Journal of the
Institute of Circuit Technology
Vol.7 No.3 Summer 2014 Issue

2013 Events

26th September *Thursday* **ICT Evening Seminar** at Newton House Hotel, Hayling Island
bill.wilkie@InstCT.org

24th October *Thursday* 9.30 Conformal Coating Reliability Seminar
NPL & SMART Group event
at NPL, Teddington
Tony Gordon info@smartgroup.org

5th November *Tuesday* **ICT Evening Seminar** at Darlington
St George Hotel, Durham Tees Valley Airport, DL2 1RH 01325 332631
bill.wilkie@InstCT.org

2014 Events

6th March *Thursday* **ICT AGM** and Winsford **Evening Seminar**
Chimney House Hotel in Sandbach.
bill.wilkie@InstCT.org

14th -17th April *Tuesday - Friday* **ICT Annual Foundation Course**
at Loughborough University
bill.wilkie@InstCT.org

7th - 9th May *Wednesday - Friday* **ECWC13 (13th Electronic Circuits World Convention)**
at Nuremberg
eipc@eipc.org

4th June *Wednesday* **ICT 40th Anniversary Dinner**
at Wiltshire Golf Club
bill.wilkie@InstCT.org

5th June *Thursday* **ICT Annual Symposium**
at Great Western Railway
STEAM Museum, Swindon
bill.wilkie@InstCT.org

23th September *Tuesday* **ICT Evening Seminar**
at Newton House Hotel, Hayling Island
bill.wilkie@InstCT.org

THE START OF TRADITION ?

When life first evolved on earth the underlying need to communicate was created, for it has been found that even the lowest order creatures are able to convey basic information to each other. So communication is an age-old problem. It is a need which first has to be recognised so that the ability to do it can then be developed.

Mankind was quick to recognise this need and to develop the ability to communicate, one with another, at first over line-of-sight distances and then over great distances even to remote locations in space. Visual signalling gave way to telegraphy and telephony and then to the use of electro-magnetic radiation in radio and television, for rapid and efficient transmission by code and by the spoken or written word. Progress in every technological field has created the need for better methods by which to convey information from one place to another and this has had led, through different technologies, to the modern day usages of electronics for the distribution of the the written and spoken word around the World. Telecommunication, data transmission, data storage and retrieval, and video systems are now all commonplace techniques and they all involve electronics which uses the printed circuit as a base component, custom built.

Such are the rapid strides of progress in the development of electronic technology that data processing capability is being concentrated into devices of ever decreasing size, such as integrated circuits. The advent of microelectronics is continuing this trend with introduction of microprocessors and techniques for making silicon 'chips' of postage stamp size having literally millions of densely packed active junctions. Naturally there are those who say this trend is ringing the death knell of the printed circuit industry, but nothing could be further from the truth.

Practical and economical limitations related to system design, and the limited ability for such devices to be modified by designers, will dictate their stabilisation at a useful size. This implies that they will have to be mounted and interconnected - the very role of the printed circuit - in accordance with the particular system requirements. . So the printed circuit is likely to remain an essential part of functional systems and equipments for the foreseeable future - in spite of those who say it is becoming obsolete - until such time that a completely new technology is first discovered and then developed.

Born just over 25 years ago, this young Printed Circuit Industry is thus assured of a long life yet. Its 'coming-of-age' is epitomised by the Industry's first ever World Convention which starts on 5th June this year *(1978).* The United Kingdom has the honour of having been chosen as the first venue and the prestige which this creates naturally extends to the Institute of Circuit Technology, one of the prime sponsors and the only British learned society which embraces the whole field.

Such a Convention organised to bring together for the first time all the top level workers from different parts of the world taxes the discipline of communication to the utmost. Not only is there a vital need to transmit information and ideas in different languages to different countries, but it is essential to be able to understand clearly and without ambiguity the reasoning behind the data which is being communicated. The task is not easy despite the present day sophisticated aids, but it is well worth while when all the hard work culminates in a face-to-face meeting of the World's highest authorities in printed circuit technology. For there is still no finer way to communicate the latest advances than to use the spoken word in live discussion; and how better can this be achieved than by arranging for all concerned to meet at an international conference ?

So, although wafer-thin 'chips' of silicon with millions of millions of implanted active elements coupled by printed circuits might well be the heart of the means of communications today, they cannot displace the human voice raised intelligently in discussion. The ICT is therefore justly proud to be one of the organisers of the Printed Circuit World Convention **1978** which, it is hoped, will be the first of many and, in the printed circuit industry, the beginning of an enduring tradition Worldwide.

