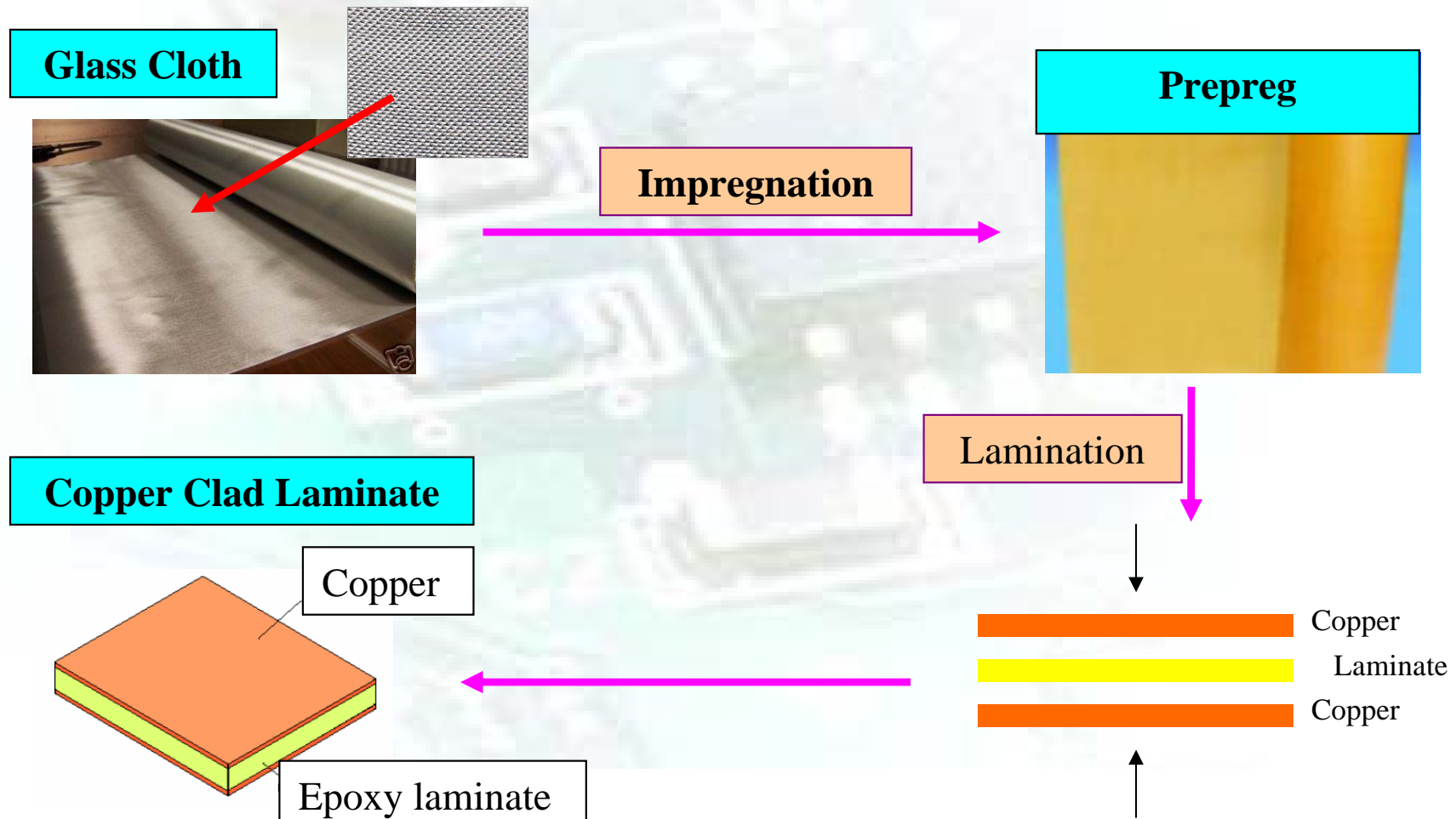
### 2.3 Renewable Resin for PCBs

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## 2. Environmental Research for Green PCB Material

### Background – Process Flow for PCB Laminate fabrication



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## 2.1.1 Flame Retardants in PCB Material

- Flame retardant PCBs are required in electronic applications (UL Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances)
- Role of flame retardants in combustion
  - Hinder initiation
  - Limit Propagation
  - Exclude flash over
- Halogenated Flame Retardants (HFRs) – Most common for PCB's
  - Typically based on bromine e.g : TBBPA, PBDE, etc.
  - Highly effective in small quantities
- Used in FR4; High end epoxies; etc.



