# *Journal of the*

# *Institute of Circuit Technology*

## 2010 Events

| | |
|---|---|
| 12th April - 15th April | **ICT Annual Foundation Course** , Loughborough University |
| *18th - 19th May* | *National Electronics Week UK Hall 1 Birmingham NEC* |
| *7th-8th June* | *EIPC Conference, Nuremberg* *www.sderhaag@eipc.org* |
| 15th June ( DATE change) | **ICT 36th Annual Symposium** Please note Bracebridge Suite, National Motorcycle Museum at Solihull *bill.wilkie@InstCT.org* |
| *30th June* | *IMAPS-UK "Beyond Solder" - NPL* *www.imaps.org.uk* |
| 15th September | 17.00 Evening Seminar, Newtown House Hotel in Hayling Island supported by Spirit Circuits. *www.newtownhouse.co.uk* |
| 2nd November | 17.00 Evening Seminar, Darlington *bill.wilkie@InstCT.org* |
| *9th - 12th November* | *Electronica 2010, Munich International Fair,Germany* *www.electronica.de* |

## 2011 Events

| | |
|---|---|
| 1st Febuary | 17.00 Evening Seminar, Darlington |
| 1st March | 17.00 Evening Seminar, Arundel, Comfort Inn |
| 4th April - 7th April | **ICT Annual Foundation Course** , Loughborough University |

## Contents




vol.3 no.3 August 2010

## Editorial

Please accept my apologies for the very late publication of what would have been the July issue of the *Journal* - It is now the August issue.

Various problems occurred including :-

i) Moving house.
ii) Lack of Broad Band - despite 4 weeks warning.
iii)Temporary personal immobility.

It is all fixed now, look out for the October issue, and keep sending your contributions.

*Bruce Routledge*



## Membership

New members notified by the Membership Secretary

**Associate(A.Inst.C.T.)**

| | |
|---|---|
| 10161 | Olivia Flaherty |
| 10162 | Justyna Wrobel |
| 10163 | Mark Woolridge |
| 10164 | Carl Cooke |
| 10165 | Steve Rimmer |
| 10166 | Jim Hope |
| 10167 | Victoria Blaisdel |

**Member (M.Inst.C.T.)**

| | |
|---|---|
| 10168 | Andy Greasley |

**Upgrades - Member to Fellow (F.Inst.C.T.)**

| | |
|---|---|
| 10026 | Andy Cobley |
| 10033 | Francesca Stern |

## Corrections and Clarifications

Bob Willis of ASKBobWillis writes :-

*Many thanks for the newsletter, just one point I notice my company name ASKbobwillis.com has been omitted from the text at the start of the article? Others have their company name? I believe you will have this on each of the pieces of text I provided??*
*Many thanks*
*Bob Willis*

The links on page 3 of vol3iss2 were incorrect they should have read :-
http://www.instct.org/secure/downloads/Materials for Flexible Printed Circuits.pdf
http://www.instct.org/secure/downloads/030210/Materials for LED Packaging.pdf
http://www.instct.org/secure/downloads/030210/Thin Film Resistor Foils.pdf
http://www.instct.org/secure/downloads/030210/Pyralux High Speed Flex Material.pdf
http://www.instct.org/secure/downloads/030210/
Trends in RF and High Speed Digital and their effect on PCB Technology Requirements.pdf
http://www.instct.org/secure/downloads/030210/
Base Materials for High End PCBs.pdf
http://www.instct.org/secure/downloads/030210/

*It is the policy of the Journal to correct errors in its next issue. Please send corrections to : -*
*e-mail : bruce.rout@btinternet.com*

*The Journal of the Institute of Circuit Technology is edited by Bruce Routledge on behalf of the*
***Institute of Circuit Technology.***
*32 Stretton Close, Penn. High Wycombe, Buckinghamshire, HP10 8EW*
*e-mail : bruce.rout@btinternet.com*

## Energy Conservation and Related Best Practices in Printed Circuit Board (PCB) Manufacturing

Martin Goosey
(Innovative Electronics Manufacturing Research Centre Loughborough University, Loughborough, LE11 3TU, UK)

and

Rod Kellner (Env-Aqua Solutions Ltd, Pailton, Rugby, CV23 0NF, UK)

## Introduction

Energy used in industrial production typically accounts for over one third of all energy consumed and it is one of the most important factors influencing the overall costs of production across a wide section of industry. Additionally, the high costs of natural gas and oil are having a major impact on European manufacturers that is directly reducing their competitiveness in global markets.

It is therefore vitally important to ensure that every viable technique for minimising energy demand within a manufacturing facility is utilized in order to reduce costs and enhance competitiveness. There are many factors which relate to energy demand and which should be actively addressed. These can be broken down into the four main categories shown in Table 1, along with the overall energy savings that can achieved.

This paper introduces some of the main energy saving techniques and related best practices that can be applied in the PCB industry. It is derived from a more substantial Best Practice Guide that has been prepared as part of a European Commission supported project called SurfEnergy. For more detailed information on energy savings best practice, reference should be made to the complete 'SurfEnergy Best Practice Guide'.

### Best Practices in PCB Manufacturing Operations

### Drag-out reduction

Drag-out loss from process chemistry is the single largest contributor to waste treatment requirements and secondary energy demand within the PCB industry.

When deploying process chemicals at elevated temperatures, drag-out loss has to be accommodated via solution replenishment and re-heating of the replaced solution volume. Reducing and recovering drag-out is therefore one of the simplest and most cost-effective strategies to implement and one which also offers significant energy savings.

Drag-out can often be reduced and recovered by numerous procedural changes that require minimal capital investment. Efforts to reduce and return drag-out will be rewarded with savings in chemical purchases, water consumption, treatment chemicals and sludge disposal, as well is in energy consumption.

Drag-out reduction can also improve quality by keeping rinses and subsequent tanks cleaner. Whilst the importance of drag-out reduction is widely recognised in respect of reducing subsequent rinsing, waste treatment and, ultimately, off-site disposal demands, the loss of a valuable raw material resource is all too often underestimated and ultimately accepted as an operational overhead.

The implementation of drag-out reduction practices will reduce the demand for rinse water. The direct correlation of drag-out and rinse water usage has resulted in the prior art within both these areas evolving into established best practice. The evolution of best practice in respect of reduction in rinse water usage has reached a higher level of sophistication than that of drag-out reduction; e.g. use of counter-flow rinse systems, water recycling systems etc.

However, what are not generally considered are the environmental and cost implications associated with drag-out other than generating a rinse water demand. Whilst environmental and cost impacts, including energy relating to drag-out are well documented, it is appropriate to note the impact on material resources contributable to drag-out.

Within the last decade, the European PCB industry has contracted significantly in the face of low cost competition from the Far East and margins have dramatically declined. It would not, therefore, be considered unreasonable to estimate that drag-out loss may be taken as typically equivalent to 15% of sales in respect of lost chemical costs. This is just the resource loss and does not take into account the cost of associated energy and rinse water, the cost of chemical treatment and, ultimately, the cost of waste disposal. Apart from the basic geometry and design of the components, the quantity of drag-out generated is affected by a number of factors and these include:

- Rack Design
- Bath Chemical
- Bath Temperature
- Surfactants

| Type of energy saving opportunity | Potential Saving/% |
|---|---|
| Waste heat and energy recovery | 35 |
| Improvements to boilers, fired systems, process heating and cooling | 17 |
| Energy source flexibility and use of combined heat and power | 16 |
| Improved sensors, controls, automation and robotics for energy systems | 4 |
| Energy system integration and best practice opportunities | 28 |
| **Total** | **100** |

Table 1 Potential energy savings for a range of different opportunities

- Slower Work Piece Removal
- Extended Drainage Time
- Agitation

For each of the above factors, methodologies and approaches for reducing drag-out have been developed. These have evolved into the best practices which are covered in more detail in the full version of the Best Practice Guide from which this paper is derived.

**Counter flow Rinsing**

Counter flow rinsing, also referred to as counter current or staged rinsing, uses a minimum of two rinse tanks connected in series. Essentially, the process involves rinse water and parts moving in opposite directions as shown in Figure 1.