R. JOSEPHS *1978 Chairman*
Institute of Circuit Technology

Membership

New members notified by the Membership Secretary

10312 Iesha Mossman A.Inst.C.T.
10313 John O'Neill A.Inst.C.T
10314 Steve Jones A.Inst.C.T
10315 Jodie Burr A.Inst.C.T
10316 Ian Craig A.Inst.C.T
10317 Graeme Martin A.Inst.C.T
10318 Paulene Meehan A.Inst.C.T
10319 Diane Hutchinson A.Inst.C.T
10320 Xenxo Docal A.Inst.C.T
10321 Joane Kirk A.Inst.C.T
10322 Andrea Oldroyd A.Inst.C.T
10323 Gina Kinson A.Inst.C.T
10324 Sue Summers A.Inst.C.T
10325 Steve Bowers A.Inst.C.T
10326 Nathan Rogers A.Inst.C.T
10327 Tom Evans A.Inst.C.T.
10328 David Edwards A.Inst.C.T.
10329 Ben Conroy A.Inst.C.T.
10330 Bradley Hildreth A.Inst.C.T.
10331 Craig Putham A.Inst.C.T.
10332 Mark Sanford A.Inst.C.T.
10333 Connar Ballard A.Inst.C.T.
10334 Philip Skillen A.Inst.C.T.
10335 Alicia Simpson A.Inst.C.T.
10336 Heath Stoyle A.Inst.C.T.
10337 Paul Rickard A.Inst.C.T.
10338 Dan Grimston A.Inst.C.T.
10339 Sean Jones A.Inst.C.T.
10340 Graham Davidson A.Inst.C.T.

Corrections and Clarifications

It is the policy of the Journal to correct errors in the next issue.
Please send corrections to : -
brucer@john-lewis.com

The Journal of the Institute of Circuit Technology is edited by Bruce Routledge on behalf of the

Xenxo Candia Docal

Report of 'Project Review Meeting' at the University of Leicester where the latest developments of :-

Sustainable Solder Flux from Novel Ionic Liquid Solvents

(A project supported by the Innovative Electronics Manufacturing Research Centre)

were revealed, explained and discussed.

by **Pete Starkey**

Dr Andrew Ballantyne

Having been an interested member of the audience at the Institute of Circuit Technology's Winsford Seminar, when Dr Andrew Ballantyne described research at University of Leicester exploring the potential benefits of ionic liquids as replacements for conventional soldering fluxes, [*see Vol.7No.2]* I was delighted to accept an invitation to visit the university and to sit in on a project review meeting, where latest developments were revealed, explained and discussed.

Dr Ballantyne gave a comprehensive account of recent, current and ongoing work on applications in electronics soldering of the class of ionic liquids known as deep eutectic solvents, which had the ability to dissolve metal oxides without the need for acidic activators.

The project, supported by the Innovative Electronics Manufacturing Research Centre, aimed to achieve a better understanding of the surface chemistry, to examine feasibility and functionality, to test and validate soldering to printed circuit boards with various surface finishes and to assess the market opportunities for commercialisation.

He reviewed the results of preliminary solderability testing with SN100C lead-free alloy on a range of PCB finishes including bare copper, OSP, ENIG, immersion silver, immersion tin, tin-lead HASL and lead-free HASL, on surface-mount pads, through-holes and BGA pads. Generally DES fluxes had performed remarkably well, an exception being a tendency to slow through-hole filling, and this effect could be overcome by dilution of the flux with water. Stainless steel and nickel-chrome had also been successfully soldered.

The interfacial properties of metal substrates such as copper, silver, gold, nickel and aluminium had been studied and characterised by scanning electron microscope - energy dispersive x-ray elemental mapping, x-ray photoelectron spectroscopy, Fourier-transform infra-red functional group mapping and atomic force microscope three-dimensional profiling.

The study had been extended to PCB test boards, with a focus on SAC 305 lead-free solder. DES fluxes had been prepared from organic salts with a range of organic hydrogen bond donors, and the influence of formulation on solderability and the nature and quantity of breakdown products had been examined. Some interesting observations had been made on the metal dissolution process during soldering, and the mechanisms were being further investigated

BGA reflow soldering trials had been carried out in co-operation with the Materials Technology Centre in Coventry. In the first instance, using BGAs with 500 micron solder balls and PCB test coupons with ENIG finish, reflow soldering was done using flux only, and no added solder paste. Several DES fluxes were compared with a commercial flux as reference. Although initially some missing bonds were apparent, dilution of the DES flux with water gave significant improvement, with results at least as good as achieved with the commercial flux.

DES formulations had been evaluated as hot-air solder levelling fluxes, in co-operation with Merlin Circuit Technology, and

BGA	Ball Grid Array
DES	Deep Eutectic Solvents
ENIG	Electroless Nickel / Immersion Gold
HASL	Hot Air Solder Levelling
SN100C	proprietary lead-free solder (it actually contains tin, copper, nickel and Germanium)

remarkably successful results had been observed, the DES fluxes giving faster and more complete wetting of PCB features than standard commercial fluxes when used with SN100C lead-free solder. A tendency to pick up dross on the solder mask appeared to be surface-tension related, and could be overcome by incorporating surfactants into the DES formulation.

An interesting outcome was the ability to solder-level PCBs with an electroless nickel finish, not previously achievable with conventional fluxes, giving the prospect of a novel solderable finish as an alternative to ENIG.

A very recent development in cooperation with Qualitek was a solder paste based on DES flux, although its effectiveness in PCB assembly had yet to be demonstrated.

Work was in progress to develop practicable methods based on DES for soldering aluminium, traditionally an extremely difficult material to solder.