- Forecast limitation in Brominated Flame Retardant application:
  1. TBBPA is under evaluation by EU. It may be potentially subjected to restriction in Electronic and Electrical Equipment
  2. According to Annex II of WEEE, for plastic containing brominated flame retardant have to be removed from any separately collected Waste of Electronic and Electrical Equipment.
- Thus, PCB industries are facing an increasing need to find halogen-free materials for flame retardancy due to the legislative actions and market pressure.





## 2.1.2 Characteristics of Halogen-Free Laminates

- Advantage of Halogen-Free Laminates
- Disadvantage of Halogen-Free Laminates





## Advantages:

- Halogen Free – cope with future potential legislation

- High Thermal Robustness due to system strong link

### Typical thermal performance of Halogen-free material

- Higher Decomposition Temp → often > 360°C
- Long T260 Times → often > 60 min
- Long T288 Times → often > 30 min

- Desirable Df value\*

\* Halogen Free material is usually associated with lower Df value. However, in some case, the Dk value would be increased





Disadvantages - Higher Moisture Absorption

Disadvantages - Lower Heat Resistance





## 2.1.3 Processing Challenges of Halogen-Free Laminates

- (a) Reduced  $T_g$
- (b) Could cause processing problems in conventional PCB fabrication.
- (c) Higher moisture absorption
- (d) Lower thermal stability
- (e) Brittleness coupled with halogen free flame retardant

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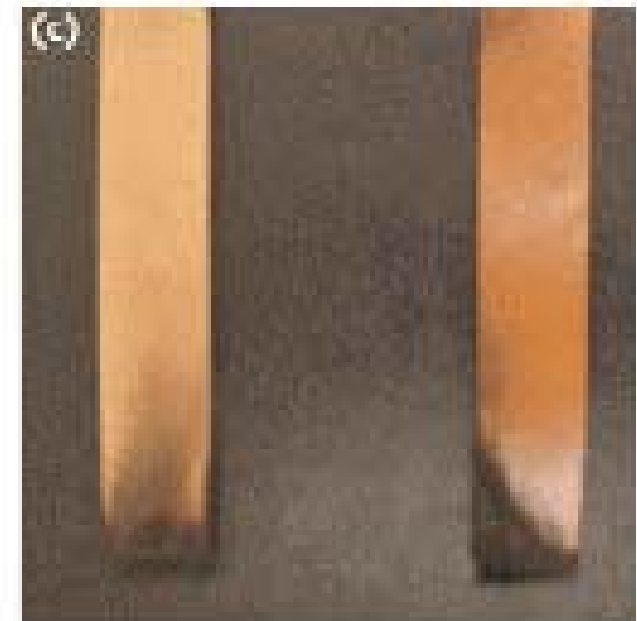
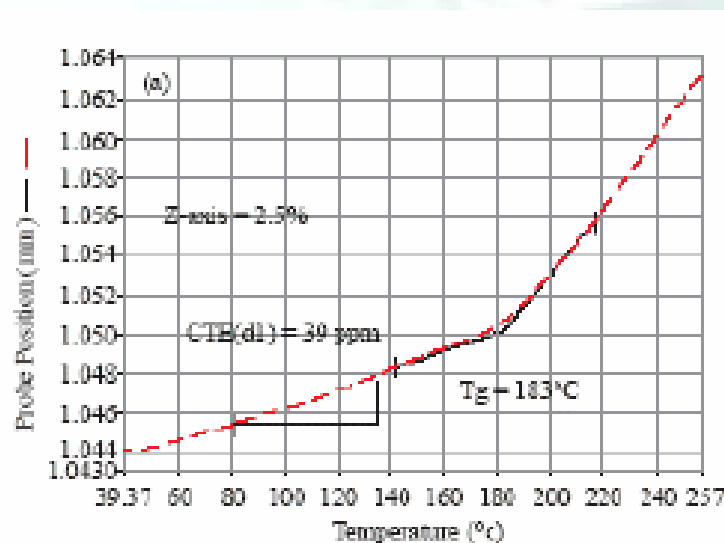
## Possible Solution to address these challenges

- Reduce the overall thermal expansion and hence expansion mismatch between the laminate and copper barrel by selecting laminates with higher  $T_g$ .
- Develop lead-free compatible laminates:
  - Laminate containing new curing agents
  - Laminate contains particulate fillers



## 2.1.4 Future Activities in Halogen-Free Laminate

- The cross-linkable, halogen & phosphorus free FR with low Z-axis CTE (2.5%), high Tg (180°C), lower moisture sensitive.





