Journal of the Institute of Circuit Technology

Contents

vol.4 no.3 14th July 2011

2011 Events

25th January — *EIPC Road Show on Reliability at Enthone Ltd., Woking*

1st February — 15.30 Afternoon facilities tour of CCE Europe
17.00 Evening Seminar,
Chimney House Hotel, Sandbach
supported by CCE Europe

1st March — 17.00 Evening Seminar,
Arundel, Norfolk Arms Hotel

11th April - 14th April — **ICT Annual Foundation Course** ,
Loughborough University
bill.wilkie@InstCT.org

1st June — **ICT 37th Annual Symposium**,
organised in collaboration with the Sonochemistry Centre, at the Coventry University Techno Centre
supported by Ventec-Europe
bill.wilkie@InstCT.org

7th September — Facility Tour of Viking Test.
17.00 ICT Evening Seminar
bill.wilkie@InstCT.org
Newtown House Hotel, Hayling Island
http://www.newtownhouse.co.uk/
supported by Spirit Circuits.

21st September — 6th Annual IeMRC Conference
Holywell Park Conference Centre,
Loughborough IeMRC@lboro.ac.uk

Editorial

Please accept the Editor's apologies for the late publication of the July issue due to circumstances beyond his control.

This issue has several references to the manufacture of extremely fine tracks and gaps, and to copper bonding. Whilst these techniques may not immediately concern members, more detailed study is highly desirable as both techniques will have an immediate effect on our future.

Bruce Routledge
2011 Council Member and Editor

Membership

New members notified by the Membership Secretary

Associate (A.Inst.C.T.)

10182 Alistair Dickson
10183 Brian Johnstone
10184 Iain Martin
10185 John Menzies
10186 Stewart Morrison
10187 Brian Yuill
10188 Nick Hughes
10189 Jason Barnett
10190 Simon Gannon
10191 Anthony Cassidy
10192 Arkadiusz Swiezynski
10193 Niam Kapadia
10194 Dominik Zoilkowski
10195 Paul Montgomery
10196 Jason Windsor
10197 Amish Chapaneri
10198 Gary Cantrill
10199 David Eliston
10200 Mariela Baron
10201 Camelia Dijkstra

Member (M.Inst.C.T.)

10202 Emma Hudson
10203 Roger Jamieson
10204 Ian Mayoh

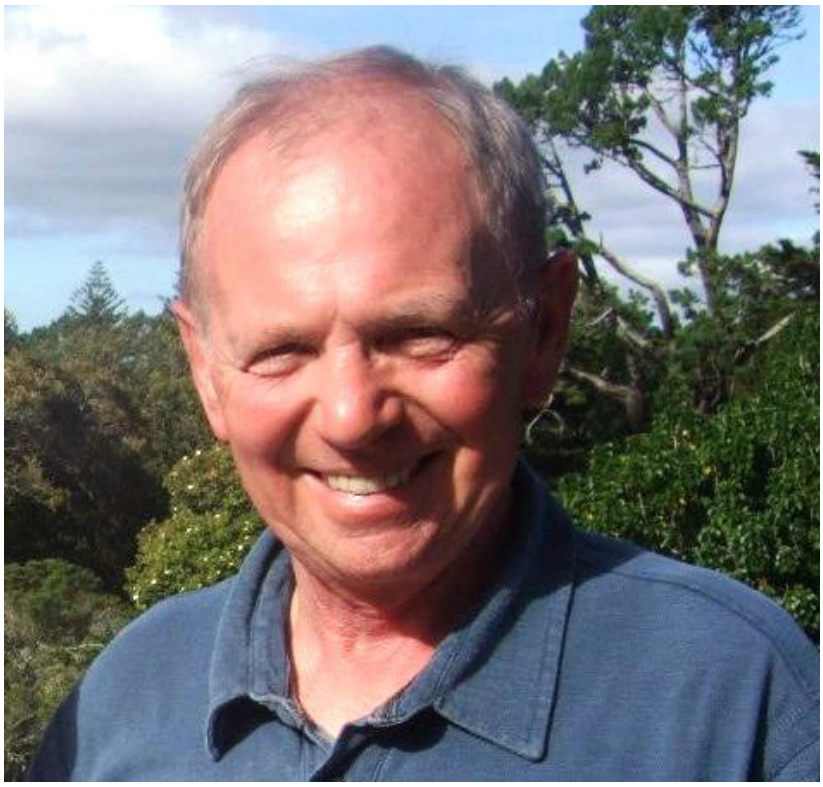
Corrections and Clarifications

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

Obituary



Frank Coultard, who died on 7th May 2011 after a struggle with cancer, was a prominent figure in the printed circuit board industry which was his life career.

Born in Liverpool in 1942, he was subsequently educated at Oundle School before going on to read Chemical Engineering at Loughborough University (where he captained the Rugby XV), both institutions for which he retained great fondness.

After leaving university, Frank worked for a while at the Marconi Research Centre in Great Baddow Essex. He then moved on and was employed by the laminate supplier, Nelco from 1982 to 1998, where he was very popular with his customers, largely working in sales out of the Skelmersdale facility.

He subsequently joined the Printed Circuit Interconnection Federation as Technical Director, at the time when it had just relocated to the Docklands area of London. This required Frank and his wife, Derry, to head south from Lancashire to live in London, something he relished with all the opportunities to indulge his love of theatre, concerts and good food.

Frank's peers always remarked on his wealth of technical knowledge and he initiated numerous technical workshops and projects to engage member companies, which in those days numbered over 400.

In 1999, he led a DTI technical trade mission to Japan with several industry colleagues; a trip that was later to be described by a fellow traveller as 'legendary', with Frank being an 'ambassador extraordinaire'. He was also a strong supporter of the PCIF's Environmental Working Group, which was active over many years in support of the UK PCB industry.

Frank was also a heavily involved with the Institute of Circuit Technology and served for many years on the Editorial Advisory Board of Circuit World.

He strongly believed that "association" was a too easily forgotten aspect of trade association life; parties were as important as the events they supported and he could cope with the full range – from the grand dinner on board HMS Belfast, to a meal in a Soho restaurant "done" the next day all over the Evening Standard for cockroach infestation. It was at these occasions when he was at his most generous and amusing. At 3 am one evening he baled out cashless colleagues recovering in the London Hilton from a stuffy black tie dinner; there was a mad rush next morning to repair the astronomical deficit before Derry inspected the account. His largesse with two barrels of beer on the PCIF stand at Nepcon was as welcome as it was short lived – stolen before the doors opened! Life with Frank was always eventful. He also enjoyed a good Merlot and it was always a pleasure to meet up with him after a long meeting for a glass of wine and a chat to end the day.

Frank retired from Intellect in 2006 and moved to Cheltenham to spend more time with his family and Coco, the family Labrador. He was a lover of the arts but had wide interests and was well read. He was also youthful in his approach to technology, possessing much of the latest gadgetry. Travel and holidays were important to Frank and for some years Gozo was a favourite haunt. Hawaii was also visited and he went several times to New Zealand, most recently this year when he became ill.

The emails pouring in following Frank's death attest to a gentleman with a great sense of humour, sensitivity and great capacity for friendship. The industry's thoughts are especially with Frank's widow, Derry, who was so supportive, and a wonderful hostess even during Frank's illness, to his sons Philip and Christian and also to his sister, Jill.