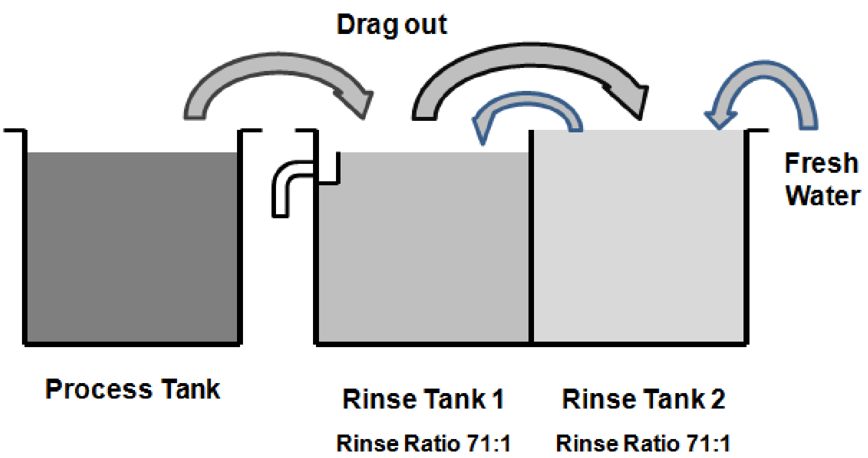



**Figure 1** Schematic representation of counter flow rinsing

Each added tank has the capability to typically reduce water consumption by >95%, depending on factors such as rinse tank agitation and drag-out. As an example a single flowing rinse of 1000 litres per hour, either within a single tank or configured as 2 x 500 litre per hour rinses, can be replaced with a two-stage counterflow rinse to give the same rinsing dilution ratio at ~33 litre per hour demand (calculated as the square root of 1000). The addition of a third counterflow rinse stage would enable equivalent rinsing at a flow rate of ~10 litres per hour (calculated as the cube root of 1000). Whilst best practice is considered to be the deployment of a three stage counterflow rinse, space restrictions and the relatively lower gain in water savings by the deployment of a three stage rather t two stage counterflow rinse system would represent the most cost effective implementation.

**Flow Restrictors**

If conductivity meters are not used, flow restrictors can be a simple and inexpensive method for reducing water consumption.

Flow restrictors are inexpensive devices that are connected in-line with the tank's water inlet piping to regulate the flow of water through the pipe

. They are typically an elastomer washer that flexes under pressure such that the higher the water pressure, the smaller the hole available for flow passage. Therefore, they maintain a relatively constant flow under variable water pressures. Flow restrictors are available in a wide range of sizes, with smaller ones being most commonly used with multiple counter flow rinse tank arrangements and the larger ones used with single overflow rinses.

Flow restrictors are ideally suited for facilities that have constant production rates. They are most effective when coupled with timer controls to ensure that rinse water only flows during rinsing operations.

**Timer and Conductivity Controls**

Timer controls operate in a similar manner to conductivity controllers; however, rather than regulating rinse water flow on the basis of rinse tank water quality, timer controls simply turn water on and off based on a pre-set time period.

Timer controls will generally have similar cost savings as conductivity controls, but will probably not result in a significant improvement in quality.

Conductivity controls are used to keep the rinse tanks operating at a desired conductivity set point and to remove much of the guessing in terms of rinse quality.

Even a cheap, hand-held conductivity meter is a worthwhile investment to evaluate the condition of rinse water.

There are two main types of conductivity sensor that find use and these are referred to as conventional and electrodeless. In many cases electrodeless sensors are preferred because they eliminate the fouling problems associated with conventional sensors. Electrodeless sensors are also easier to operate and maintain because they require less frequent cleaning. They are more versatile than conventional sensors because they are capable of measuring a large conductivity range, rather than being limited to a specific conductivity range.

Good rinse water circulation and proper sensor placement are necessary in order to achieve accurate sensor readings and efficient rinsing.

Rinse tank circulation can be ensured by using air agitation, diverters at the clean water inlet, or by an appropriate form of mechanical mixing.

By implementing a suitable conductivity control system, it is possible to reduce water use and costs associated with waste treatment, including sludge production and disposal, which ultimately equates to additional energy savings.

**Spray Rinsing**

Spray rinsing can be performed over plating, drag-out, and rinse tanks. It reduces the amount of rinse water used and can reduce chemical usage if the rinse is recovered into the plating tanks. A common use of spray rinsing is to substitute a spray rinse tank for an overflow rinse tank. Depending on the board type and configuration, spray rinsing generally uses from an eighth to a quarter of the amount of water that would be used for equivalent dip rinsing. Spray rinsing is typically most effective for flat-surfaced parts and is less effective with recessed and hidden surfaces.

The design of a spray rinse must take into account the size and shape of the part to be rinsed. Spray nozzles are available in many sizes and spray patterns and should be selected appropriately.

### Rinse Water Recovery into Cleaning/Plating Tanks

For solutions maintained at elevated temperatures, the reuse of rinse water into plating tanks can offer many advantages, including reduced chemical and water usage and reduced treatment and sludge disposal.

For this method to be effective, rinse waters need to be fed with deionised water, so that plating tanks do not become contaminated with the impurities typically found in mains water. In addition, holding tanks and filtration may be necessary. However, caution should be used so as not to add contaminants with the saved rinse, as they will concentrate during evaporation. Greater care must be taken with bath maintenance and more frequent bath analysis may be necessary. Reactive rinsing would preclude this option for acid and base tanks.

### Reduce Peak Demand/Tank Heating

Monthly electricity rates are often based on the peak demand registered by the electricity meter. Equipment that uses large amounts of power (e.g., induction loads) should not be started all at once, but instead staged. Heating tanks can account for more than 40% of overall energy costs in a facility.

Efforts to reduce evaporation will reduce energy consumption, since more than 70% of heat loss from tanks occurs due to evaporation. For example, the highest energy losses occur from solutions with air extraction and liquid agitation. The presence of air extraction above the surface of a process solution enhances the level of evaporation and thus the amount of energy lost.

Significant savings can be realized by using ball blankets to reduce tank surface area and by covering tanks when not in use.

Strategies to reduce evaporation will provide savings in both electricity and water consumption. Covering tanks when not in use may also improve quality by minimizing contamination.

### Facility Related Opportunities Specific PCB Processing Equipment

Although a large proportion of the overall energy used within a PCB manufacturing site is related to solution heating, there are other specific pieces of equipment that also use significant quantities of energy.

These typically include laminating presses, drilling machines and the various pieces of apparatus required for the primary and secondary imaging operations.

Dry film laminators, exposure units/printers and other general clean room equipment fall in this latter category (as examples of this type of equipment, a typical six spindle drilling machine may be rated at 10 kW and an electric laminating press could easily consume in the region of 50 kW of power). Much of this equipment can consume relatively large quantities of power and thus it is essential that appropriate operating methodologies are implemented whenever possible in order to maximise utilisation during a specific operational period and to avoid having the equipment operational when it is not needed.

For example, within the PCB drilling shop, in addition to the drilling machines themselves, there are also likely to be cooling units, compressors, air dryers, a vacuum system and air conditioning, all of which consume energy.

In an example of best practice, one Austrian PCB drilling company has been able to use the waste heat from its compressors, exhausters and the drilling machines themselves to heat 30,000 litres of water to 80C. The energy stored in this water is then used to provide heating for their entire building.

In the case of photoimaging, it has been found that a move to the use of fully automatic exposure units can offer higher resolution and an improved registration capability, which in turn gives better yields and thus less waste and reduced energy consumption compared to the use of conventional manual exposure units.

Similarly, the use of the latest advanced spray coating units for solder mask applications can give improved solder mask distribution, which again results in improved yields and less waste.

Where air conditioning is needed, the use of fully automated control systems to monitor and adjust the room temperature and humidity helps to reduce energy consumption, as does the use of high-accuracy sensors for temperature, humidity and air pressure monitoring.

Additionally, high efficiency water chillers with advanced functions to adjust input power according to the loading requirement can provide further energy savings.

### Conserve Compressed Air

Compressed air is often referred to as the fourth utility (after water, electricity and gas) due to its widespread use throughout industry.

It is also the most expensive industrial utility, with about 10% of all electrical energy used by industry employed in compressing air.

Although often overlooked, even small air leaks can cost hundreds of pounds per year. Leaks should be repaired quickly, as a small air leak can represent more than □1000 per year in costs.

Compressor efficiency can be improved when air intakes are located in a cool place and away from exhaust heat sources. In many industrial plants, air is supplied at a higher pressure than is actually required, resulting in greater energy consumption and increased costs.

By ensuring that leaks and pressure drops are minimised, the pressure can be properly matched to the system demand. In some cases, such as cooling, drying and air agitation, it may be more economical to use blowers instead of compressed air because the electric motors that run these systems are much cheaper to operate than air compressor motors.

Consideration should also be given to utilising the waste heat from compressors to pre-heat boiler feed water, process hot water, or for other useful tasks.

Up to 90% of the electrical energy used by a compressor is converted to waste heat. As with many approaches to saving energy, the key to making reductions is having a good understanding of how and where compressed air is used.

An optimised compressed air system will create energy savings that will impact on electricity bills and inevitably a company's bottom line. Conversely, doing nothing will ensure that the existing system will work inefficiently. It will consume unnecessary energy and require increasing levels of upkeep and maintenance, with the result that energy will be wasted and the company will incur unnecessary additional costs.

### Heated tanks

It has been shown that any process stage heated above 30C should be externally lagged, with the inclusion of the tank base.

The loss of heat by conduction through the walls of tanks can be reduced by constructing them with double walls and packing the space between with high quality lagging material such as foam, glass fibre or rock wool.