## 2.2 Reduction of Toxic Solvents

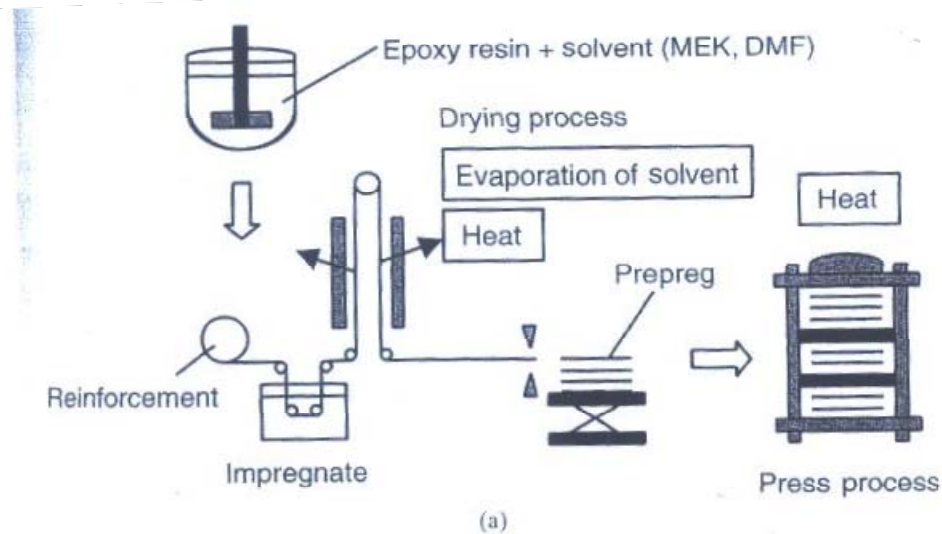
### 2.2.1 Elimination of Solvent Emission

#### 2.2.2 New Solvent-less Process

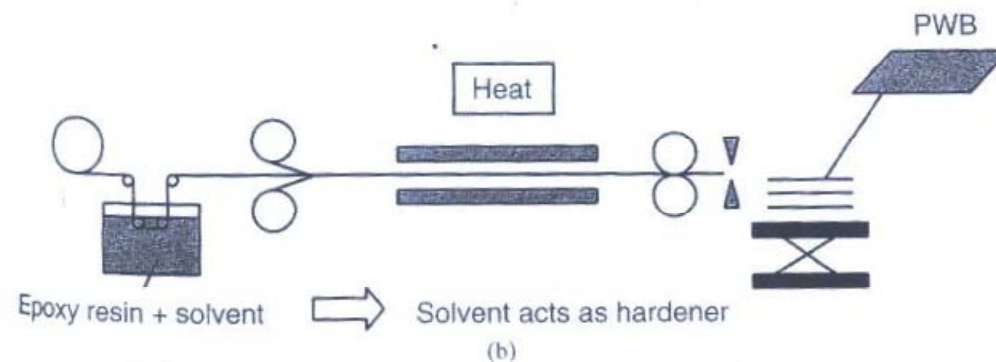
#### 2.2.3 Water based Resin System



## 2.2.1 Comparison of PCB Fabrication Process



(a) Solvent usage in conventional process



(b) New process without emission of solvent



## Concluding Remarks

- This new process can save energy by avoiding heating for solvent evaporation.
- Since the process is continuous, heating and cooling steps are eliminated during lamination.
- This process has a much lower environmental impact in terms of solvent emission and thermal energy efficiency.