Richard Waterhouse

May 2010

Printed Electronics: Where From Here?

Steve Jones
Printed Electronics Ltd

Who's Steve Jones

- Started career as an academic for 8 years at Sheffield
- Moved into industry and set up my own service/development company in 1974
- Focussed on PCBs, split out Manchester Circuits 1978; mainly aerospace
- Sold out and buyee taken over by Viasystems Inc. 1997; then the largest global producer of circuits and big player in contract manufacture of electronics. $2bn. I became European Director of Research and Development

  Worked with most of the big players on wants and needs: mobile/fixed-line telecoms, networks, automotive, computing, instrumentation, etc
- Trained and worked with Chinese facilities to transfer low technology products
- Obvious what was going to happen with product migration and 2000 started to look at other technologies that would stay in Europe eg lasers and inkjet
- Dot.com bust in 2001/2 and European/US companies closed; retired for 2 weeks; drove wife crazy moved back into service and development leading to Printed Electronics Ltd in 2005/6. Have .com, co.uk and .eu.
- Merged with Invotec Jan 2011 to develop industrial inkjet processes
- I have spent a chunk of my life moving things out of development into production

What is Electronics ?

Electronics is about **interconnecting** and **integrating** components to form a functional device

Display, internal power, input and out,

And it does something...makes phone calls, controls the washing machine, plays a musical doorbell, etc

Electronics is so ubiquitous it has become invisible.

We don't tend to talk about electronics; we talk about the application and its functionality. Even specificity is being lost and we refer to "platforms" whose functionality is programmable eg mobile phone.

An electronic design is based on a library of component data; many suppliers and millions of man years of data on function and reliability.

Electronics has form, function and purpose, and is fit for the purpose for which it was designed ie it's reliable and durable: what's paranoia. The reliability and durability of electronics is taken for granted. The chances are we buy new when the old still works: fashion and branding has become more important than function.

It is about having a toolbox that contains all the components needed for a functional circuit

Batteries, Displays,

Resistors, Capacitors,

Silicon in its various guises,

An integration process, Etc..

★ Circuitry created with conductive and/or electro-active inks using a wide variety of

What is Printed Electronics?

printing techniques ie the inks are the components usually in the form of nano-particles in a carrier that gives an appropriate surface tension and viscosity for the printing method.

★ An electron follows the law of physics: it will follow the path of least resistance and it does not care how the path was formed.

★ We presently do not have a library of component data; few suppliers and little data on function and reliability

★ We do have a pretty bare toolbox for generic circuit products

★ However, printed electronics must also have form, function and purpose, and is fit for the purpose for which it was designed ie it's reliable and durable in the outside world

★ Whatever anybody might think of printed electronics, ... reliable it is not ... yet

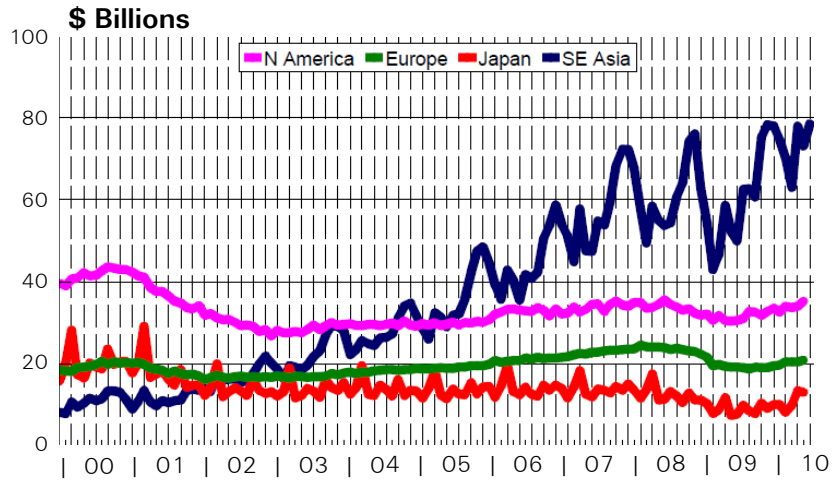
★ If printed electronics does not enhance a product, it is doomed to failure.

★ Technology does not stand still: where is OLED vs LED backlit LCD?

Why Bother ?

World Electronic Equipment Monthly Shipments

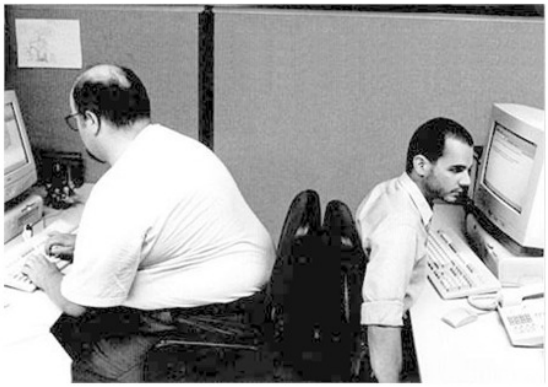
Converted @ Constant 2008 Exchange Rates



Source: Custer Consulting Group CALENDAR YEAR

In **2000** Europe and Japan each produced x 2 and the US x 10 the output of SE Asia.
In **2010** SE Asia produced ca the combined total of Europe, Japan and the US. China dominates and the growth rate is phenomenal

Why Bother ? (2)



For UK, the US and European electronics manufacturers:
things went from bad to worse in the early 2000s:
what will we be sitting next to in the next few years?

Who makes electronics:

Electronic manufacturing services

EMS

- EMS is the term used for companies that design, test, manufacture, distribute, and provide return/repair services for electronic components and assemblies for original equipment manufacturers (OEMs).
- Taiwan's Foxconn is the biggest; its Chinese turnover is $80bn and it is the biggest exporter in China
- Its China-based subsidiary plans to raise its workforce in China to 1.3 million from the current 920,000 over the next 12 months.
- 450,000 workers are employed at the Longhua Science & Technology Park, sometimes referred to as "Foxconn City" or "iPod City". The population of Cambridge is ca 120,000; Sheffield is ca 550,000; Birmingham ca 1,020,000
- Apple is Foxconn's biggest customer,
  - shipments of iPads will triple to 36.5 million in 2011 from 12.9 million in 2010.
  - iPhone shipments hit 53.5 million 2010, up from 25.1 million in 2009.
- 1.7bn mobile phones are likely to be made in 2011 and most of them will not be made by mobile phone companies.