Alternatively, on single wall tanks, the outer walls can be lined with 40 mm lagging board and then fully encapsulated with chemical resistant sheeting. Adding insulation is one of the simplest ways for process companies to control energy costs.

Computer programs are freely available that enable a company to quantify the potential energy, environmental and cost savings as a result of increasing tank, pipe, and duct insulation within their industrial facilities.

### Extraction systems

The amount of air extracted from a facility in order to effect efficient extraction from the process baths can be vast and, additionally in some cases, the air output has to be made up via some form of air input system in order to keep the balance equal within the facility.

Fortunately, several steps can be taken to minimise energy consumption. For example, it is important to ensure that the extraction fan is sized correctly and is controlled via an AC inverter, so its speed can be varied and set easily. Alternatively, a two-speed motor can be utilised and the lower speed selected during periods of shut down or night time. Using a timer to bring on the fan at appropriate times before the start of a shift and to switch it off at the end is also a very useful approach.

In some larger installations, especially in winter periods, a large amount of heated air can be extracted to atmosphere. In this case, energy positive systems should be considered whereby the use of a heat exchanger fitted in the ductwork can recover up to 60% of the heat from the exhaust air and return it to the internal shop heating source.

### Improve Lighting

Lighting can account for 15% of the energy used within PCB companies. Lighting requirements can be reduced by maximising the input of natural light to the facility via skylights and windows etc, by installing motion sensors or timer controls, and by turning off lights when an area is not in use. Painting floors, ceiling, and walls white can increase reflectance, thus reducing lighting requirements. Further energy savings can be made by introducing smart monitoring and control of lighting to couple occupancy sensing with daylight linking, so that the lights are turned on or off in response to occupancy and natural light levels. Traditional light bulbs, i.e. incandescent lamps, which work by heating a tungsten filament will be completely phased out in Europe over the next few years in favour of low energy bulbs. These low energy bulbs are currently typically CFLs but LED-based lamps are now starting to become more widely available.

### Operating, Maintenance and Housekeeping Measures

Considerable opportunities for energy reductions are available through the implementation of a focused programme of operating, maintenance and housekeeping measures. It is also important to ensure that a plant is taking advantage of all possible relevant low cost physical techniques in order to ensure that energy consumption is minimized. These should be in place to avoid gross inefficiencies.

Such basic approaches include insulation, containment methods, (such as seals and self-closing doors) and avoidance of unnecessary discharge of heated water or air (e.g. by fitting simple control systems such as timers and sensors as mentioned above). Energy efficient building services should be in place to deliver the requirements of all building services demands.

For energy-intensive industries, these issues may be of minor impact and should not distract effort from the major energy issues, but they should, nonetheless, find a place in any energy use minimisation programme, particularly where they can provide an opportunity for a more than 5% reduction in the total energy consumption.

Many of the organizations promoting resource efficiency regularly state that a key to achieving optimum savings is to have a suitable measurement system in place. While it is still possible to achieve energy savings without such a monitoring and measurement system in place, having a full understanding of where and how much energy is being used undoubtedly offers the chance to maximize the potential energy savings.

Consequently, it is recommended that such energy monitoring and management techniques should be in place, noting, in particular, the need for monitoring of energy flows and targeting of areas for reductions.

Where appropriate and possible, consideration should also be given to reductions in energy consumption via management of the incoming energy supply. For example, in some cases, it may be possible to have energy supplied from a combined heat and power (CHP) source or even to consider the generation of energy from waste.

There may also be opportunities to use less polluting fuels or to consider alternative energy supplies, e.g. solar, especially if grants may be available.

Although the above sections have focused on specific examples, it is important that energy optimization is carried out in an integrated manner, since there are often synergies and additional benefits that may be achieved. For example, it is possible to become more energy and material efficient by optimising processing to give better overall process stability.

Therefore, more general approaches to manufacturing should also be considered and, where appropriate, implemented. This could encompass a zero-waste-production approach to avoid the manufacturing and processing of defective parts, thereby avoiding the generation of scrap and/or the need to rework, both of which result in the use of more energy. By moving towards zero waste a considerable contribution can be made towards both resource efficiency and energy savings.

## Benchmarking and Monitoring

A key element of any approach to the minimization of energy consumption in a PCB manufacturing environment is having an actual understanding of where and how much energy is being used. It is important, therefore, to both monitor energy consumption and to benchmark it using a suitable approach whenever possible, so that targets can be set for the energy savings that should be achievable and actual performance related to that which is realistically feasible.

Energy should be regarded as a controllable operating expense and it needs to be managed with the same expertise as other parts of a business. Therefore, it is good practice to have a specific person within the organization who has personal responsibility for energy within the facility. This dedicated person can then undertake a series of key tasks such as evaluating the company's operating systems for waste and misuse, ensuring that equipment and machinery are operated as designed, eliminating leaks, increasing insulation where appropriate and ensuring that system designs are specifically suitable for the plant's needs.

For larger organisations, establishing a team responsible for energy enables individual members to apply their expertise in specific departments.

## Summary and Conclusions

In recent years, increasing energy costs have had a significant impact on many aspects of life and the drive for improved energy efficiency is a now major factor in all manufacturing, including the printed circuit board industries.

As a consequence, there have been significant increases in process equipment energy efficiency and in process design and management approaches for reducing energy usage. However, even when specific process choices are determined by end user performance requirements, or when there are seemingly no alternative low energy processes available, there are still many areas within a facility where there are energy savings opportunities.

Energy is one of the largest controllable costs in most organisations and, because there is usually considerable scope for reducing consumption in buildings, identifying where the saving opportunities lie is often a good way to save money.

This brief paper has attempted to highlight the key areas in the printed circuit board industry where there are opportunities to save energy and to reduce costs. For further information reference should be made to the full 'SurfEnergy Best Practice Guide'.

## References


1) Energy Demand and Conservation/Management within the Surface Engineering and Allied Sectors – a Best Practice Guide, Goosey M. and Keller R. Produced as part of EC funded SurfEnergy project and available for download from www.SurfEnergy.eu.

2) 'Energy Efficiency in the Drilling Department', Ferner N., Proceedings of the EIPC 2009 Summer Conference, June 18 and 19, St Michael Im Lungau, Austria. Copies available via www.eipc.org



## Martin Goosey

Martin Goosey is Industrial Director of the Innovative Electronics Manufacturing Research Centre (IeMRC) at Loughborough University. A chemist by training with a PhD in microelectronics reliability, Martin has over 30 years experience in the electronics industry. Prior to joining the IeMRC, he was Chief Scientist and Technology Fellow with Rohm and Haas Electronic Materials. He also spent 15 years at Plessey's Caswell Research Laboratories, and also worked at the Morton Chemical Research Centre in Woodstock, Illinois. Martin is a Chartered Scientist, a Chartered Chemist, a Fellow of the Royal Society of Chemistry, a Fellow of the Institute of Materials and a Fellow of the Institute of Circuit Technology.

## Rod Kellner

Rod Kellner is an independent technical consultant in the environmental sector having specific expertise and wide-ranging experience in the surface engineering, electronics, metals, aerospace, mining and chemical industries. Rod has graduate and post-graduate qualifications in chemistry with a doctorate in chemical physics and, from an initial R&D background he has been actively engaged within the environmental sector for the past 25 years. His particular areas of expertise embrace waste minimisation and recovery based technologies, the development of new environmental methodologies and techniques, the design and implementation of turnkey waste treatment and pollution control systems and the integration of legislative and treatment demands within an industrial environmental infrastructure.

## Technical News

**Len Pillinger F.Inst.C.T.**

## Mixed news on :- RoHS v2 and REACh

*RoHS version 2 - Argument and Counter Argument*

My last report on RoHS highlighted the campaign by sections of industry and the 'green lobby' to effectively ban all halogens from electronic products. Recent developments suggest that some middle ground has been achieved.

Middle ground has not always been easy to find. In April 2006, I presented at the "IPC -Soldertec Global 4th International Electronics Conference and Exhibition on RoHS Compliance". Over lunch I found myself seated between a German industrial chemist and a local environmentalist. With the serious lack of entertainment in the chosen venue of Malmo, this was an ideal scenario for me to create some mischief and I was considering what innocent remark I could make to initiate a debate between these two gentlemen.

The Environmentalist started without me. His statement was to the effect that "There are no good halogens. They should be banned wherever possible". The Chemist enquired whether the Scandinavian was a 'Green' and received an affirmative reply. There was a follow-up question regarding why environmentalists chose the colour green which received a mumbled reply about chlorophyll.

The industrial chemist moved in for the kill; "I do not know your academic qualifications, but you must be aware that 'Chloro' indicates that you have chosen to colour yourself with a halogen!" Having been adequately entertained, I returned to the conference hall. The debate may still be raging somewhere in Sweden.

The point of my anecdote is that with environmental issues, highly polarised positions inevitably seem to be the norm rather than a balanced viewpoint.