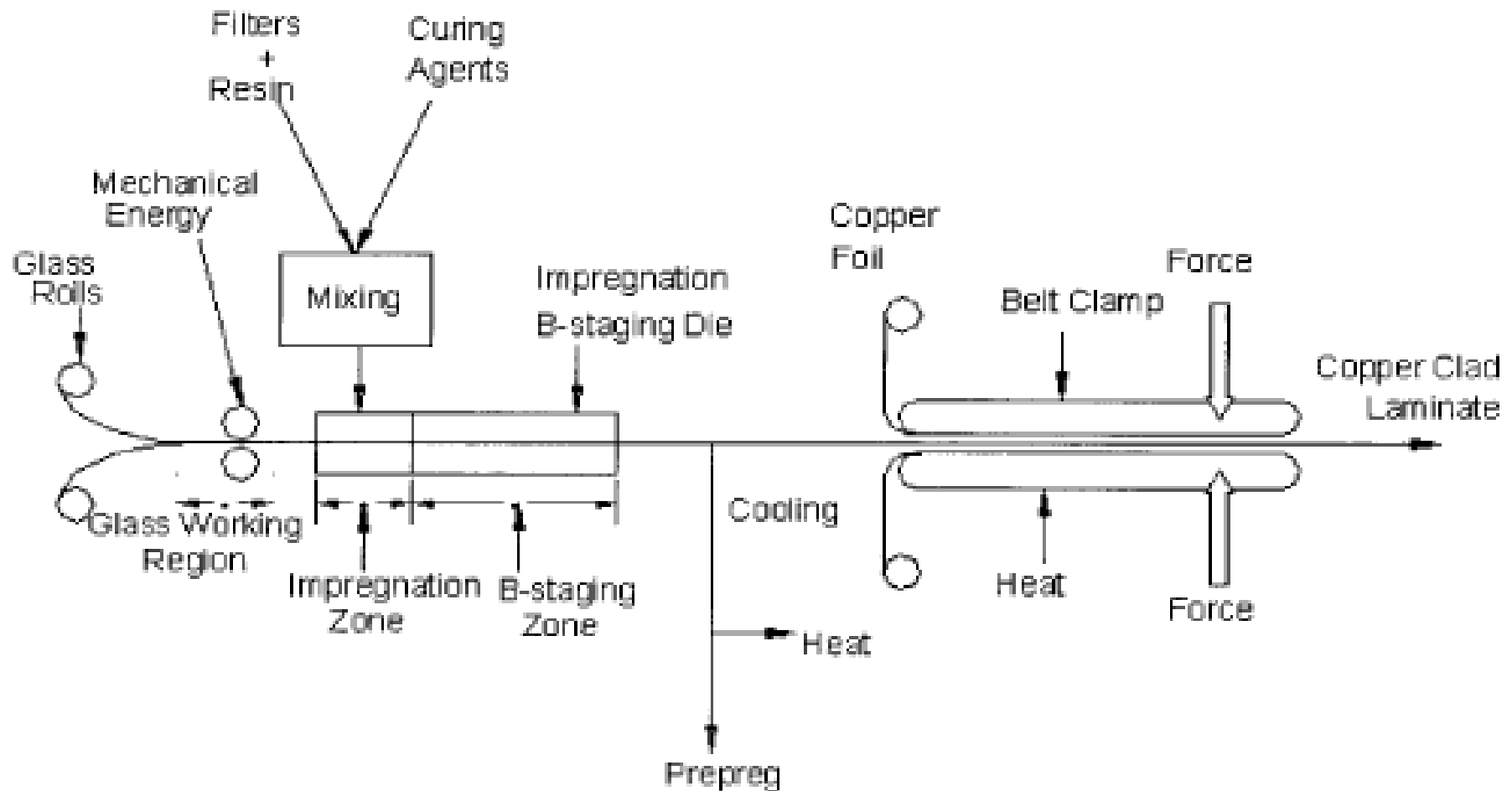
## 2.2 Reduction of Toxic Solvents

### 2.2.2 New Solvent-less Process

- It is a continuous process based on the concept of injection pultrusion
- The impregnation is performed by the injection of a solventless resin system into a die under pressure instead of the fiber being dipped into a solvent-based system in an open pan



# Fabrication process





# Concluding Remarks

- This process has a potential of eliminating cigar voids because of a better wetting ability of resin system
- No solvent is used
- The prepreg can be fed into a continuous lamination belt clamp to manufacture copper clad laminates, or it can just be stored





## 2.2 Reduction of Toxic Solvents

### 2.2.3 Water based Resin System

- For the manufacturing of prepreg, one of the alternative is in water-based resin systems.
- Initial tests indicate that after water removal, the prepreg has essentially identical properties as prepreg made from organic solvents.
- Laminates fabricated from water-based resin have similar electrical, physical, and mechanical properties as those from solvent-based.
- Effective processing of water-based resins requires microwave radiation to ensure a fast drying and curing process.
- With the use of microwave radiation, the energy savings for a typical tower operation can be reduced from 1MW to 20-30kW.