How will PE compete or even live with the ODMs, EMSs and OEMs

- Basically you would be mentally deranged to even think about competing but we will have to live with them
- We have little infrastructure in Europe and certainly not in the UK to support such organisations: we require complex supply chains
- Printed electronic products are immature TRL 3-5 at present i.e. demonstrators/proof of concept
- A lot of rubbish is still spoken about PE: products need a market pull rather than a technology push
- There are lots of ugly babies out there; any product or process that requires a bunch of PhDs to make it work is going nowhere
- Have to think niche, new products, moving into areas where electronics has not gone
  eg smart packaging or anti-counterfeiting
- UK well placed in PE from a technology stand-point. The TSB and academic institutions have been supportive; five centres of excellence

Heroes, Frontiersmen and Engineers

- In an new technology area we need people of vision, people who are brave who will drive the industrialisation process:
  lab-to-fab
- Heroes are called heroes because they tend to be dead: they have crashed and burned in a spectacular way (tends to be collateral damage)
- Frontiersmen are called frontiersmen because they tend to be dead: face down in the sand with an arrow in the back (most of us would prefer to be heroes)
- Engineers will spend all your money and still not make a decision
- (However, engineers are critical: technology without engineering is a black hole that consumes money. You just need to keep a hand on your money and their throat.)
- Resource is required to keep the wings on and buy a Kevlar shirt
- Resource providers take risks but like to envisage a crock of gold not just a crock (look at Plastic Logic)
- Unfortunately, it takes time to convince both users and investors
- "Printed Electronics" was being hyped ca 2005 but a critical analysis of the underlying technology indicated fundamental gaps in the toolbox
- The biggest problem we saw at the time was integration methodologies and technologies: this has not changed and remains the big problem for a fragmented supply chain of small companies. There is a litter of dead integrators who could not make a living out of their platforms
- Some people can't or don't deliver and not necessarily because they don't care or are stupid but we only know what we know; not what we don't. So don't oversell your capability
- Don't look to the Hewlett Packards and Epsons; they are vertically integrated and any

products and processes will have their name on it

- Collaboration and cooperation is what is important for small companies: generally we are pretty good at this in the UK and we have many friends in industry and academia with whom we work.

Printed Electronics Ltd

- We wanted to make generic electronics ie anything. We did not want to make batteries or capacitors or develop inks, we wanted a supply chain similar to RS Components or Farnels where we could buy best in class for a particular customer specification.
- We would integrate the components because we understand electronic applications
- The DTI had the Direct Write call in 2005 and it allowed us to form the company
- The £ for £ allowed us to put together the facility in Cambridge and we spent four years working with our TSB project partners to understand the core issues, build equipment, and find and develop process solutions. I particularly thank the IfM group, Ian Hutchings, Graham Martin and Kai Hsiao; Xaar and Rob Harvey; SunChemical; Debbie Thorpe and others here in Cambridge for their particular help during the early phase
- We picked up other TSB projects but the most important thing to come out of these projects was the networking with like minded people.

I'm the biggest TSB fan in this room

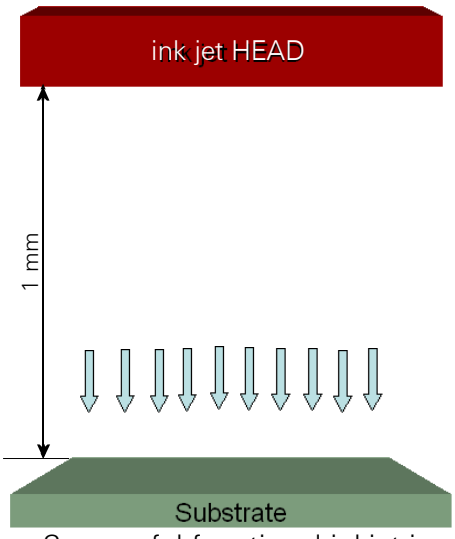
- We considered it technically, professionally and commercially inappropriate to put a cogent business plan together with a 5 year-to-market story
- One needs to be heroic and passionate, and explore boundaries but preferably avoid death
- Looking through the hype there were non-trivial issues: with inks and nanoparticles that form the interconnects and components; ink interactions with substrates to form multilayer structures; and the functionalisation of electronic attributes. These issues are still with us 5 years on.
- But the potential for PE was and remains huge and not just to replace conventional electronics but to transform where electronics can go
- Personal money was available but no comfort zone

The Toolbox

- Electronics is a generic term and we need to be able to put printed electronics anywhere and on anything
- Generic electronics requires components and interconnections that make up the toolbox
- That PE toolbox is pretty bare compared with mainstream electronics
- But we can customise products that cannot easily be done using mainstream high volume processes
- We chose inkjet printing as our preferred printing method because it is toolless, non-contact and lends itself to proof of concept demonstrators

Visualisation Tools

"The 1mm Journey"



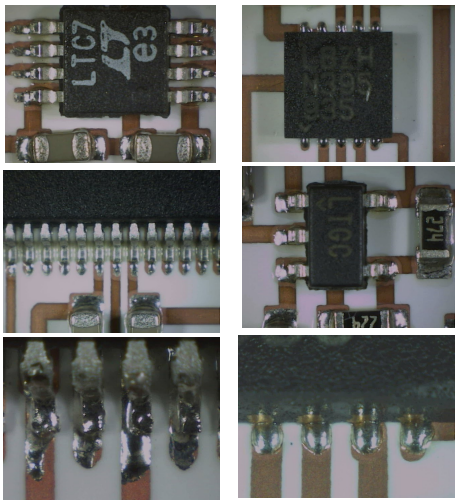
- Successful functional inkjet is entirely about the "1mm journey"
  - From Nozzle to Substrate
- Correct drop formation is controlled by the waveform
- The drop characteristics when it hits the substrate are a complex function of many parameters

Non Conformal Substrates

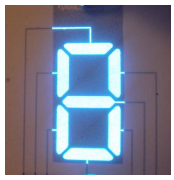
Combine Graphics: smart packaging

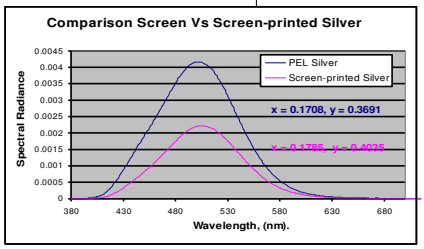

Plastic and Paper Assemblies

- Good wetting to the copper CIT process or
- Xe flashed nanoparticulate copper or
- silver base material.
- Solder joints are strong and a reasonable fillet is formed



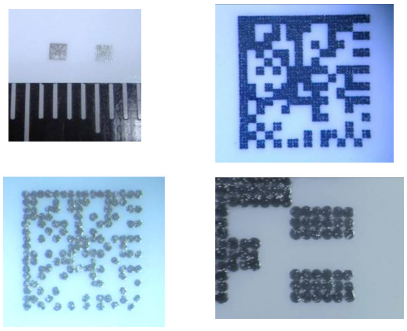
Low Cost Display Elements on Paper

Very high definition images can be produced as well as very bright images. This costs <£0.10 for materials

DataMatrix bar codes and security printing



Single pixel 2D bar codes are extremely difficult to counterfeit when everyone is different and we can overprint a covert image to 2 micron.

Where from Here?

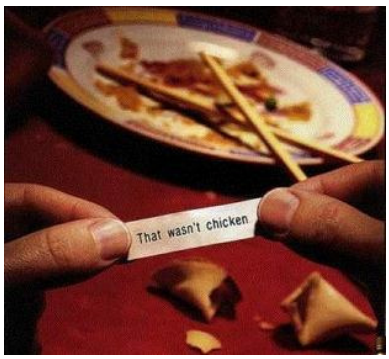
- We have a partially filled toolbox, with a good knowledge base and experience of making proof of concept products
- We have our own electronic grade paper (best in class), some good inks that work reasonably well and we understand applications
- We hire out the equipment and people to knowledgeable users; and develop processes and products for newcomers
- We run successful training courses
- We are a small company and conversations with mainstream money lenders this past 18 months has not been easy
- We took the decision to JV with a like minded company from 1 January 2011 with Invotec Circuits Ltd who had been a TSB project partner. This gives us a more stable platform on which to grow the company without the infrastructural costs that are so important to a growing company

So starts another journey!

Printed Electronics is Different. Learn to love it

"We have functionality Jim, but not as we know it!"