You may recall that the designated EU Parliament 'Reporter' for RoHS v2 "(Jill Evans MEP; Plaid Cymru) was calling for the restriction of PVC and other halogenated polymers to a halogen threshold of 900ppm (0.0009%).

A recent Chemsec press release suggests that there has been a significant level of support from industry for these proposals including some key suppliers of IT equipment keen to demonstrate their green credentials:

- "Hewlett Packard is working with suppliers globally to remove these chemicals from personal computing product lines", said Ray Moskaluk at Hewlett Packard. "We know safer substitutes exist through our scientific assessment of alternatives. We support these restrictions in a revised RoHS directive."
- "Sony Ericsson is committed to a complete phase-out of halogenated organic substances from its products, and at the current time has phased out almost all brominated flame retardants (BFRs)," said Daniel Paska, Environmental Expert at Sony Ericsson. "We believe the electronics industry has a responsibility to move proactively to find substitutes to replace BFR and PVC and are therefore calling on EU legislators to show leadership on this issue by voting to tighten the RoHS directive."
- "Dell supports including BFRs and PVC among the substances restricted by RoHS, as well as a full ban on these substances in 2015," said Mark Newton, Dell's director of sustainability. "Given the ongoing discussions in the EU Institutions on the RoHS recast, we hope EU decision makers revise RoHS to prohibit the use of PVC and BFRs in electrical and electronic equipment."
- "The transition away from environmentally sensitive substances, such as brominated flame retardants and PVC is well under way at Acer. However we do not have the leverage to move the entire supply–chain on our own. Legislators can help in this process", explains Acer. "By introducing restrictions, and thereby ensuring that the entire supply–chain is on board, costs are kept down and availability of safer alternative material is promoted."

These quotes are included in a Chemsec report which goes on to assert "A recent research report released by ChemSec demonstrates that most applications of PVC and BFRs have been removed from over 500 product models on the market today, including mobile phones, computers, washing machines, coffee machines and TVs. Products from 28 companies, among them Acer, Apple, Dell, HP, Nokia, Philips, Samsung and Sony Ericsson, are listed in the report."

An important counter-argument has been eloquently put by IPC's Fern Abrams: "While the report intends to show that it is technically feasible to remove BFRs from products, it does not provide indication of any environmental benefit in doing so. The report also fails to identify the alternative flame retardants used and whether they are better for human health and the environment than the BFRs they are intended to replace. We reject the report's implication that the sheer ability to remove BFRs from a specific product proves that the action is beneficial." IPC's position is to advocate a revised RoHS to be based on sound science and fully aligned with the REACH methodology for substance restrictions.

However Chemsec point out; the use of PVC and brominated flame retardants in electronics is known to be highly problematic from both an environmental and a human health perspective. When incinerated, they have the potential to transform into some of the most toxic chemicals we have ever produced: dioxins and furans. Dioxins and furans are global pollutants that are highly persistent in the environment and can cause cancer, birth defects and neurological damage. Moreover, chlorinated dioxins are generated from the burning of PVC plastic and have been classified as one of the top global pollutants by the International Stockholm Convention. Brominated flame retardants also have the potential to generate dioxins in substandard treatment and their presence in products has been shown to present risks to workers in shredding facilities.

*So what did the EU Parliament decide?*

It appears that a balanced view has iindeed been taken.

Unexpectedly, Jill Evans MEP withdrew her call for an early ban on halogens in electronics. (Perhaps she met the German industrial chemist from Malmo!). The Parliament voted overwhelmingly in favour of:

- Further investigation into a number of substances not currently restricted by RoHS, including BFRs and PVC, but no immediate additions to the list of banned substances.
- To create better legal clarity, the scope of RoHS to be opened-out to cover all electrical and electronic equipment, rather than the current 10 categories listed in the WEEE Directive. However, they recommended that a select number of areas remain explicitly out-of-scope including vehicles, military equipment, equipment for renewable energy generation and some large-scale installations. Specific listed exclusions to be still allowed but time limited.
- An immediate ban on nanosilver and long-walled carbon nanotubes, and labelling of other nanomaterials

There is to be further debate in July. This is then followed by the European Council adopting a position and a plenary parliament meeting scheduled for October. This does sound like a laboured process which suggests that the proposed date for RoHS v2 of 2012 is likely to slip into 2013 or even 2014.

It seems that BFRs are likely at some point mid-decade to be severely restricted in electronics. However, the pressure from within the industry may create a voluntary phase-out well before the regulations are implemented. The most obvious impact on our industry will be to our flame retarded laminates which typically use Tetrabromobisphenol –A (TBBA). Although TBBA is reacted-in to the base material resin and is said to be incapable of forming dioxins and furans, it seems inevitable that TBBA will be caught-up in the drive to eliminate halogens.

### *REACh Update*

The list of candidate SVHCs (Substances of Very High Concern) has been increased to 35 with a further eight substances:

The relatively small number of 35 to date has been the subject of criticism and ECHA (European Chemicals Agency) has promised a further 200 over the next two years. The use of these SVHC is heavily restricted and their presence in articles if greater than 0.1% w/w must be notified to customers. The PCB supply chain has got off relatively lightly to date, but a list of 200+ is likely to mean significant impact in the future.

Len Pillinger
F Inst CT

REACh: 3rd List of candidate Substances of Very High Concern (SVHC) @ 10/3/2010

| Substance | CAS number | Usage |
|---|---|---|
| Trichloroethylene | 79-01-6 | Sheet metal working , degreasing metals, used in adhesives, plastics and paints |
| Boric Acid | 10043-35-3<br>11113-50-1 | Wood preservative, flame retardant, cleaner, paints and pigments, fluxing agent, lubricant, corrosion inhibitor, pH stabiliser |
| Disodium tetraborate, anhydrous | 1303-96-4<br>1330-43-4<br>12179-04-3 | |
| Tetraboron disodium heptaoxide, hydrate | 12267-73-1 | |
| Sodium chromate<br>Potassium chromate<br>Ammonium chromate<br>Potassium dichromate | 7775-11-3<br>7789-00-6<br>7789-09-5<br>7778-50-9 | Chromate finishes on metal, corrosion inhibitor, mordant for textile dyes, aluminium etchant, pigment, etchant |

## THE UK PCB INDUSTRY IN 2009

Francesca Stern of BPA

BPA has just completed an annual survey of the UK PCB industry which has revealed a few surprises.

Contrary to popular rumour there are still more than 50 PCB shops in operation in the UK.

The list includes 51 companies, including flex fabricators.

The total value of PCB production in the UK in 2009 was £129m ($202m).

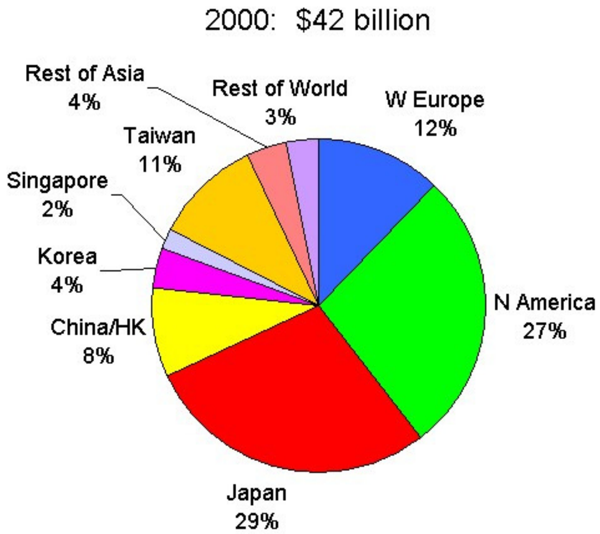
Only the top 5 fabricators had annual revenue in excess of £6.5m ($10m) and no fabricator had revenues exceeding £25m in 2009.

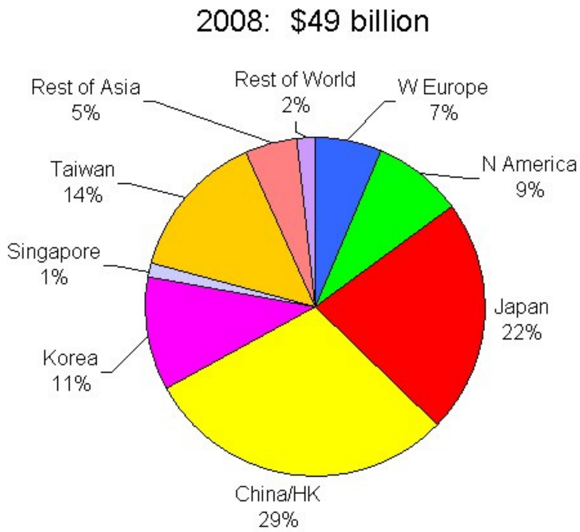
There are just 7 companies with revenues between £3.5m and £6.5m and the remaining 39 all have revenues of less than £3.5m.