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# Concluding Remarks:

- Application of microwave technology is attractive because it will transfer their energy directly to the resin and solvent without losing heat to convection losses.
- Microwave technology has great potential to eliminate the solvents that are used in PCB manufacturing, reduce energy consumption, and provide lower cost, more impact tooling, and enable the use of water-based resins.





## 2.3 Renewable resins for PCBs

- Use of biopolymers to replace the oil-based epoxy resins – Lignin.
- What is Lignin?
  - The glue that found ties the cellulose together in plant and tree
  - Produced in large volume as a by-product of paper manufacturing
  - Its molecular structure provides the thermal stability and chemical resistance necessary for PCBs.





# Rooms for further development:

- Lignin is still in research stage, but research results show that some of the resin systems based on lignin can provide a PCB with equivalent or better thermal and electrical performance than current high-volume PCBs.
- The cost of resin materials can be significantly lowered and dependence on fossil fuels is substantially reduced.





## 3. Environmental Policy in China

- 3.1 China-RoHS 《電子信息產品污染控制管理辦法》 (2)
- 3.2 Economize Energy and Reduce Pollution 《節能減排》 (2)
- 3.3 Pearl River Delta Environment Conservation Plan & Environment Conservation Planning in Guangdong (1)
- 3.4 Concluding Remarks (3)





### 3.1 China-RoHS 《電子信息產品污染控制管理辦法》

- Came into force in 1<sup>st</sup> March 2007 and applies to a wide range of Electronic Information Products (EIP) manufactured and sold in China
- Main requirements:
  - All EIPs must be marked to indicate whether any of the six substances are present (Lead, Cadmium, mercury, Hexavalent chromium, PBB and PBDE)
  - Packaging must be non-toxic, biodegradable and recyclable, and marked with material content
  - Producers must contract with local recyclers to recover products after safety period and finance recycling





## 3.2 Economize Energy and Reduce Pollution 《節能減排》

- Regulated by Development Revolution Council.
- Proposal Content
  - The value-added water usage of an industry should be decreased by 30% by 2010.
  - Control of high-exhaustion energy and the over-rapid growth of highly-polluted industries.
  - Grasp the departmental interactive mechanism of establishing newly developed special case management and special case approval mechanism
  - Seriously execute the necessary criteria of project development

(Reference: HKPCA Marketing Survey 2006 Version)

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### 3.3 Pearl River Delta Environment Conservation Plan & Environment Conservation Planning in Guangdong

- Develop the new era of “establishing and obeying planning which embodies environment conservation”.
- Establish environmental elimination mechanism which phases out the manufacturers with old production technology and productivity for the sake of reducing the total amount of discharged waste.
- Heavily-polluting industries such as electro-plating, pulp and paper making, dyeing and textile industry, leader manufacturing, etc. all have to implement planning and focal establishment.

(Reference: HKPCA Marketing Survey 2006 Version)