Mr Spock



Plastic Electronics Strategy Group

Supported by:

BIS Department for Business Innovation & Skills

Technology Strategy Board
Driving Innovation

Snapshot of current UK Capability

- Excellent science base
- Around 70 UK Businesses

} ~108 organisations[1]

- 5 Centres of excellence
  - CIKC, Imperial (DTC), OMIC, PETeC, WCPC
- UKDL closed with >450 UK organisations expressing an interest in Plastic Electronics *(most are still watching)*
- Technology is mostly pre-revenue, but some material and process areas are maturing
- New players are starting to engage from outside the conventional electronics communities
- **Now is the time to fully exploit the opportunity**

[1] Zella King/Cathy Curling review

Len Pillinger F.Inst.C.T.
(The Institute of Circuit Technology representative at REACh)

RoHS v2.0 has been agreed

The horse trading is over and the final draft text of the 'recast' RoHS Directive was published by the European Parliament and Council on the 22nd of March. From the point of view of a PCB fabricator or assembler it has to be said that that very little has changed despite significant urging by the Green lobby to add dozens more to the original list of six restricted substances. However, there are still a number of pitfalls to avoid.

Winding the clock back eighteen months, there was the prospect of a 'priority list' of about forty substances to be added to RoHS at some point in the future. The list included PVC, compounds of arsenic, beryllium copper and (at one point) all organobromines were in the frame. Whether or not actually restricted, the priority list of substances would have become a *de facto* banned list for many consumer OEMs wishing to demonstrate their green credentials.

The Green lobby has argued on the basis of the 'precautionary principle' which is being followed in REACh. It has to be said that the Greens appear to have been better organised than the industry lobby. The fact that an equitable outcome has resulted is to the credit of those involved in Brussels. It also has to be said that IPC have been very active in arguing for decisions based on science rather than fear. Fern Abrams has worked particularly hard and with great expertise.

The new document is referred to as a *recast* of the RoHS Directive rather than a revision since the new Directive when formally published will have a new number (probably known by the time this article is published). Even if you feel that your organisation is unaffected by the changes detailed below, you will have to make changes to any published media detailing the Directive.

New Substance Restrictions?

One brominated flame retardant and three phthalate-based plasticisers have been nominated: -

- Hexabromocyclododecane (HBCDD)
- Bis-ethylhexyl phthalate (DEHP)
- Butyl benzyl phthalate (BBP)
- Dibutyl phthalate (DBP)

These will become restricted according to the timetable of the REACh Regulation. Whilst these substances are not relevant to PCB fabrication, they may be of greater concern to the electronics design and OEM community, particularly with respect to PVC.

New Equipment Types impacted

The recast RoHS Directive will have its own list of categories of equipment affected. The original RoHS took its scope from the WEEE Directive. Monitoring and control equipment was included in the WEEE categories, but excluded from RoHS. This exclusion now goes with consumer products to be included three years after and industrial equipment six years after the Directive enters into force.

The position of medical equipment similarly changes with general equipment to be included three years and in vitro equipment five years after the Directive enters into force.

A new eleventh category of all other electrical or electronic equipment is to be included after eight years. There are still areas that fall completely outside the scope of RoHS such as, military / defence equipment, electronics for use in a means of transportation, active implantable medical devices, large scale industrial tools and fixed installations. Equipment to be used in space is outside the scope of RoHS. This hardly needs saying since space is surely outside the EU! Moreover, the 0.1w/w maximum for the restricted substances can hardly apply in a weightless environment! It is worth noting that other Directives for substance restrictions may apply. An example is the End of Life Vehicles Directive which limits the use of lead and other substances in road vehicles.

RoHS becomes a CE Marking Directive

There has been a glut of Pb-free and RoHS markings created in the last six years or so. RoHS now becomes the subject of CE marking. The CE mark is applied at the equipment level, but this does not necessarily mean that

the PCB fabricators and assemblers get off scot free. The Low Voltage Directive, also a CE marking Directive, has spawned a significant third-party certification industry for safety critical supplies. Similarly, certification bodies are already offering services in support of OEMs wishing to ensure that their supply chain is RoHS compliant.

Being legally obliged to detail, in a Technical Construction File for the product, how RoHS compliance has been achieved will focus the minds of OEMs who will need evidential quality documentation to support their CE 'Declaration of Conformity'.

An OEM needs to be able to trust data provided by the supply chain. The official UK Government guidance for the current RoHS Directive states "A defence of 'due diligence' is available where a person can show he took all reasonable steps and exercised all due diligence to avoid committing an offence. This may include reference to an act or default of, or reliance on information given by, a third party, in which case it must be accompanied by such information identifying the third party, as is information in the possession of the defendant."

Without such data there is little point in offering a defence based on due diligence if a product is challenged or subject to market surveillance by the authorities. Be assured that RoHS is being enforced. In the (UK) National Measurement Office's last annual report it was stated that they conducted "direct investigations of over 250 individual companies resulting in the establishing of : -

12 improvement plans,
3 EU notifications,
4 product withdrawals,
5 Compliance notices and
3 warning letters

Do not expect to make 'may contain nuts' statements which disclaim responsibility for any stray substances 'not intentionally added'. Whilst this has always been the case, the advent of CE marking for RoHS will reinforce the need for clear accurate supply chain data.

The summing-up

The recast of RoHS has been fairly kind to the PCB fabrication sector. Attempts to restrict 'all organobromines' would presumably have been the death of our workhorse flame retardant Tetrabromobisphenol-A.

More electronics sectors are being brought into RoHS. If you have key customers in one of the new product areas, it might be worth a chat with them before investing in that new tin-lead deposition system.

The paperwork, particularly materials declarations, required by customers is likely to become more formalised and subject to audit and / or challenge.

Don't forget REACh

REACh is now catching-up with the electronics industry. From the 1st July this year, producers of articles will be obliged to provide information to end-users regarding the presence of 'substances of very high concern (SVHC)' in their products. There are only thirty-eight at this time, but a further two hundred have been 'promised' by the end of 2012. There is little current impact for the PCB industry, but the extra two hundred will almost certainly include some familiar substances. The long list of materials that the Green lobby wanted added to RoHS will be considered under REACh over the next few years.

The Institute has already received a request for support from a PCB fabricator in receipt of a request to declare whether any of a list of thirty-eight SVHC was present in their products. The pain has begun!

Len Pillinger;
May 2011

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CE

The CE mark will soon be used for RoHS compliance

Uncontrolled and illegal third-world 'recycling' of EU WEEE is one factor driving the revisions to the RoHS and WEEE Directives.

Military equipment is still outside the scope of RoHS; particularly this moth-eaten decoy seen on the Lincolnshire coast

IC Package Innovation: *Choosing the Right Solution*

organised by the National Microelectronics Institute (NMI) with support from the Innovative Electronics Manufacturing Research Centre (IeMRC)

TWI, Granta Park, Abington, Cambridge. 26th May 2011

The focus of the event was emerging packaging technologies and it started with an introduction and welcome to the capacity audience by **Paul Jarvie** from **NMI**.

The keynote presentation entitled, **'Technology Trends and Roadmaps for Packaging Innovation** was given by **Grace O'Malley** of **iNEMI.**

Grace began with an overview of **iNEMI.** whose mission was to forecast and accelerate improvements in the electronics manufacturing industry for a sustainable future. iNEMI took part in technology roadmapping, collaborative projects and in producing position papers.