Dr Ballantyne's presentation initiated some lively discussion amongst the project collaborators, and many practical and theoretical issues were debated at length, generating valuable feedback to the benefit of the future direction of the project.

Pete Starkey,

Connect007, April 2014

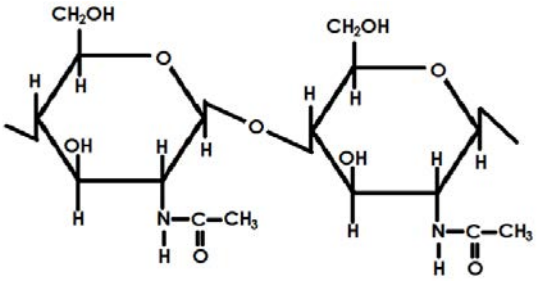
Crab Shell Biosorbents and Metal Recovery from PCB Effluent

by Dr Emma Goosey

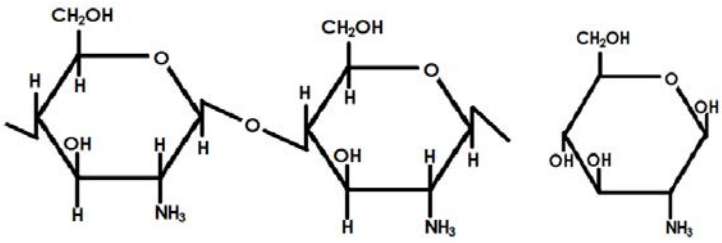
Dr Emma Goosey

At the beginning of the year this journal introduced a new project in which the ICT was playing an active part. The project was STOWURC (Sustainable Treatment of Waste Using Recycled Chitosans), which planned to use crab shells to remove and capture metals from PCB effluent. Nine months into the project, exciting developments have been achieved and this article gives a brief update.

Chitosan, the product of interest, is a natural polymer (structurally similar to glucosamine). It is produced from chitin, the polymer naturally formed in crab shells (and other crustacea) and fungi cell walls, and it is within these that the majority of the world's chitin resides. Chitin and chitosan are of particular interest because of their biocompatibility compared to most synthetic polymers. The natural polymer characteristics include biodegradability, non-toxicity, adsorptive properties and chelating abilities and these materials are not currently commercially synthesizable.



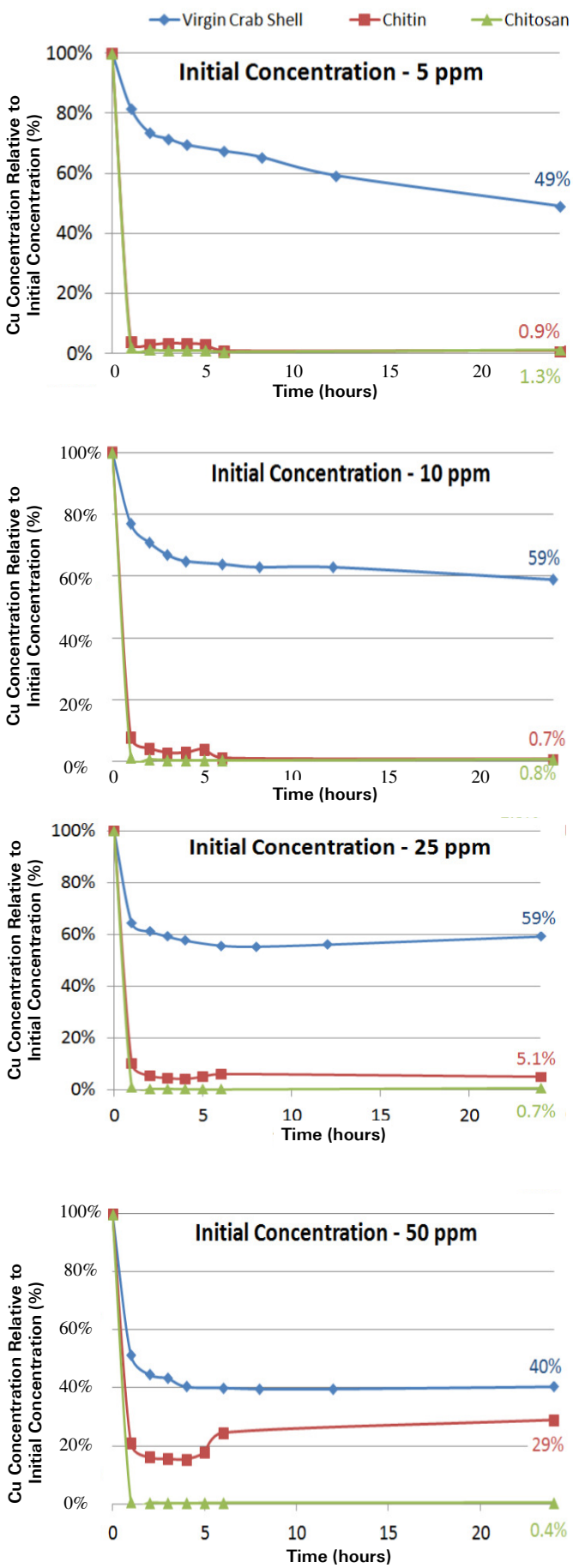
Chitin Glucosamine



Chitosan

Brown crabs (*Cancer Pagarus*) are the most commonly fished crabs in UK waters and provide the raw shells from which the STOWURC biosorbent is produced. These crabs are memorable by their pie-crust like detailing around the shell, and grow to be >25 cm in diameter. Approximately 30 ktonnes of crabs are landed in the UK each year and, once the flesh has been removed, there is a large amount of shell waste to be discarded.