In this study we look at how the UK has changed over the past ten years in its contribution to European and ultimately worldwide PCB production. World numbers for 2009 have not yet been finalised and for the purpose of this article some 2008 numbers are being used.

Figure 1 shows how Europe's share of world PCB production has shrunk from 12% in 2000 to barely 7% by 2000. At the same time, Asia's share of PCB production has increased from 58% to 82%, even with Japan's decline from 29% to 22%, while China's contribution increasing from just 8% in 2000 to over 29% by 2008

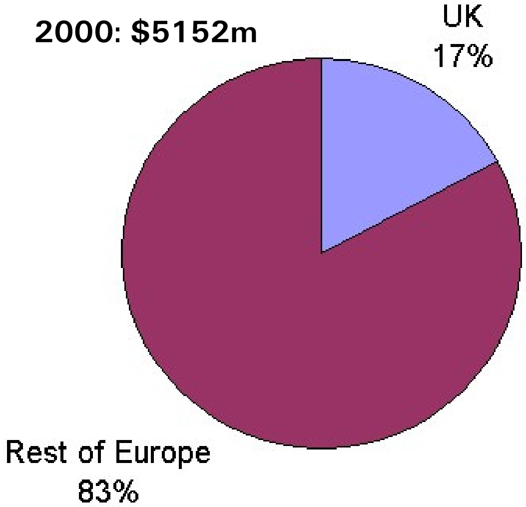
Figure 1 WORLD PCB PRODUCTION

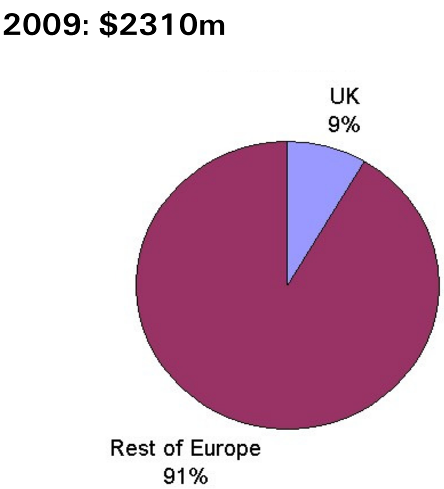



In 2000, the UK accounted for 17% of Europe's PCB production total of $5132m. By 2009, this had declined to just under 9% of the £1478 ($2310m) pie as shown in Figure 2.

Figure 2 UK SHARE OF EUROPEAN PCB PRODUCTION



The product mix for the UK has also changed over the last ten years, both in terms of board technology as shown in Figure 3 and end markets. In 2009, 58% of multilayer board production was HDI (defined as designs having microvia diameters of 150 micron or less). The UK is also heavily oriented towards industrial, instrumentation, military and aerospace as shown in Figure 4. Computer and communications which were so important a decade ago are now concentrated in Asia.

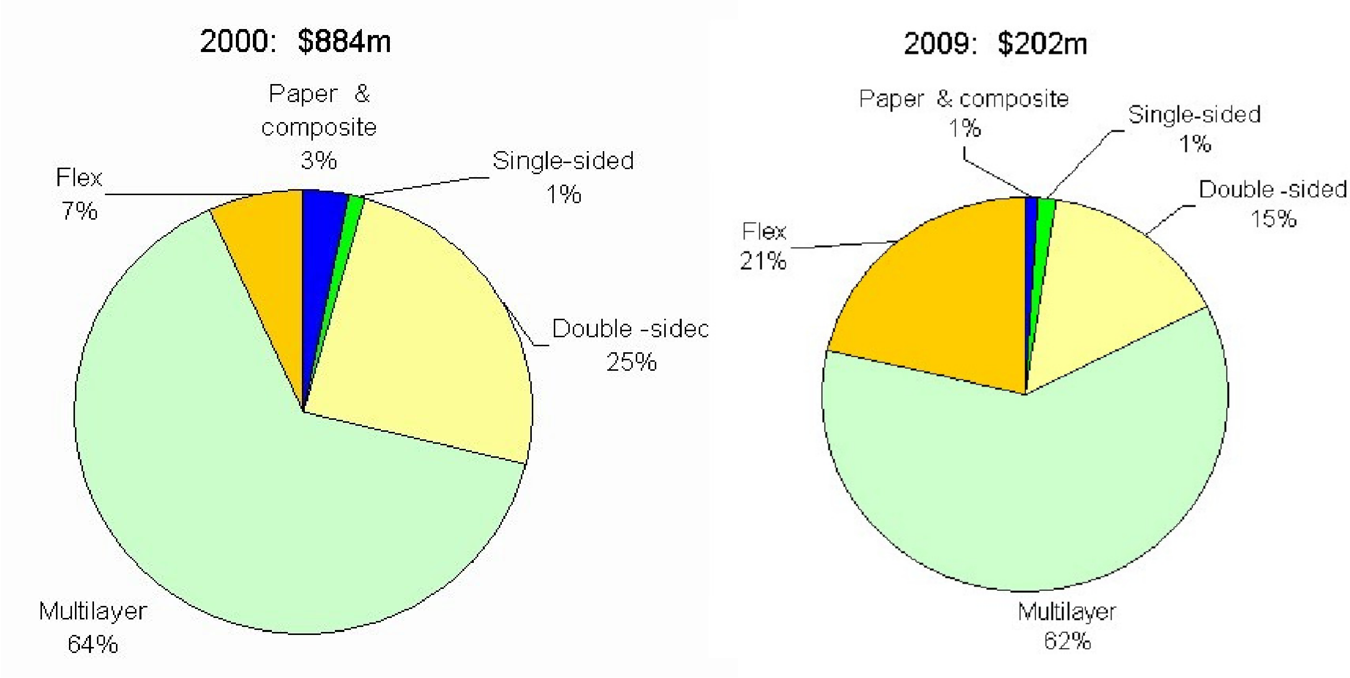



Figure 3 UK PCB PRODUCTION

Meanwhile, net imports into the UK have also decreased from $300m in 2000 to around $40m in 2008 following a decline in the market for PCBs in the UK from $1180m (£814m) in 2000 to $303m (£218m) in 2008. Most of the imports are single-sided and double-sided boards. Multilayer board volumes have also declined but UK continues to export this product category to the value of $40-45m each year.

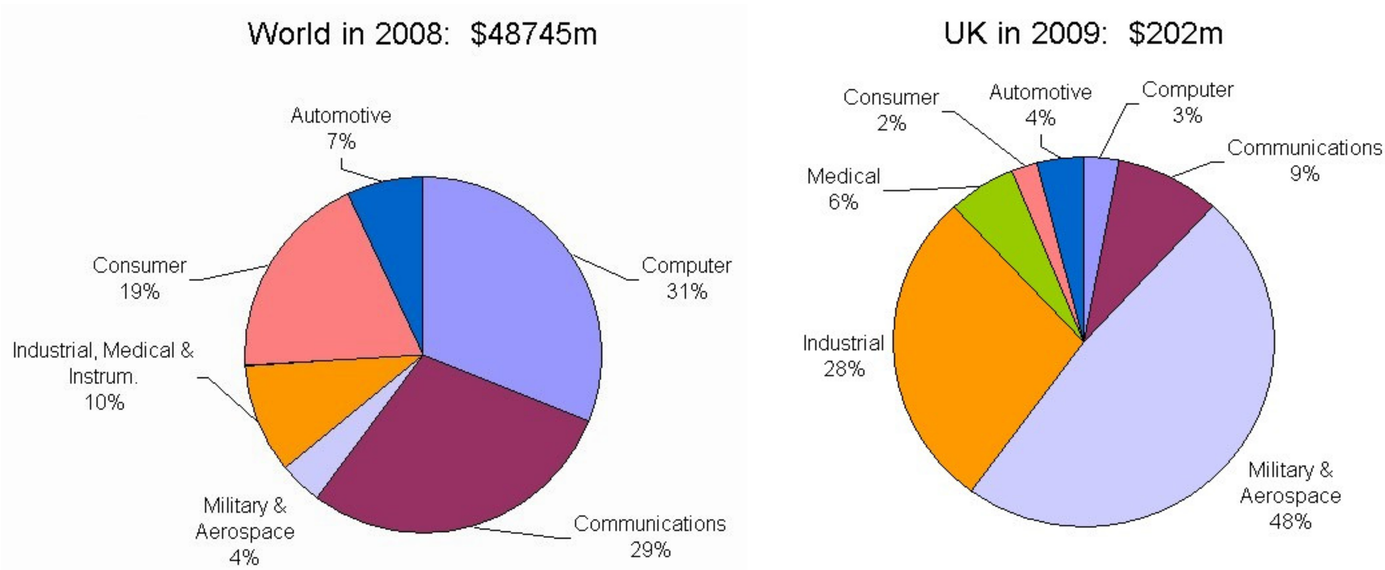



Figure 4 PCB PRODUCTION FOR END MARKETS

**Institute of Circuit Technology**
**3**6th Annual Symposium
June 2010

The 36th Annual Symposium of the Institute of Circuit Technology was held on 15th June 2010 at the National Motorcycle Museum near Birmingham, England.