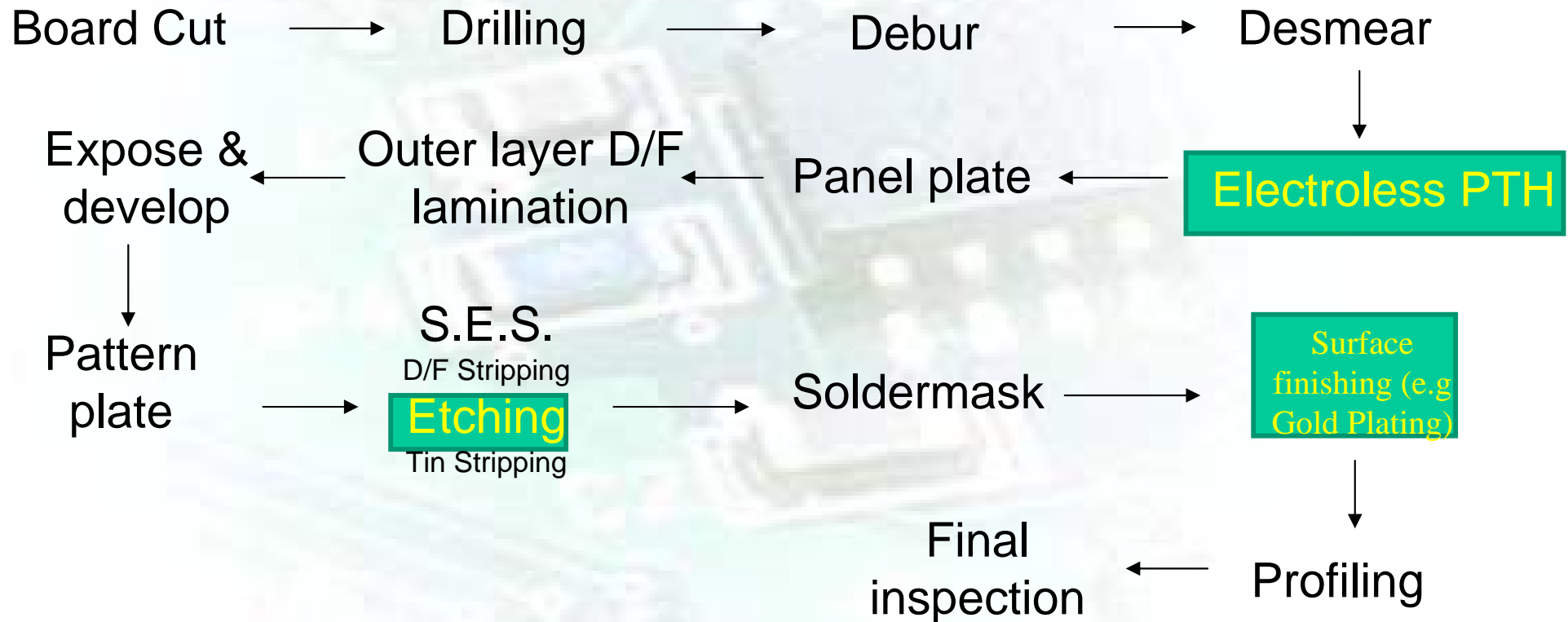
## 3.4 Concluding Remarks

- PCB manufacturers in China have to adopt the **advance fabrication techniques and equipments** to increase market competitiveness, as well as to reduce pollution.
- **Effective use of raw materials** can lower manufacturing cost, increase economic benefits, at the same time reduce material waste.



# 4. Environmental Research for Green PCB Processes

## Background - Manufacturing process (simplified) for PCB



Process associated with hazardous chemicals or heavy metals



## 4. Environmental Research for Green PCB Processes

### 4.1 Metal Recovery in PCB Fabrication Processes





## 4.1 Metal Recovery in PCB Fabrication Process

- Approximately 7 million liters of etchant is being used each year.
- A total amount of HK\$24million is being spent for waste treatment on top of the HK\$9 million chemical cost.
- There is a need to regenerate spent etchant and recover copper to minimize the operating cost of the etching process.

Ref.: Development of a re-circulate copper etching system to enhance the precision of the HDI PCB manufacturing, Journal of the HKPCA, No. 25, Q3, 2007, p16-21.

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# Methods of Regenerating Etchant

## A. Solvent extraction - Background

- In the manufacturing of printed circuit boards (PCB), copper is commonly etched with an ammoniacal solutions (etchant), containing free ammonia, ammonium chloride and some oxidants.
- Use of ammonia complicates waste treatment and makes recovery of copper difficult.
- Optimal etching efficiency is obtained when the copper concentration in the etchant is 140 - 160 g/l.

Reference:

[http://www.meab-mx.se/en/proc\\_mecer.htm](http://www.meab-mx.se/en/proc_mecer.htm)

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## B. Oxidation techniques

- By means of Boron Doped Diamond (BDD) electrode, it proves to be able to generate hydroxyl radicals which efficiently oxidized cuprous ions and regenerate copper etchant. Meanwhile copper is recovered on cathode.





## 4. Environmental Research for Green PCB Process

### 4.2 Replacement of Hazardous chemical in PCB fabrication

#### 4.2.1 Eliminating Cyanide in PCB fabrication

#### 4.2.2 Eliminating formaldehyde in PCB fabrication



## 4.2.1 Use of CN plating in PCB fabrication

### Non-Cyanide gold plating - Current Approach

1. Sulfite baths  $[\text{Au}(\text{SO}_3)_2]^{3-}$
2. Thiosulfate-Sulfite mixed ligand baths
  - Have been shown recently to be capable of providing much more stable baths for both electroplating and electroless plating.