A crab shell contains 20 – 30% chitin and, to remove it, acid is applied to dissolve the calcium carbonate, followed by an alkali treatment remove the proteins and fat. These stages are performed on crushed and pulverised crab shells, and result in a fine particulate being formed. To produce chitosan from the chitin, a further acid treatment is employed and deacetylation of



the chitin polymer occurs. The greater the level of deacetylation, the more efficient the chitosan is at removing metals from solution.

Laboratory tests have indicated that relatively pure chitosan flakes can be produced from the crab shells; which has proven to be more efficient than commercially available chitosans. The efficiency of the materials has been tested on model copper effluent solutions and results indicate that >60% of Cu can be removed using un-treated crab shells, >70% using chitin and >99% Cu using chitosan. The speed at which the metal uptake occurs ranged between 5 minutes and 4 hours, with the refined materials being the fastest absorbers.

In the current climate, with primary raw material resources becoming more scarce, the impact of EU environmental policies for waste management and increasing metal prices, making use of chitosan from crab shells offers an economically viable and sustainable effluent treatment method. Previously, the costs of alternate disposal methods for crab shells were lower and unregulated, allowing both disposal at sea and landfill to be economically viable.

However, this is no longer the case and using the shells for chitosan production can add-value to a waste material, and provide a financial incentive for diverting the material from landfill.

Utilising the crab shells in this manner is thus preventing land fill, which can be associated with adverse environmental effects from run-off and methane releases, as well as the arising costs for disposal. Additionally, the simple introduction of the biosorbent to the effluent and the high metal recovery efficiency (shown to remove > 99% of metals in lab tests) potentially offers a cost effective alternative to ion exchange resins and other effluent treatment methods used in the PCB and related industries.

The project will continue with the optimisation of metal recovery by electroplating, and regeneration of the chitosan for continued use. Further updates on progress will be provided in future issues of this journal but, in the mean time, more information can also be found on the project website; www.stowurc.co.uk

Dr Emma Goosey
June 2014

Review of the UK PCB Industry in 2013

by **Francesca Stern F.Inst.C.T.**

Francesca Stern F.Inst.C.T.

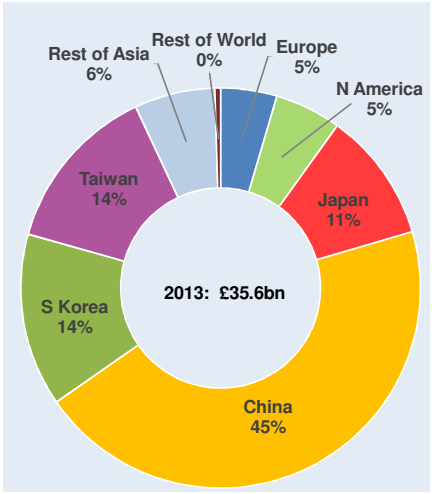


Fig. 1 Global PCB Production in 2013

There are 59 PCB fabricators remaining in the UK including 8 who specialise in manufacturing flexible circuits. Some PCB fabricators also import PCBs for resale as do multiple distributors. UK PCB fabricators serve not only the UK electronics equipment production markets but also export substantial quantities to mainland Europe, North America and Asia. All the figures reported here are based on a detailed survey of UK fabricators as well as a global survey and information collected from various sources such as annual reports, trade organizations and government statistics departments.

Annual revenues from sales of PCB made in the UK in 2013 are estimated at £135m, a 2.9% decline on 2012 revenues of £139m.

In the context of global PCB production, total Europe is estimated at £1.65bn ($2.54bn) or just 5% of the global total of £35.6bn ($55.7m) (see Fig.1 *to left*). UK PCB production accounts for 8% of W Europe's production and slightly less than a 0.5% of total world production.