ICT Chairman, Professor Martin Goosey, welcomed a full house of delegates and was pleased to report that the Institute's membership numbers continued to increase and that the ICT had been appointed project coordinator of the European Framework 7 ASPIS project on solderable finishes, which was currently at the contract negotiation stage.

As a prelude to the symposium programme, Professor Goosey briefly reviewed some emerging technologies and their implications for circuitry and interconnect. Interconnection was driven by device technology, and semiconductors, already at the 32-nanometre node, were expected move towards the 22-nanometre node during 2011-2012. Intel had already developed a 64Gb multilevel cell NAND flash device at 25 nanometres that represented a data-per-unit-area utilisation of 0.00138 square microns per bit. Could the trend continue? It was clear that the PCB and interconnection industry would continue to face challenges to provide interconnects for increasingly complex devices and their packages, and that the PCB would increasingly become integrated a functional component of electronic devices. Professor Goosey introduced a programme of six presentations, all topical and relevant to the "new and emerging technologies" symposium theme.

The first two presentations each focused on photovoltaic technologies.

Tony Ridler from Dow Chemical began his photovoltaics overview by quoting a forecast that the world annual electricity demand would likely double to 3 terawatt hours by 2030.

Solar energy presently represented only 0.3% of world electricity generation capacity but hypothetically had the potential to fulfil the global demand more than 8000 times over. With reference to the social, political, environmental and economic drivers for photovoltaic power generation, he observed that cost per watt peak was the overriding issue, and examined the various existing technologies for the manufacture of solar cells.

Two principal technologies were evident: crystalline silicon and thin film. Thin film was rapidly evolving, particularly in China, India and Taiwan, and was typically based on glass with vapour-deposited copper-indium diselenide, each panel becoming in effect a single solar cell.

But whilst research continued on different thin-film approaches, the world photovoltaics market remained dominated by crystalline silicon wafer-based technology, even though costs of materials, specifically silicon and silver, were significantly higher than for thin film.

A typical 80-metre production line had a annual capacity of 15 million wafers, each equivalent to 45 megawatts.

Ongoing development objectives were to increase the conversion efficiencies of solar cells in terms of watts per unit area, whilst reducing material costs per watt and improving manufacturing yields.

Tony Ridler's paper neatly prefaced the presentation of

Frando van der Pas from Enthone in the Netherlands, who indicated that the immediate goal of the photovoltaic market was to achieve "grid parity", the point at which the cost of a kilowatt-hour of solar energy equated to that of electricity generated from other fuel sources, and it was anticipated that this might be achievable within the next few years.

He explored routes to cost reduction in solar cell production, with the initial target of reducing cost per Watt to less than one US dollar, then working down towards a cost of $0.65.

There had been a substantial increase in the production of solar-grade silicon, which was a major cost factor, and wafers were being sliced thinner. New manufacturing methods were being introduced to achieve higher efficiencies per cell and to further reduce material costs.

One of these was to increase the available top-side area by reducing the line-width of silver contact patterns, with the added benefit of substantial savings in metal cost.

The established technique for forming these contacts was by screen-printing silver paste. The new methodology used electroplating, initially on a fine-line screen-printed silver base layer, but with the ultimate objectives of eliminating screen printing using direct metallisation, and subsequently eliminating the use of precious metals.

Because photovoltaic manufacture had evolved out of the semiconductor industry and depended largely on batch-production techniques, there was scope for a change of production philosophy towards a more cost-effective PCB-type approach. Continuous electroplating equipment already established in PCB fabrication could be adapted for processing solar cells, and the mainstream electronics industry was beginning to recognize the opportunities presented in photovoltaic manufacture.

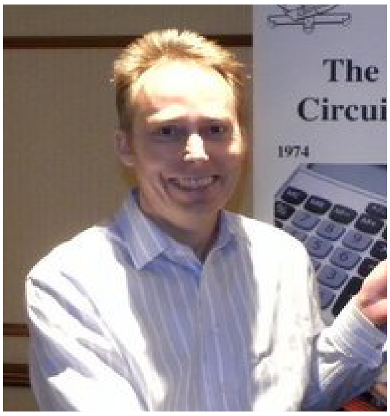
Working partnerships had already been announced between AT&S and Solland Solar, and between Schweizer and SMA Solar Technology

Mark Goodwin, MD of Ventec Europe, spoke on the topic of Thermally Conductive PCB Substrates in a context of the increasing need for dissipation of heat from electronic modules, with particular reference to the dramatic growth in applications of high-brightness LEDs.

Reviewing available methods for heat transfer and dispersal, he explained that insulated metal substrates had become established as preferred base material for the manufacture of circuits for LED applications, and offered cost effective performance with straightforward fabrication, good mechanical stability and a range of thermal conductivities to suit particular configurations. These materials typically consisted of copper foil bonded to an aluminium substrate with a thermally conductive FR4-type bonding resin, either woven-glass reinforced or non-reinforced, heavily loaded with ceramic filler.

The choice of dielectric for a given application was determined by the need to achieve a balance between thermal conductivity, dielectric strength, reliability and price. In general, reinforced dielectrics had lower thermal conductivity, but higher breakdown voltage, superior thickness uniformity, and cost less than non-reinforced grades. Woven glass reinforcement of the dielectric reduced its coefficient of thermal expansion both in the XY plane and in the Z-axis, such that the CTE mismatch between copper, dielectric and aluminium was significantly less than for unreinforced dielectric, a significant factor in determining reliability.

Goodwin urged designers to think in terms of the actual thermal impedance of an insulated metal substrate, rather than its Watts per metre Kelvin coefficient, and to avoid taking data sheet values too literally without performing their own qualification tests to select materials to suit specific applications.




Dr Andy Cobley described a research programme being carried out at Coventry University to investigate the feasibility of using ultrasonically dispersed copper nanoparticles for plating through-holes in printed circuits.

Two routes had been considered: using the nanoparticles as a palladium replacement for electroless copper initiation, or as a direct metallisation process to form a conductive layer for subsequent electroplating.

A characteristic of nanoparticles was their tendency to agglomerate, and ultrasonics was a more reliable method than mechanical agitation for keeping them dispersed.

Experiments to functionalise through-holes using 50nm copper nanoparticles, ultrasonically agitated at 40KHz, as initiator for electroless copper had shown some encouraging results, although coverage so far observed was inferior to that achieved using palladium initiation.

Work was continuing to investigate the effects of frequency, intensity and conditioner chemistry. Direct plating trials had not been successful: even at increased nanoparticle concentration, electroplate penetration into the holes was minimal.

Francesca Stern of BPA steered the subject from technology to market research, using her "driving a car" analogy to illustrate the dependence of management on good forecast information to support the decision-making process, as she presented an analysis of worldwide market and technology trends in the PCB industry.

European multilayer PCB prices were generally trending upwards, although there remained a substantial price differential between Europe and Asia. Production was growing back towards 2008 levels in China, Korea and Taiwan, and Asia's market share was increasing at the expense of Europe and North America. World PCB production had grown from 42 billion USD in 2000 to 49 billion USD in 2008 and during that period North America's share had fallen from 27% to 9%, and Western Europe from 12% to 7%, whilst China had grown from 8% to 29%.

The UK's share of the European market had fallen from 17% of 5.2 billion USD in 2000 to 9% of 2.3 billion USD in 2009, and it was interesting to note that of 51companies manufacturing PCBs in the UK, only 5 were turning over more than 10 million USD, 7 between 5-10 million USD and 21 between 1-5 million USD, whereas Germany had 78 in total, of which 22 were turning over more than 10 million USD.

Back to technology for the final presentation,

Dr David Selviah of the Department of Electronic and Electrical Engineering at University College London, gave an overview on the 3-year Integrated Optical and Electronic Interconnect PCB Manufacturing OPCB project, which had been supported by EPSRC, the UK Engineering and Physical Sciences Research Council, via IeMRC, the Innovative electronics Manufacturing Research Centre.

Dr Selviah commented that at data rates in excess of 10 Gb/sec, copper interconnect would become more seriously affected by the fundamental constraints of high frequency electronic data transmission such as dielectric loss, skin effect, crosstalk and electro-magnetic interference.

As 12 Gb/s is now on the roadmap for data storage system manufacturers there was considerable interest in incorporating optical waveguides into PCB backplanes for communication between central processor arrays, hard disk drive arrays and through data routing switches.

Benefits of optical interconnection included low loss, low cost, low power, low crosstalk and low clock skew, but they were unable to transmit electrical power.

The OPCB project explored methods for manufacturing optical waveguides within a polymer layer incorporated into the structure of PCB backplanes, with in-plane butt connections to VCSEL transmitters and detectors, using techniques compatible with those already established in commercial PCB manufacture. Several processes and materials had been evaluated for waveguide fabrication, including direct laser-writing with a Helium-Cadmium laser on photo-polymerisable acrylic resin, laser ablation using Excimer, Nd-YAG and CO2 lasers on acrylic or polysiloxane resins, inkjetting with UV-curable polymer, and photolithography.