The 2011 Process Roadmap had recently been published. Grace then described some of the technology trends identified in the new roadmap.

Connectivity was the key to consumer electronics growth and this, in turn, was driving the development of packaging technology.

Consumer electronics required lower cost, higher performance and many other features and these meant that there was a continuing need to provide smaller package sizes.

System in Package (SiP) was said to be rapidly penetrating most major market segments and by 2014 it was estimated that there would be 15.9 billion units produced.

3D integration was also receiving much attention and there were a number of different approaches in use. Through silicon vias (TSVs) would be key to the success of 3D integration, although there were also a number of difficult challenges to be overcome.

Examples of wafer level packaging (WLP) and MEMS were also presented and these are now covered in the iNEMI roadmap.

Key long term challenges were then discussed. SiP and WLP were demanding new equipment and there were also many new reliability challenges. On the materials side, there was a move to greener alternatives and processes.

Yann Guillou from **ST-Ericsson** followed with **'Packaging Technologies for Smartphones: Trends, Challenges, Roadmaps'**. Yann began by giving an overview of his company, which was a leading supplier of platforms and semiconductors for wireless devices. The mobile industry was said to be one of the most challenging areas in terms of performance, integration and cost of packaging.

Packaging was becoming a significant percentage of the platform hardware costs and also a key contributor to the overall performance of the device.

Co-design was needed between IC packaging and the PCB in order to achieve an optimised system solution.

Yann discussed key enabling packaging technologies. The first was bumping and flip chip where ST-Ericsson had seen exponential growth in flip chip technology in its products.

The main drivers were I/O density and the demand for shorter paths to meet performance requirements.

Main technologies were solder bumps and copper pillars. With tighter pitches, solder bumping was becoming more challenging and new approaches were needed, such as those based on thermocompression.

Wafer level chip scale packaging was finding increasing use in cell phones, as it obviated the need for a laminate substrate and it enabled the smallest footprint on the PCB. Both 'fan in' and 'fan out' approaches were being used, depending on the die size. The through mould via approach was described, where vias were produced in the moulding compound that enabled die to be stacked on top of each other and connected.

Examples of the next key generation of "package on package" technologies were discussed where a number of approaches had been adopted to solve some of the key challenges such as footprint reduction, thickness reduction, increasing numbers of I/Os and decreasing pitch etc.

The final approach discussed was TSV technology, and this was being driven by the 'More than Moore' approach which included heterogeneous integration. TSVs provided an interconnect technology enabling 3D integration at the IC level.

Yann concluded by introducing the so-called 'wide I/O interface with TSV' approach, which gave the best bandwidth/power trade off. TSVs were still expensive and there were only limited products in the marketplace at the moment.

Andy Whittaker of **TWI Ltd** presented **"IC Packaging for Harsh Environments and Testing"** begining by stating that packaging needed to catch up with some of the new semiconductor technologies. He then detailed the required functions of a practical package and defined what was actually meant by a harsh environment. A harsh environment was defined as having at least one extreme stress from the application that could impact the device lifetime. All conventional packaging materials tended to have some deficiencies, especially as many of the new semiconductor devices were required to operate at very high temperatures. The

thermal capabilities of adhesives and encapsulants were then reviewed and these were also seen to be deficient at the elevated temperatures required for many new applications.

A key approach to developing more reliable packages was to reduce the number of joints and to use, for example, integrated passive technology.

TWI had also done a lot of work to extend the applicability of wire bonding through improved performance and the use of alternative materials.

Work had also been carried out to improve adhesives and encapsulants via the development of organic-inorganic hybrid materials based on silsesquioxane chemistry. These had a ceramic core with an organic shell that could be functionalised.

Andy then discussed moisture permeability testing and the approaches that had been used by TWI. Work to improve thermal conductivity using carbon nanotubes was also discussed and key thermal management material selection issues were reviewed.

The final presentation of the morning was given by **Larry Zu,** from **Global Unichip Corporation,** who gave a presentation on **'The driving force behind today's packaging technology'.**

After giving an overview of the evolution of semiconductor packaging he pointed out that there was typically a thirty year period from invention to household use. 3D packaging using TSVs was still five years away from widespread commercial use and would require a major input from the design community.

He also described the key performance and cost drivers for packaging technology.

Larry then showed how the use of TSVs could provide solutions to many of the limitations of current SiP and chip stacking approaches.

However, there were still many 3D TSV challenges including the lack of EDA tools, the lack of standards, design complexity, power and thermal issues, assembly and test and the manufacturing costs.

He also discussed the use of copper pillar technology, which had been in production since 2006, when it was first used in an Intel 'Pentium' processor. Copper pillars offered a number of advantages, including lower cost, good current carrying capability and pitches of 50 microns.

Larry summarised by saying that copper wire was now a viable mature technology for mass production.

The afternoon session had a focus on copper bonding and began with a presentation on **'the industrialisation of fine pitch copper wire bonding'** by **Brad Factor** from **ASE Europe**.

The key motivation for moving to copper had been the increasing cost of gold. However, there were many challenges that needed to be addressed if copper was to find widespread use, and these included surface oxidation, the need to use forming gas and the hardness of the copper.

There were also benefits in addition to the reduced cost and these included higher thermal conductivity.

Studies had been undertaken to optimise ball formation with copper. Generally, the process window tended to be narrower for copper than gold. If aluminium pads were used, the optimum thickness was 0.8 to 1.5 microns. Work had been undertaken to optimise the moulding compounds in terms of reduced chloride content for use with copper wire bonds, because chloride ions reacted with the IMC and degraded bond strength.

Copper wire qualification and testing were also described and this included data from accelerated testing studies.

Studies had also been carried out to investigate the growth of intermetallics with copper wire bonding.

ASE had been using 2 mil. copper wire bonding in volume production since 2002. There were 4300 wire bonders installed by quarter 1 of 2011 and it was anticipated that this would reach 6700 by the end of 2011.

The design challenges for fine pitch were also described and it was stated that the copper ball was wider for a given wire diameter and thus larger bond pad openings were recommended.

Multiple die packages were also now in volume production with copper and examples were shown. Brad concluded with a summary of the overall potential and status of copper wire bonding.

The second paper of the session was entitled **'Transition to Copper Bonding – an End User Perspective'** and was given by **Mark Dellow of Picochip Ltd**.

Picochip was described as a fabless semiconductor company that developed semiconductors, software and systems for cellular networks.

Picochip were also keen to use copper because of the large increases in the price of gold. Copper had better electrical and thermal conductivity, slower intermetallic strength and better rigidity and tensile strength. It suffered from oxidation, but this could be reduced by the use of an inert or reducing atmosphere, although palladium coatings on copper wire had been developed in 2006 and this approach gave better bond strengths.

Issues with copper wire bonding were said to include pad cracking, aluminium splash and reliability but many of these had now been overcome.

Picochip had two products in production with copper wire

bonding at the start of 2010. Bonding trials had been carried out to optimise the bonding parameters for 50 micron pads. Bond pull and shear strength had been measured for devices exposed to high temperature and thermal cycling conditions and there were no signs of failures for devices bonded with palladium coated copper wire.

The recommendation was to carry out an initial set up run with a reasonable quantity of devices to confirm that the performance required could be achieved. For wires thicker than 0.8 mil, the copper wire price was 10 to 40% less than gold and Picochip had achieved an overall cost saving of 22 to 30% by switching to copper bonding.