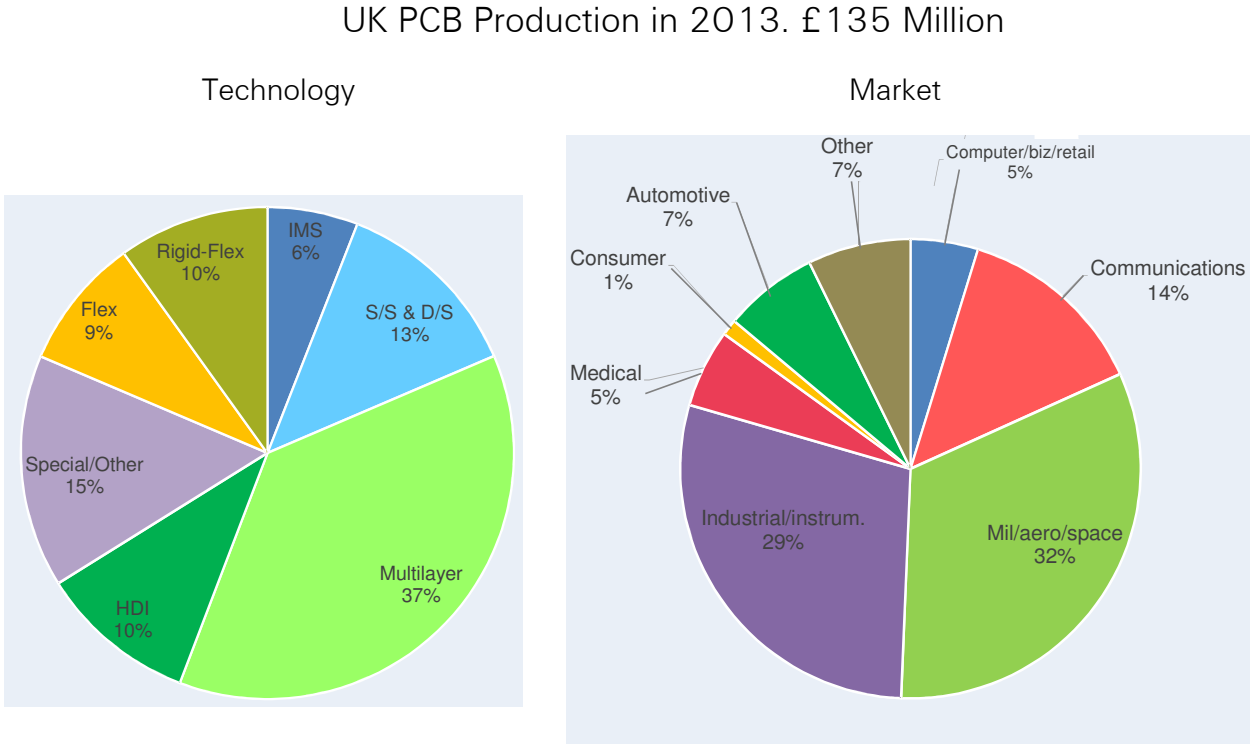


Fig. 2 shows UK PCB production revenue totals split by technology and by market sector

Of the 59 fabricators remaining in the UK, 41 (69%) had sales revenues (this excludes resales and assembly activities) of less than £2m in 2013. This is shown in Figure 3.

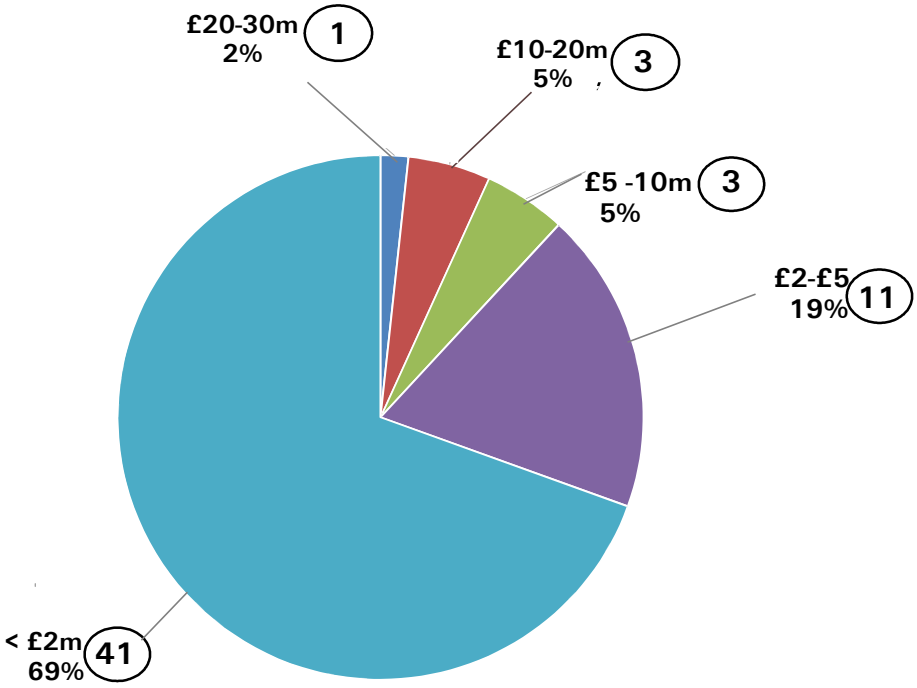


Fig. 3 59 UK Fabricators Banded by Revenue Group

The top ten fabricators, listed below accounted for 66% of UK production. Despite its losses, Teknoflex still managed to stay in the top ten (just).

- Invotec
- Exception
- Graphic
- Merlin PCB
- Stevenage
- Labtech (Teledyne)
- GSPK
- ZOT Eng
- Teknoflex
- Eurotech Group

The next ten fabricators accounted for a further 23%.