## Rooms for further development

- Finally, it should be noted that there is neither electroless hard gold bath, nor non-cyanide electroplating hard gold bath currently available. Development of new systems to fill these gaps can be anticipated in the future.





## 4.2.2 Eliminating formaldehyde in PCB fabrication-Background

- Although electroless copper has been successfully used for more than three decades in PCB industry, limitations of it still persist. Among the deficiencies are:
  - Use of formaldehyde as reducing agent which is a probable human carcinogen.
  - The process requires stabilizing additives such as EDTA to avoid copper precipitation which is difficult to be decomposed.
  - The large number of process and rinse tanks causes high water consumption.





## Replacing formaldehyde in PCB fabrication (3/5)

- Carbon-based Alternative
- Graphite-based Alternative
- Conductive Polymer Alternative
- Palladium-based Alternatives



## Summary of occupational hazards, exposures, and risks of potential concern

Metal Hole Conductive (MHC)	No. of chemical products with hazardous properties reviewed by MSDSs	No. of Chemicals of Concern for an MHC line operator		No. of Suspected Carcinogens
		Inhalation	Dermal	
Electroless Copper, non-conveyorized (BASELINE)	68	10	8	5
Carbon conveyorized	11	0	0	1
Conductive Polymer, conveyorized	8	0	0	0
Graphite, conveyorized	12	0	0	2
Organic-Palladium, non conveyorized	8	0	1	0



## 5. Conclusions

- It is inevitable that the transition to environmental compliance will have a significant impact on the business landscape in PCB and electronic industries.
- Capability & Timeliness to comply with RoHS, WEEE, REACH and China environmental regulations now become key competitive differentiators in the industry.





## 5. PCB Technology Center's Research in Green Manufacturing:

- PTH Reliability Studies of Halogen Free Laminates under Lead Free Soldering Condition (Ref. 2.1)
- Development of Environmental Friendly Solventless Process for Prepregs (Ref. 2.2)
- R & D on Recyclable Laminates (e.g. Development of LCP-based PCBs, Ref. 2.3)
- Metal Recovery in PCB Manufacturing Process (Consultancy Service in Waste Water Treatment Issue, Ref. 4.1)





# Recent Research Projects in PCBTC

1. A Cost-effective Advanced Thermal Material for Metal-Core Printed Circuit Board (MCPCB)
2. Development of Printed Organic Electronics manufacturing technology for high volume production
3. A Macroscopic and Microscopic study of different reliability tests of high performance Printed Circuit Boards (PCBs)
4. Development of Plasma Processing Technology for PCB applications

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## Research and Industrial Projects (over 30)

- (I) Advanced Materials
- (II) Microvias Drilling
- (III) Microvia Metallisation and Electroplating
- (IV) Fine-line Circuit Patterning
- (V) Embedded Passive
- (VI) Rigid Flex Printed Circuits
- (VII) Micro-Electro-Mechanical-System (MEMS) Fabrication
- (VIII) Quality and Reliability
- (IX) Green Manufacturing



# PCB Technology Center



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- PCBTC has received many research funding, contract research projects and consultancy:
  - **9** HKSAR Government's ITF/ISF projects: Total grant of *HK\$ 37 Millions*
  - **3** Research Grant Council's CERG funded and fundable projects
  - **15** other research projects: Total grant of *HK\$ 5.5 Millions*
  - **4** Government-funded Teaching Company Scheme projects
- PCBTC is **the pioneer and leader** to introduce to Hong Kong via-hole drilling by laser ablation. With this technology transfer and development efforts, many large-scale and medium sized PCB and substrate manufacturers have acquired via-hole laser-drilling technology and installed laser-drilling systems. As of Sept 2007, there are totally **134** laser systems installed in **10** local and South China PCB and substrate manufacturers and the business spawned is over HKD **523.4 Millions** (USD **67.1 Millions**).

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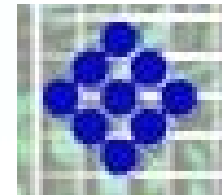


# Some Industrial Partners of PCB Technology



Center

ASM

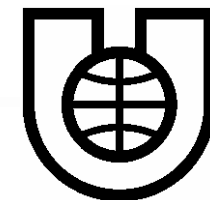


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# Staffing of the Centre

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Research and Project Staff 18



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