Methods had been developed for characterisation of waveguide performance, by modelling and by measurement, to enable design rules to be formulated for incorporation into PCB CAD systems.

Dr Selviah showed examples of system-demonstrator assemblies, and quoted performance data for crosstalk, optical loss and misalignment tolerance.

The Institute of Circuit Technology continues to thrive. This was an outstanding Annual Symposium: an informative and well-balanced programme, first-rate presenters, an attentive audience and a superb networking opportunity. The venue was well chosen: central location, excellent conference facilities, and ICT Technical Director Bill Wilkie had negotiated free admittance to the museum for delegates. There seems to be a remarkable synergy between motorcycling and PCB manufacture – maybe the noise, the smell, the element of risk, the feeling of being not quite in control – and it's amazing how many PCB guys are past, present or aspiring bikers.

**Pete Starkey,**

ICT Council, June 2010

# IMAPS-UK 'Beyond Solder' Technical Seminar

National Physical Laboratory,

30thJune 2010

On 30th June 2010, IMAPS-UK held a one day technical seminar in conjunction with the Innovative electronics Manufacturing Research Centre (IeMRC), The Welding Institute (TWI) and The National Physical Laboratory (NPL) at the NPL in Teddington.

This event had the objective of providing an opportunity to learn more about the new interconnection processes and materials that were increasingly providing alternatives to conventional solder.

Chris Hunt of NPL and IMAPS welcomed the attendees to Bushey House and invited each of the exhibitors to introduce their organisations. These included Inseto, Tecan, TWI, J P Kummer, and MacGregor Systems.

The keynote presentation was given by Martin Goosey, Industrial Director of the IeMRC, who outlined the role of the IeMRC in supporting research in UK academia that was directly aimed at meeting the future technology needs of the UK electronics industry.

He then presented some of the benefits, challenges and opportunities that were possible by using solder-free connections. He reminded the audience that soldering and adhesive joining technologies had been successfully employed for thousands of years.

Moving beyond solder, there were a wide range of applications that could be addressed by the use of alternative materials and examples cited included press fit connectors, conductive adhesives, eutectic bonding and the use of nanotechnology.

One of the key reasons for moving away from soldering had been the move to lead-free and the need for higher soldering temperatures.

Another reason was associated with the growth of printed and polymer electronics, where it was often not possible for the materials used to survive soldering temperatures. Although there were real benefits to be realised from the use of solder alternatives, there could also be challenges that needed to be addressed, such as reduced electrical and thermal conductivities and properties that changed with environmental exposure.

Some examples of novel, non-solder based interconnect technologies were then given. Martin also briefly discussed the use of nanotechnology in electronics assembly and he suggested that materials such as carbon nanotubes offered great potential.

The presentation concluded with an affirmation that the world beyond solder was offering many new opportunities for those working in the electronics industry.

The next presentation was given by Mark Currie of Henkel Corporation who discussed 'Alternatives for High Thermal Power Packages' for the semiconductor industry.

He began by reviewing high power thermal packages and the market split into the different types that were used. High power large discretes tended to use solder whereas low power small discretes used adhesives in their assembly.

The market was currently dominated by the use of high lead-solders that had a RoHS exemption until 2013. Solder was used because of its high thermal and electrical conductivities, low cost and because it was well suited for small die applications on lead frames. However, solder was not used in every solution.

Mark then discussed the materials that were used to assemble thermal packages and highlighted where solder was used. He also showed the standard assembly process for these packages. The solders used in package assembly had to survive the SMT assembly process and thus needed higher melting points. There were only a few solders that were suitable and lead-free, eg Au/Sn, but cost often limited its use.

There was thus a big question about which approaches would be used once the RoHS exemption was removed. Possible solutions included conductive films for and thermosetting materials in low cost pastes. There would also be the use of silver pastes and it was anticipated that some lead exemptions might also be permitted for certain specific applications.

Mark then discussed transient liquid phase sintering (TLPS). For power packages, TLPS would need to avoid excessive brittle IMC formation and it must form a bond to typical materials such as copper, nickel, silver and even silicon.

One TLPS process was then demonstrated schematically and DSC curves shown which illustrated the increased melting point of the newly formed compound. Work was also underway to combine different technology platforms eg by combining lead-free solutions with organic carriers – the example cited combined flux technology with underfill. The aim of this approach was to effectively lock in or encapsulate the solder during the subsequent reflow process. Mark concluded by stating that there was currently no viable non-lead solution.

The third presentation was given by Simon Broadhurst of Kuliche and Soffa (K&S), who talked about 'Advanced Wire Bonded Interconnects'.

He began by giving an overview of copper wire bonding, which had first been used for discretes and power ICs. There had been renewed interest in converting to copper since 2006 when gold prices had increased significantly. Today, many of the knowledge gaps had been closed and contract assemblers were switching from gold to copper.

There was data to show that around 15% of the total market was now using copper, with the biggest market growth being in Taiwan. The majority of mass production was using 50 micron wire, with smaller diameters currently at the qualification stage.

There was also a growing trend towards the use of nickel palladium gold (ENIPIG) and bare copper finishes for wire bonding. It was a given requirement that assemblers should be able to run exactly the same baseline process with copper as for gold. Multitier wire bonding with copper was also emerging as a possibility due to the ability to perform consistent looping and packages with up to 2000 bonds were currently being produced.

One of the key challenges with copper wire bonding had been ball formation, particularly as sizes were getting smaller. The use of an inert environment during copper ball formation was found to help improve ball formation and much modelling had been performed on gas flow rates during bonding, which had helped with optimisation of the chamber.

Copper wire was much harder than gold and thus there was the potential for bond pad damage. Work had been undertaken to reduce this effect and a multistep first bond process had been developed which included an initial scrub prior to the use of the ultrasonic phase. This helped to initiate intermetalllic formation in the X-direction, which in turn helped to reduce movement of the aluminium and improved the reliability.

There were also problems that needed to be addressed on the second bond and the example of 'copper roll' was described. The second bond could be improved by using a two stage process to give a well deformed stitch shape. The capillary tip had also been modified to produce a unique granular morphology that improved the grip between the wire and the capillary during bond formation. This helped to reduce the ultrasonic energy needed and minimised pad damage.

K&S had also carried out studies to understand what was happening in the bond pads during the bonding process and a key conclusion was that a very deep copper layer was needed to avoid the possibility of pad flexing and subsequent reliability issues. This was why a nickel palladium gold finish was often added as an alternative to aluminium on the pads, as it helped to harden the surface.

Copper-aluminium intermetallic growth had been found to be much slower than for the gold-aluminium intermetallic. For the future, bond pads would increasingly be designed for copper wire bonding and new equipment would be designed for use with copper as standard.

The final presentation of the morning was 'Press Fit Connections for Automotive and High Reliability Applications' by Andy Longford of PandA Europe.

Andy began by giving an overview of press fit basics and the function of press fit technology. It had been used for many years in telecoms applications and was also now being adopted by the automotive industry. The force needed to form the connection could vary from a few grams to many kilograms, depending on the specific connector type and application.

The 'eye of the needle' type press fit connector was a standard used in telecoms applications.

The demands for automotive applications were much more stringent than for telecom. Retention forces could be from 20 to 40 Newtons and they had to be stable at high temperatures and under vibration conditions. Use of a press fit module offered advantages for connecting capacitors to PCBs in automotive applications.

The PCB requirements for press fit were also described and high Tg boards were increasingly being used. Testing criteria for press fit included insertion force, vibration in temperature, thermal shock, plated through hole integrity, high temperature exposure and a number of other properties.

For under hood and near engine applications testing to 175C was a requirement. Testing of plated through hole integrity was performed to the IEC 60352-5 standard. Andy then went on to describe press fit module development that enabled stress-free assembly.

Main automotive applications included tyre pressure monitors, junction boxes, position sensors, inverters and power modules and there was also increasing use in energy applications, including interconnects for solar power and their accompanying inverter modules.

The presentation concluded with a summary of the basic advantages of press fit technology. Ease of disassembly was a useful feature for 'green system' development. Press fit interconnects were an enabler for more reliable and robust connections for harsh environments. Motor and power control equipment were said to be the next key development area for press fit applications.

The first paper after lunch was by Martin Wickham of NPL, who presented 'End of Life Options for Electronic Interconnects'.

He began by discussing the size of the UK PCB waste stream and the implications of the WEEE Directive, which he stated had been in place since July 2007.

There was a need to develop new recycling processes for PCBs and some more artistic examples of uses for recycled PCBs were shown.

Most PCBs, however, were simply shredded into smaller pieces and consigned to smelting for metal recovery. The thermoset resins used in circuit boards were not amenable to recycling and there were few thermoplastic PCB substrate materials currently being used, although polyetherimide (PEI) had been employed in disc drives and car radios.