- Spirit Circuits
- CC Electronics Europe
- Faraday Printed Circuits
- DK Thermal (GSPK)
- Garner Osborne Circuits
- Express Circuits
- Trackwise
- Wrekin Circuits
- Yeovil Circuits
- Lyncolec (acquired by Spirit in 2014)

The market for PCBs depends on demand for electronic systems and equipment. Global electronic equipment production is estimated at just under £900bn ($1.4 trillion) in 2013. This is split regionally as shown in Figure 4. Note that the rest of world category includes E Europe and Mexico.

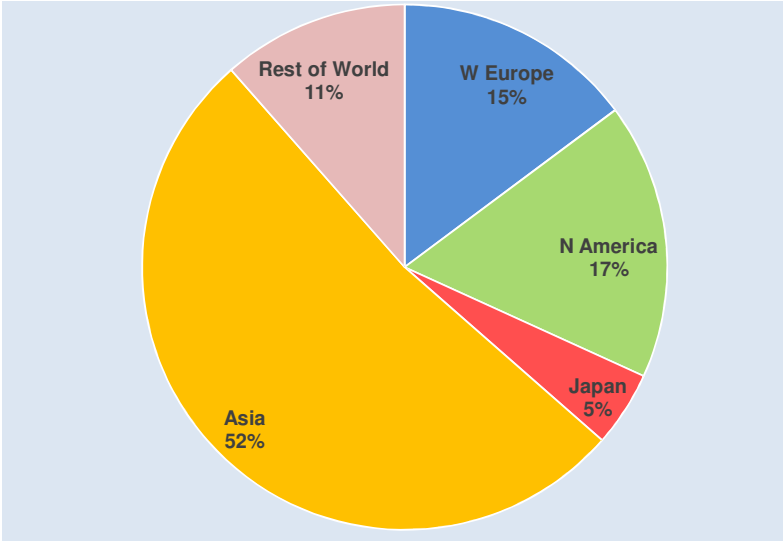


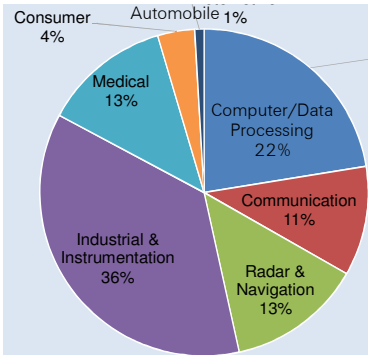
Fig.4 Global Electronic Equipment Production

In the UK electronic equipment production is estimated at just £10bn in 2012. Final data for 2013 is not yet available but monthly trend information for 2013 indicates a decline of 10%. It is noted that the reported data also includes a small percentage of non-electronic equipment. The military market accounts for a major share of UK electronics equipment production and, with budget cuts over the past couple of years, this has contributed significantly to the decline.

Growth in demand for commercial aerospace and satellite electronics as well as for industrial and instrumentation have contributed to some balancing of this decline.

Fig. 5 compares electronics equipment production in the UK with Europe. The data (*source: Prodcom*) is for 2012 as 2013 data is not available at the time of writing. Military and aerospace components are not reported separately and therefore are accounted for in data processing, communications and industrial and instrumentation. Radar and navigation includes both aerospace and marine components. Automotive components likewise are included in data processing, communications and instrumentation; the exception to this is automotive lighting.

UK £10bn



EU27 £136bn

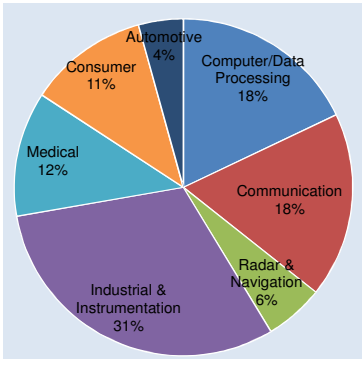


Fig.5 Electronic Equipment Production UK and Europe Compared

Prodcom - A division of the Eurostat organization (compiles stats for all EU countries)

ONS - UK Office of National Statistics

According to the ONS results, electronic equipment production has picked up at the start of 2014, likewise survey results show that demand for PCBs is also picking up. While 2014 is expected to be an improvement on 2013, the higher growth will come in 2015 before the markets fall again.

Net imports and exports of PCBs into the UK in 2012 are reported as shown in Table 1. From this it can be seen that the UK imports a high volume of single-sided boards (low value) while slightly fewer multilayer boards are imported than exported. There is a slight change on 2011 when net import value of multilayer boards was£2.7m. 2013 data is not available at the time of writing but is expected to be similar to 2012.

	Import Value £m	Export Value £m	Net Import £m
Single-sided (and other)	67.3	41.2	26.1
Multilayer PCBs (including double/sided	47.2	49.5	-2.3

Table 1 UK PCB Imports and Exports in 2012

Fig. 7 below shows the 12/12 growth chart for the UK PCB industry with extrapolated forecast out to 2017. A 12/12 growth curve is obtained by dividing the average value over a 12 month period by the average value of the 12 month period one year earlier. This results in a very smooth curve which irons out monthly and quarterly oscillations and therefore current growth or decline may not be apparent. Each point is centred and therefore the last "actual" point is always 6 months prior to current time. The immediate extrapolation from the most recent point is based on the most recent current data. Looking at the chart it can be seen that if the current trend continues, low single digit growth may be expected for 2014 with 5% growth in 2015.