Adrian Dent from **Bourns** then gave a presentation on 'copper bonding in opto-package applications'. Bourns had converted their power devices from gold wire to copper. These typically had sixteen bond wires and were produced at a rate of millions per week. The company had switched to copper four years ago and had since saved around $1 million. The bond pull strengths for copper had been found to be much higher than for gold. The lead frames used were also copper and Bourns was therefore routinely undertaking copper to copper bonding. A full copper wire bonding qualification trial had been carried out in 2008 and there had been no subsequent reliability issues. Bourns was also planning to convert additional products to copper bonding.

The last presentation was by **Mark Nichols** from **Eltek Semiconductor** on **'Hi Reliability Packaging'.**

Eltek provided an assembly and test capability for its customers including a wide range of packaging. Mark began by defining reliability and stated that its absolute definition was not always the same to different people.

Some of the potential causes of reliability issues were then described and these were said to include wafer back grinding, die singulation and poor quality probe testing, where pad damage due to heavy probing could lead to subsequent failures.

Other factors impacting packaged device reliability included die attach, wire bonding, lid sealing and encapsulation.

Mark concluded by saying that it was important to consider the whole process when seeking to provide packaged device reliability.

The final part of the programme was devoted to a panel session entitled **'Packaging and the Next Decade'.** This was chaired by **David Pedder (TWI)** with panellists **Martin Goosey (IeMRC), Yann Guillou (ST-Ericsson) and Grace O'Malley (iNEMI)** and it involved a detailed interactive discussion of future packaging challenges and areas that would need further research.

In summary, this was an excellent conference with much new, useful and interesting information provided to a large, capacity audience. NMI are to be congratulated for organising such a useful and timely conference.

Martin Goosey

26th May 2011

L to R: David Pedder (TWI), Grace O'Malley (iNEMI) and Martin Goosey (IeMRC)

L to R: Larry Zu (Global Unichip Corporation) and Paul Jarvie (NMI)

The Institute of Circuit Technology 37th Annual Symposium

Coventry, UK. 1st June 2011

The TechnoCentre at Coventry University was an appropriate venue for the 37th Annual Symposium of the Institute of Circuit Technology.
"Complex PCB Solutions" was the theme and the symposium was introduced by ICT Chairman Professor Martin Goosey.

Before commencing the proceedings, Professor Goosey said a few words in tribute to the memory of Frank Coultard, formerly Technical Director of the Printed Circuit Interconnection Federation and a tireless supporter of ICT, who had recently passed away.

The keynote presentation, entitled **Polymer Interconnects for Datacom and Sensing on FR4 Substrates**, was given by **Richard Penty**, Professor of Photonics at the University of Cambridge.

Professor Penty discussed the benefits of optical interconnects and techniques for the successful integration of photonics into printed circuit boards.

A proprietary siloxane polymer had been engineered to exhibit a good balance of mechanical, thermal and optical properties. It could be spin-coated on to the PCB substrate and imaged photolithographically to produce optical waveguides, typically with 50 x 50 micron or 50 x 20 micron cross-section on 250 micron pitch, in a whole range of geometries and configurations.

These waveguides exhibited low loss and very low crosstalk, even on crossovers, and Professor Penty demonstrated that a 10-card optical backplane combining 100 waveguides each with a 90º bend and up to 90 crossovers had the capacity to carry data at Terabit level with worst-case crosstalk less that -35dB.

There had been widespread industry interest, particularly from manufacturers of supercomputers

He went on to explain how optical coupling could be achieved using electro-optic L-connectors, which had sufficient positional tolerance to enable pick-and-place assembly, and how these could be employed in designs where the electrical components and power plane were positioned on one side of an FR4 substrate and optical waveguides and ground plane on the other.

Whereas multimode siloxane waveguides presented a promising technology for use in high-speed short-reach interconnection applications, alternative applications were being explored in the integration of photonic, electronic and microfluidic components on to PCBs to produce low-cost gas sensors.

Stuart Hayton, Sales and Marketing Director at **Mutracx,** gave a frank and factual account of the realities of bringing the ink-jet primary imaging process from concept to commercial product status.

He described the background of the Lunaris project, which had set out to utilise technology developed by Océ for the graphic arts market to address the opportunity presented in printed circuit fabrication to rationalise the process of producing etch resist images on inner layers.

Hayton explained how the original technology demonstrator had been critically evaluated, in close co-operation with Mutracx's lead customers, and how each component and operation had been either refined, or where necessary re-engineered from first principles, as one of a series of functional models.

These individual elements had subsequently been integrated into a product demonstrator which fulfilled the specification objectives: 100 micron lines and 60 micron spaces as printed, with line edge sharpness better than 7.5 micron wave and front-to-back registration better than 25 microns over the total image area.

The result was a fully-automatic self-contained machine capable of being placed in-line with etch-and-strip, producing a minimum of 60 defect-free cores per hour. Ink-jet imaging of inner layers was seen not as a rival to laser direct imaging, which addressed a particular market niche, but as a production-efficient and cost-effective

alternative to mainstream contact-printing.

Beta-site evaluation was about to commence, with commercial installations planned for 4th quarter 2011.

"Don't die of ignorance...." **Wendy Heyes**, Sales and Marketing Director at **CC Electronics Europe** and Chair of the Intellect PCB Fabricators and Suppliers Group, urged her counterparts in the industry in her presentation entitled **The Future of PCB Manufacturing and the Internet.**

"You may be the best manufacturer or supplier, but you might be missing out if you don't connect, interact and communicate effectively with your customers." Her opinion was that the current generation of printed circuit buyers were very much orientated towards the internet and keen to take the opportunity to play a more active role in the process of quoting and capacity planning, provided that PCB fabricators were prepared to offer an open and honest route into their internal costing and production control systems.

CCEE specialised in small-batch quick-turn manufacture and were typically shipping about 30 jobs a day, of which 20 were new designs.

Historically, they had been quoting up to 1200 jobs per month – an enormous task if it included checking-out the data for every job and pricing several delivery-time options.

CCEE had developed a web-based system to which the customer could log-in at any time of day or night and check the status of his jobs in manufacture, look at available capacity, enter design and specification attributes of new jobs, see panelisation options and material utilisation, and generate quotes for different quantity and delivery alternatives.

"How much of your company intelligence is still locked into people?" Ms Heyes asked. The two most difficult problems had been overcome: getting peoples' knowledge and intelligence into the system, and integrating the internal system with the customer portal, and CCEE were now successfully encouraging and educating their customers to participate in a procedure which offered clear benefits to both sides.

Professor Martin Goosey returned to the platform to review the progress of the ASPIS project, funded under the European Union FP7 programme, which sought to develop more reliable materials and processes for electroless nickel immersion gold finishing of printed circuit boards.

The initial objective had been to understand the fundamental modes and mechanisms of failure associated with the finish, and particularly to characterise the "black pad" phenomenon and to predict the probability of its occurrence.

Research at the Lithuanian Institute of Science and Technology had begun by studying electroless nickel deposition parameters and their effects on phosphorus content, thickness, porosity and internal strength of the deposit, then examined corrosion behaviour in citrate media: the interaction between immersion gold and the nickel-phosphorus surface, grain boundary effects and the influence of residual phosphorus at the interface.