The work carried out by NPL had focussed on moulded substrates (MIDs) and had been performed in conjunction with the company Moulded Circuits. In this case, the polymer used to produce circuit boards via an additive process was ULTEM (PEI). Assembly had been undertaken using tin-bismuth solder (mp 137°C) and a 150°C peak reflow temperature. The boards produced achieved no failures after 1000 cycles of -55 to 125C thermal cycling testing.

However, the main approach taken had been to use isotropic conductive adhesives to assemble the components. Assembled boards had been subjected to various accelerated testing conditions and performance data was shown.

A polyester film coupled with silver loaded conductive inks had also been used to produce boards.

Thirdly, ink jet printing had been utilised in collaboration with the company Conductive Ink Technology (CIT) to produce an NPL developed 'direct write test' design on Melinex.

Performance and reliability data for the various approaches were compared; damp heat testing (85C/85%RH) was found to have the largest effect. Martin concluded by giving a brief overview of the other related projects with which NPL was currently also involved.

Norman Stockham from TWI then gave a presentation on 'Joining and Packaging Technology for High Temperature Electronics'.

He began by outlining the increasing need for electronics to operate at high temperatures; this could be as high as 800C and he detailed the melting points of conventional solders which often melted below the operating temperatures required for some high temperature electronics. The key advantages of solders were also then outlined and these included reworkability and their gap filling capability.

The temperature tolerances of various semiconductors were also shown, with gallium arsenide, silicon carbide and diamond being capable of operating at much higher temperatures than silicon.

One of the key design issues for high temperature electronics was the need accommodate the high thermal stresses that could be encountered in some assemblies due to thermal expansion mismatches.

Many organic materials were unsuitable for higher temperature assemblies and an alternative possibility was gold-silicon eutectic bonding, although it was more limited to smaller devices ( eg <8 x 8 mm).

Brazing and direct copper bonding offered other suitable joining approaches. An example of a silicon carbide wafer brazed onto a tungsten substrate was shown. It was also possible to weld directly to certain ceramics eg ultrasonic bonding of aluminium to alumina.

Other bonding techniques that could be used included friction welding and diffusion bonding.

Thermal expansion mismatch issues could be reduced by employing interlayers and TWI were investigating the use of carbon nanotubes in a composite structure to provide a high thermal conductivity interface.

Norman then discussed the various interconnect options that were suitable for high temperature electronics and he highlighted some of the possible wire and pad combinations.

Package sealing could be achieved using existing techniques and materials, although the use of polymer based materials might be limited, depending on the temperature; conventional brazing and welding techniques were probably more suitable.

The final area discussed was the provision of external interconnects and this had traditionally been achieved using solders.

Suitable alternatives could include friction acoustic bonding and welding.

Another option to overcome some of the problems was to remove the joints, or as many of them as possible, eg via the use of high density packaging and the use of embedded passive devices.

The presentation concluded with a presentation of the general thermal material hierarchy.

Solder technology would not be easily replaced in high volume PCB applications but, for high temperature electronics, there were a number of viable alternatives to solder for joining and interconnections that needed to operate at above 200°C.

The penultimate presentation of the day was from Mike Fenner of Indium Corporation who spoke on 'Bonding with Nanotechnology'.

He began by introducing the concept of nanobonding using 'NanoFoil' in a joint forming exothermic reaction similar to the 'thermite' process.

A practical demonstration of two pieces of aluminium being instantly joined was given, with the reaction being initiated with an electrical input from a PP3 battery.

The advantages of the nanobond process were then described and these included the fact that components were not exposed to reflow temperatures. It was a flux-free process, was suitable for materials with dissimilar CTEs and offered a good thermal conductivity.

The technology had originally been developed for joining large areas of dissimilar materials such as sputtering targets. Because the nanobonding process was so rapid, there was no opportunity for the typical stresses to develop.

Examples of the benefits of using 'NanoFoil' were then described, the first one was in the attachment of LEDs to a substrate, thereby avoiding conventional soldering temperatures that could damage the LED's lens; assembly yield improvements of 15 to 20% had also been achieved and there was no drop in light output.

Automated nanobond assembly equipment had been developed that used a conventional tape and reel approach and it was being used in power die attach and thermal management applications. The technology was currently at the prototype stage and still relatively expensive compared to solder, although prices were expected to drop as the production was ramped up.

The final presentation of the seminar was entitled 'Optimisation of a Process for a Fine Pitch ICA Interconnection Scheme for the Assembly of Pyroelectric Thermal Sensing Arrays' and was given by Alan Butler of Irisys.

A basic outline of the overall process developed by Irisys and the structure of the assembled devices were shown and then the individual stages of the process were described in more detail.

Printing was performed using a DEK260 printer tooled for 150 mm wafer printing. The ICA bumps were then characterised using various techniques including optical profilometry. Ceramic die placement onto the silicon was achieved using a customised die bonder with an ultra light pressure. Yield improvements had been achieved via attention to the stencil surface texture and aperture shape; it had been found that a poorly formed stencil gasket could damage the surface of the silicon.

Overall, a high yield, reliable process had been developed with print yield defect issues being <30 ppm. Building on this work with 16 x 16 arrays at 500 micron pitch, progress had been made to 47 x 47 arrays, which had a much finer pitch of 170 microns and a bump diameter of only 85 microns. An example of this array was shown and the reliability and yields were also acceptable, although not quite as good as for the 16 x 16 arrays.

Further pitch reductions would be possible, but there were a number of factors that needed to be taken into account in order to achieve the required reliability and yields.

Chris Hunt then introduced a closing panel discussion session in which the speakers answered a series of questions that focussed on future packaging opportunities. These were thought to be mainly in the automotive, oil and gas and medical areas, amongst others. At the end of this session the seminar was brought to a close.

In summary, this highly pertinent seminar provided a lot of useful information on the materials and process technologies that could be used as alternatives to conventional solders. IMAPS are to be congratulated for organising such a successful event.

Martin Goosey

30th June 2010

Speakers :
L to R : Chris Hunt, Alan Butler, Mark Currie, Simon Broadhurst, Norman Stockham, Andy Longford, and Martin Wickham.


L to R: Martin Goosey and Andy Longford

The IMAPS seminar organising team
L to R : Chris Hunt, Suzanne Millar, Matt Brown, John Carr, and Andy Longford.


L to R : Andy Longford and Matt Brown of IMAPS

## Group Members of The Institute of Circuit Technology August 2010

| Organisation | Address | Communication |
|---|---|---|
| **Anglia Circuits Ltd.** | Burrel Road, St.Ives, Huntingdon PE27 3LB | 01480 467 770 www.angliacircuits.com |
| **Artetch Circuits Ltd.** | Riverside Ind. Est. ,Littlehampton BN17 5DF | 01903 725 365 www.artetch.co.uk |
| **Atotech UK Ltd.** | William Street, West Bromwich. B70 0BE | 01210 067 777 www.atotech.de |
| **CCE Europe** | Wharton Ind. Est., Nat Lane, Winsford | 01606 861 155 www.ccee.co.uk |
| **Electra Polymers Ltd.** | Roughway Mill, Dunks Green, Tonbridge TN11 9SG | 01732 811 118 www.electrapolymers.com |
| **Faraday Printed Circuits Ltd** | 15-19 Faraday Close, Pattinson North Ind. Est., Washington. NE38 8QJ | 01914 153 350 www.faraday-circuits.co.uk |
| **Merlin Flex-Ability Ltd** | Prospect Way, Park View Ind. Est., Hartlepool TS25 1UD | 01429 860 233 www.merlinflex-ability.co.uk |
| **Graphic plc** | Down End, Lords Meadow Ind. Est., Crediton EX17 1HN | 01363 774 874 www.graphic.plc.uk |
| **Invotec Group Ltd** | Hedging Lane, Dosthill , Tamworth B77 5HH | 01827 263 000 www.invotecgroup.com |
| **Kelan Circuits Ltd** | Wetherby Road, Boroughbridge. YO51 9UY | 01423 321 100 www.kelan.co.uk |
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## The Membership Secretary's notes August 2010


This quarter has been taken up with the preparation leading up to our Annual Symposium on the 5th June. The event is reported elsewhere in the Journal, but it is worth repeating that it was a very successful day, great papers, great venue and a great buffet and we were well taken care off by the folk at the National Motorcycle Museum.

Our next Southern Area event will be held on Hayling Island on the 15th September and I look forward to seeing many of our members there.

John Walker, the Hon Sec and I are compiling a history of the Institute, which we hope to publish in the next journal. We intend this to be very much a live document and we will encourage Members to contribute. We will also place the History on our website as a permanent record – much of it has already been in place, but until recently it has been fragmented and it will be good to have it in one document

***Bill Wilkie***

*Edited by Bruce Routledge on behalf of the*
***Institute of Circuit Technology.***
*32 Stretton Close, Penn. High Wycombe, Buckinghamshire, HP10 8EW*