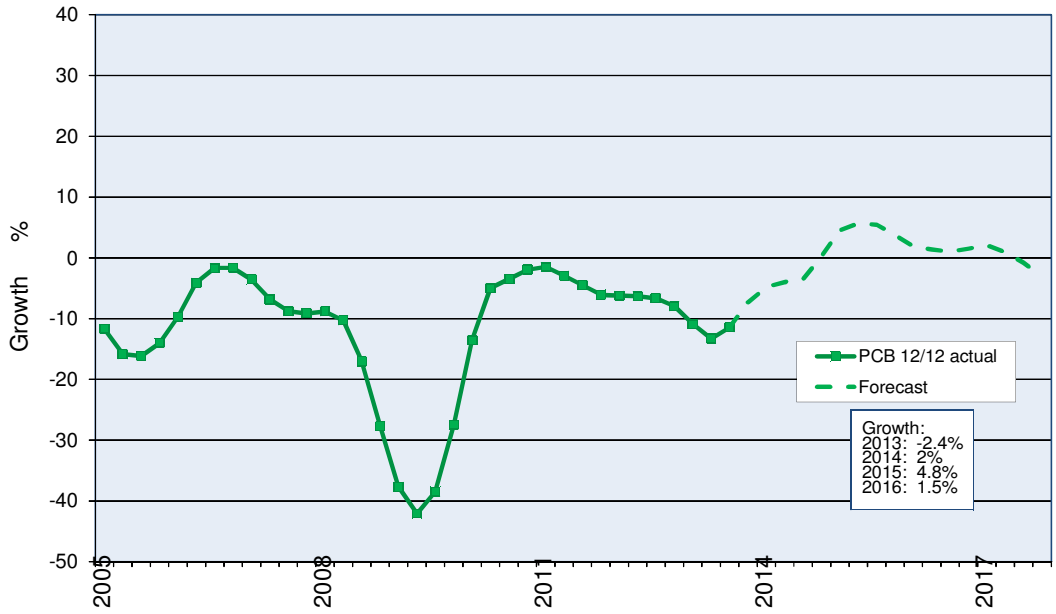


Fig.7 UK PCB Production, Historic and Forecast
smoothed 12/12 Growth curve

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The Markets Session

a Review by **Peter Starkey**

On the first day of the 13th Electronic Circuits World Convention, delegates crowded into the Kiew Room of the Nuremberg Messe to hear four of the world's leading experts on PCB markets and market trends make their analysis of what the future held for the industry. Introduced and moderated by IPC's Marc Carter, the session included presentations from Dr Hayao Nakahara, Walt Custer, Michael Weinhold and Bill Burr.

Dr Nakahara

"Cost, cost, cost – unless you can meet the cost, you can't continue your business!" These were **Dr Nakahara's** opening words as he examined the business situation in China and discussed the alternative market areas attracting investment.

In 2012, China's share of the world PCB production was 44%, and it had seemed destined to continue its domination into the long term. However, rising wages, labour shortages, high personnel turnover and tougher environmental regulations were making it increasingly difficult to operate, particularly in the coastal regions.

Japanese PCB makers had stopped investing in China and were expanding operations in South East Asia, particularly in Thailand and Vietnam, as were some Taiwanese and South Korean manufacturers. Thailand was the largest PCB producing area in South East Asia, with output already exceeding that of Germany, followed by Vietnam, Malaysia, the Philippines, Singapore and Indonesia. No substantial Japanese investments were being made in the Philippines and Indonesia, and costs were so high in Singapore that new investment was out of the question.

Why not India or Brazil? Although there had been much speculation over the years, there were no signs of expansion. Government regulations and lack of infrastructure made it difficult to make large investments in India, and although the importation of PCBs continued to increase, domestic production was relatively static. Brazil lacked infrastructure and had the additional burden of a complex taxation system. Output had fallen substantially since Multek had closed down its Brazilian operation.

By comparison, South East Asia had reasonable infrastructure, although nowhere near as highly developed as China, and there were laminate factories in Thailand, Singapore and Malaysia, which also had the world's largest foil plant.

Dr Nakahara forecast that South East Asia's share of the world PCB market would rise from 6.8% in 2013 to 8.2% in 2017, and be worth over $5 billion.

Walt Custer

At major conventions, it is customary to expect **Walt Custer** to give an up-to-the-minute global business outlook for the electronics industry. At ECWC13, he took a slightly different approach and gave delegates an opportunity to learn how to apply supply chain data to make meaningful forecasts for individual businesses, in a presentation elegantly entitled: *"Global Electronic Industry Supply Chain Dynamics: Forecasting Equipment and Component Demand caused by Business Cycles, Product and Technology Changes and Geographical Shifts".*

He summarised the principal factors determining business cycles: economic fluctuations, cataclysmic events, new product

cycles, inventory build-ups and declines, double ordering in anticipation of shortages, poor management practices, geographic shifts and abrupt technology changes, then listed the global and regional data sources and leading indicators used to monitor and measure growth within the electronics food chain.