Indications were that corrosion of the nickel surface was due to activity in the immersion gold process and that black pad formation was promoted by a high pH in the immersion gold bath together with a high citrate content. Inadequate copper substrate preparation was another contributory factor.

The afternoon session was moderated by

Bill Wilkie
ICT Technical Director .
He introduced **Ian Mayoh**, Technical Support Manager with **Ventec Europe**

who observed that exponential increases in the need for thermal dissipation at the circuit level, driven in largely by growth in LED systems which were forecast to represent 40% of the global lighting market by 2020, had prompted increasing interest in cost-effective thermal management.

His presentation reviewed the current status of thermally conductive printed circuit substrate options in terms of performance, construction and processing, and discussed future

developments. With particular reference to insulated metal substrates, he explained the electrical, mechanical and cost considerations to be taken into account when selecting an appropriate IMS material for a particular application.

There appeared to be some confusion as to the practical significance of Watts-per-metre-Kelvin values. Mayoh commented that W/mK was simply a coefficient, and the actual thermal impedance of a material was a more meaningful measure of its suitability. Moreover, in the absence of international standards for IMS materials, data sheet values could be based on arbitrary in-house tests and might be misleading if taken literally.

He stressed the importance of carrying out proper qualification tests before specifying a particular material.

"Mostly good news but with a possible sting in the tail" was the subtitle of the presentation on the re-cast of the **RoHS Directive** by **Len Pillinger, Product Compliance Manager** with **HMGCC**,

who has a particular talent for making a potentially unexciting topic interesting and informative. The "re-cast" was effectively a scheduled review of the RoHS directive, in anticipation of tougher WEEE recycling targets.

Of forty originally-proposed new substance restrictions, only four remained in the re-cast, due to be published in June 2011 and to come into UK law by the end of 2012.

These were ;-

Hexabromocyclododecane (HBCDD)
Bis-ethylhexyl phthalate (DEHP)
Butyl benzyl phthalate (BBP)
Dibutyl phthalate (DBP)

none of which would have any particular direct impact on the printed circuit industry.

There were some changes to excluded equipment, and a new catch-all, Category 11, but military and transportation equipment and active implantable devices were not included.

The "sting in the tail" related to a significant change in CE marking, applied at equipment level, which would require a legally binding declaration of conformity, and any defence on the basis of Due Diligence would need to be backed by comprehensive supply chain data. Furthermore, liability could extend to persons other than the principal offender. Phrases like "not intentionally added", "to the best of our knowledge" and "we accept no responsibility" were to be avoided.

The final presentation came from **Jeremy Rygate, Engineering Director of Stevenage Circuits,** describing the development of

processes and materials for manufacturing stretchable PCBs, which had potential applications in medical electronics for diagnostic and monitoring purposes.

Early trials using copper patterns deposited on fibrous materials had given unsatisfactory results because of non-reversible increases in resistance upon stretching, and recent work had been carried out with a base material made by bonding copper foil to a 50 micron polyurethane film, which could be processed through a conventional PCB manufacturing route.

Although the material had limitations in dimensional stability and heat resistance, Stevenage Circuits had successfully fabricated "stretch-rigid" constructions, with copper tracks etched in a meander-pattern through stretchable areas.

Rygate showed actual examples, and demonstrated with video how conductors maintained a consistent low resistance and full elastic recovery whilst being stretched to elongations of 69%. At 113% elongation conductors began to go open circuit there was evidence of a permanent set in the elastomeric substrate.

Stretch-rigid circuits had been successfully assembled using low-melting-point solder.

In his closing remarks, **Bill Wilkie** thanked **Ventec Europe** for supporting the symposium, and **Dr Andy Cobley** for arranging the venue.

Now in its 38th year, the **Institute of Circuit Technology** continues to attract new members, to organise outstanding technical training courses, seminars and symposia, and to provide a focal point for circuit technologists to share knowledge and to network with their peers in the printed circuit industry.

Pete Starkey
ICT Council

SURFENERGY Energy Efficiency Advisor - Free Energy Saving Tools for PCB Manufacturing

The SURFENERGY project supports the introduction of energy efficiency measures by Small and Medium Enterprises (SMEs) in the Printed Circuit Board (PCB) manufacturing industry sector.

The aim is to increase the awareness of manufacturing companies to the introduction of energy management systems and the potential benefits that could result.

The project addresses non-technological barriers to the implementation of efficient energy management in this SME-dominated sector. The project also covers energy efficiency in the surface finishing sector.

The main interface between the project and SMEs will be through an Energy Efficiency Advisor Toolkit found on the SURFENERGY web site (www.surfenergy.eu). This toolkit is specifically targeted at the relevant industry sectors and enables users to reduce energy consumption, reduce costs and make informed decisions on investments. Supported by Intelligent Energy Europe, the advisor tool is provided by SurfEnergy free of charge.

Production methods involved in PCB manufacturing and surface finishing are very complex with some factories having as many as 800 different processes. Therefore, an extensive set of tools, methodologies and information has been developed to cover all aspects of these industries, including energy management systems, measuring and analysing performance, energy saving opportunities, forecasting and investment decision making.

To enable easy access to all these items, a logical graphical interface has been developed to guide the user through the process.

The SURFENERGY Path To Energy Efficiency allows the user to work from one stepping stone to the next, at each stage collecting information or completing the interactive functions. By the time the user has reached the end of the path, they will have all the necessary tools to make real energy savings to their business.

SurfEnergy Path to Energy Efficiency

Moving along the Path to Energy Efficiency, the steps help the user in the following ways:

Setting Up an Energy Management System

Ad-hoc changes to operation in an attempt to save energy will typically only make temporary improvements.

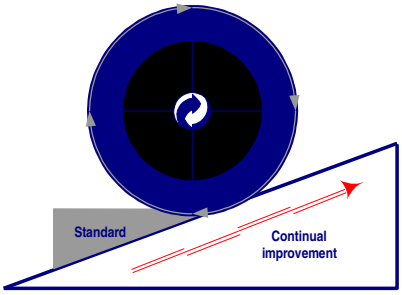
In order to sustain energy consumption over a long period of time, a formal structured energy management system is vital.

Commitment to an energy management system must be made at all levels of the company, with full awareness of the requirements throughout the organisation.

Existing methodologies such as ISO14001 and EN16001 provide a good starting point, promoting continual improvement in energy management through a plan-do-check-act process.

They also enable the establishment of an accredited system which can be used to promote the company.

SurfEnergy describes how to incorporate this into the PCB and surface finishing sector to achieve results without large amounts of effort.



Continual improvement through energy management.

Energy Auditing Requirements

Carrying out an energy audit to ascertain the current performance of the organisation is a key part to energy strategy to quantify continual improvement.

Through consultation with project experts and carrying out many audits within the project, the optimum method for the PCB and surface finishing industries has been identified.

The main steps to this audit are shown below, and full details are presented in a report downloadable from the web site.

- PHASE 1: Collection of initial information
- PHASE 2: Visit to the factory
- PHASE 3: Technical analysis of the energy situation in the factory
- PHASE 4: Energy efficiency measures proposal
- PHASE 5: Technical report

Measure Lists and Key Performance Indicators (KPIs)

To complement the auditing requirements, a list of data requirements has been drawn up for each process type.

For PCB manufacturing, the complex tasks can broadly be split into 9 categories as follows:

- Drilling
- Primary Imaging
- Lamination
- PTH Technology
- Etching
- Soldermask
- Final Finishing
- Inspection and testing
- Water Treatment

For each process the required measurable parameters for analysis are provided e.g.

annual production (m/year)
or electrical energy consumption (kWh).

From the studies in the project the KPIs for each process have also been established, i.e. those measures which define how well a process is performing.

For example this could be energy use per square metre of PCB produced.

A list of process categories has also been established for the surface finishing manufacturing sector.

The main interactive sections of the Path to Energy Efficiency are the tools *Benchmarking* and *Energy Efficiency*.

Separate versions of these tools are available for the two targeted industry sectors.

Benchmarking Tool

The benchmark tool enables a quick check on company performance to be made. Carried out on-line, the user enters general data about production and energy use. Instant feedback is then provided as to how this performance measures up against the industry standard.

This is an important exercise to carry out, because it shows how a business is performing against competitors.

The benchmarking tool only provides a quick check on performance, but will indicate the potential savings that can be achieved in terms of energy and cost.

Strict confidentiality is applied to individual company data and only aggregated data is displayed.

Energy Efficiency Tool

The energy efficiency tool is a downloadable spreadsheet designed to assist companies in fully analysing their

energy and cost performance. It goes much further than the benchmarking tool by enabling forecasts on future energy use, thus providing comparisons between *business as usual* and potential scenarios which could be achieve through implementation of energy saving techniques.

The tool requires companies to enter detailed data to produce future energy use forecasts with the main aim of improving energy performance. It also features a calculation enabling purchase decision making on new equipment.

Example of an output from the Energy Efficiency Tool

Investment Decision

Energy efficiency gains are often achieved by investment in new machinery. The ultimate decision to purchase is usually based on an economical rather than an environmental case.

Factors effecting this decision can include:

- Energy cost savings.
- Reduction in downtime and maintenance.
- Increased production rates. Increased operating hours.
- Automation of processes.
- Reduced waste.
- Improved quality.

It is necessary to analyse all these areas to conclude whether or not an investment will add value to the company.

Analysis techniques can include cash flow and net present value calculation over the expected life of the equipment.

As well as the savings which can be made, there are often funds and assistance available for equipment that offers environmental improvements. This can include grants, interest free loans and tax relief.

The information accessed through the energy efficiency advisor takes the reader through the options for using external loans or own company finance. It describes the use of a third party to either lease the equipment or to use energy services companies. It also details the potential funds available in various European countries.

Energy Saving Opportunities

The main path describes the route to energy efficiency. Additional information is also available, which can be accessed through the signpost *Energy Saving Opportunities* at the side of the path and contains the following:

- Technology Intelligence and Roadmap – Technologies, know-how + other measures with the potential to reduce energy consumption during manufacturing.
- Best practice guides - Detailed guide of surface finishing processes and related industries including advice on drag out reduction, air agitation, extending bath life, rinsing techniques and heating. Also includes general energy saving good practice e.g. space heating and lighting.
- Benchmarking methodology – A full description of how the numbers used in the benchmarking tool have been generated.
- Ideal Factory Priorities – Goes into more detail regarding the order in which to implement energy saving practices. Also reviews regulation and personnel issues.
- Life Cycle Assessment (LCA) – It is important that energy saving measures do not result in increased environmental load from other impacts e.g. toxicity, waste production. This study details methods of analysing typical processes using LCA techniques which consider all environmental issues.

The project is being completed by a consortium from across Europe. The partners are selected to offer the necessary mix of skills, experience, industry contacts and dissemination routes to enable production of useful tools for energy efficiency:

- C-Tech Innovation Ltd, United Kingdom (Co-ordinator)
- European Institute of Printed Circuits (EIPC), Netherlands
- Union des Industries de Traitement de Surfaces (UITS), France
- Protection des Métaux, France
- Env-Aqua Solutions Ltd, United Kingdom
- BESEL, S.A., Spain

The SURFERNEGY project is supported by funding from Intelligent Energy Europe.

Group Members of The Institute of Circuit Technology July 2011

Organisation	*Address*	*Communication*
Anglia Circuits Ltd.	Burrel Road, St.Ives, Huntingdon PE27 3LB	01480 467 770 www.angliacircuits.com
Atotech UK Ltd.	William Street, West Bromwich. B70 0BE	01210 067 777 www.atotech.de
CCE Europe	Wharton Ind. Est., Nat Lane, Winsford CW7 3B	01606 861 155 www.ccee.co.uk
Electra Polymers Ltd.	Roughway Mill, Dunks Green, Tonbridge TN11 9SG	01732 811 118 www.electrapolymers.com
Falcon Group	Riverside Ind. Est. ,Littlehampton BN17 5DF	01903 725 365 www.falconpcbgroup.com
Faraday Printed Circuits Ltd	15-19 Faraday Close, Pattinson North Ind. Est., Washington. NE38 8QJ	01914 153 350 www.faraday-circuits.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
Stevenage Circuits Ltd	Caxton Way, Stevenage. SG1 2DF	01438 751 800 www.stevenagecircuits.co.uk
Teknoflex Ltd	Quarry Lane, Chichester PO19 8PE	01243 832 80 www.teknoflex.com
Zot Engineering Ltd	Inveresk Industrial Park Musselburgh, EH21 7UQ	0131-653-6834 www.data@zot.co.uk

The Membership Secretary's notes - July 2011

Our Annual Foundation Course attracted a record number of delegates this year and our Annual Symposium and AGM at the Coventry TechnoCentre was also very well attended at what was an excellent venue. Looking back at the year 2010 for our AGM, in what was a difficult year for the Industry, I was struck by the high level of support we receive at all levels from the companies in the UK and I would like to add my thanks for all their efforts. Membership applications have improved over last year and the ICT Register now stands at over 240.

We are now planning for our next seminar at Hayling Island on the 7th September 2011, sponsored once again by Spirit Circuits. It should be an interesting evening, rounding off with Peter Cook, the motivational speaker from The Academy of Rock and 'Riffs and Myths'.

Bill Wilkie

The Institute of Circuit Technology

Southern Area Evening Seminar
about
Supporting Industries Needs
at
17.00 (registration 16.30)
Wednesday 7th September 2011
in the
Newtown House Hotel, Hayling Island
http://www.newtownhouse.co.uk/

Provisional Agenda

Paper from Spirit Circuits

Paper from Photo Data

Paper to be finalised

Peter Cook - Human Dynamics and the Academy of Rock
International Trouble Shooting
a creative management consultancy, with over 20 years' business, academic and consultancy experience: Leading innovation teams; nternational trouble-shooting; Internal business and OD consultancy: leadership and management development.

This interactive event will examine the following topics:

1. What can we learn from top business schools about leadership?
2. Can we learn the same lessons from the field of music?

Expect a heady combination of great ideas about the practice of leadership plus some opportunities to get involved through questions, answers, heckling (formerly known as feedback) and one or two musical demonstrations if you are inclined to do so. Or just watch from a safe distance.

The four papers will be followed by a Buffet.

During the afternoon there will be a Facility Tour of Viking Test, Petersfield - *please confirm a place when registering.*

By request, we will issue a 'certificate of attendance', to provide an official record of participation in the event. This certificate can be used to keep professional development records up to date and also as proof of career development.

Register with: **Bill Wilkie** **Technical Director, Institute of Circuit Technology**
Tel - 01573 226131 **bill.wilkie@instCT.org**