Useful data could be acquired from trade organisations, government statistics, published market research studies, company financial reports and consolidated sector statistics. Purchasing managers' indices were a valuable group of leading indicators.

With appropriate reference data gathered and in place, Custer demonstrated how it was possible to forecast an individual company's sales by organising its monthly or quarterly sales figures on a spreadsheet and comparing them with related industry time series for the same period using 3/12 growth rates, then determining lead times against company data, forecasting company sales based on lead times and estimating the company's gains or losses in market share by comparing company growth to a related industry sector. The methodology had been proved to work, and to give companies good warning of what to expect. *He made it look easy!*

Michael Weinhold

Michael Weinhold posed the question *"What business are we in?"* Whether the nominal response was the making of PCB's, or electronic components, or electronic devices, or cars, the real answer was *"We are in the business of making money!"*

The electronics industry offered the potential to make money through innovative new electronic products focused on large volume production, using competence and existing know-how, investing money and resources in future technologies and target markets with growth opportunities. And Weinhold saw component embedding in printed circuit boards as a significant future niche-market opportunity, with particular significance in Europe where the number of PCB fabricators had dwindled from 2,500 in the 1960s and 1970s to barely 250 now, and innovation and differentiation were vital survival strategies in a market otherwise held to ransom by buyers and purchasing agents.

Device embedding technology had a long history in Europe in the ceramic hybrid sector, and had been employed in PCBs since the late 1990s. The technology had the benefits of fast design and fabrication. High-reliability product development was possible and standard components could be embedded in small and medium quantities. The alternative was to design on silicon, which could offer substantial cost and size reduction but involved high set-up expenses and long design cycles and was only appropriate for large-scale production.

Weinhold showed examples of various techniques, proprietary and non-proprietary, for component embedding, inspection and test, and made some value-in-use comparisons to illustrate costs and break-even points. It was clear that embedded technology had the potential to improve quality, miniaturisation, energy efficiency and thermal management, but also clear that PCB fabricators would have to learn how to absorb and master the challenges of fabrication, assembly, device testing and end-use application. And it had to be understood that the market opportunity was determined by quantity. Once quantities were sufficiently large to make it economically viable for silicon and chip packaging industries to take an interest, they would sooner or

later find a solution. The silicon solution would be selected and implemented, and that particular product would be lost to the PCB industry.

To properly realise the opportunity presented by embedded component technology, it was important that the PCB industry should encourage electronic designers to recognise it as a fast and cost-effective route to market. This would stimulate demand for small-to-medium batch quantities and offer a good return for PCB fabricators.

Bill Burr

Bill Burr delivered that final paper of the session, with some thought-provoking observations and alternative views on the growth of the solid state lighting market and its impact on the PCB industry: *"Is it really time for overdrive? The LED dilemma."* He foresaw a fundamental paradigm shift driven by the technical and market parameters of solid state lighting and a Moore's Law counterpart known as Haitz's Law, which stated that every decade, the cost per lumen would fall by a factor of 10, and the amount of light generated per LED package would increase by a factor of 20.

"The times they are a-changing!" There had been artificial lighting since man first discovered fire, and of recent times the lighting business had been dominated by a few big-name manufacturers whose business model was to churn out billions of replacement light bulbs. Then came LEDs, characterised by low power consumption, low operating voltage and small form factor. And they had a much longer life expectancy than conventional bulbs, typically 50,000 hours compared with 1,000 hours. There were an estimated 14 billion light-bulb sockets in the world. Each time a conventional bulb was replaced by a solid state device, it effectively took one socket off the market.

Burr talked about *"The Bothersome Bump"* – the initial filling-up of light-bulb sockets was forecast to consume 2 billion bulbs worth of capacity per year. But after an initial build-up, peaking at about 6 years, there would be an enormous capacity hangover. Perhaps a smaller secondary peak would be seen at 9 years, and another, even smaller, at 12 years corresponding to replacement cycles, but steady state demand volume would show only a gradual linear increase in line with ongoing growth of the total number of sockets. That was where Haitz's Law diverged from Moore's Law. There was a limit to how much light the world needed, so whereas the demand for computing power was near infinite, lighting requirements were finite, and as LED efficiencies improved, the actual number of luminaires required to achieve a given lighting level was decreasing significantly.

What would be the consequence on the PCB industry? Rapidly growing markets would drive substrate volumes. Increasing power density – more output per LED and more LEDs per unit area – would demand greater thermal conductivity and create a substantial and growing demand for metal-in-board substrates.

Developments in the technology of LEDs themselves, for example the alternatives for producing a pure white light by the use of coloured phosphors on basic blue-white LEDs, or white and multi-colours by combination of monochromatic red, green and blue LEDs, powered and switched separately and requiring more complex metal-in-board interconnects.

The initial market surge was expected to subside in the middle of the decade, although it was anticipated that the shortfall would

be filled by new applications as new capabilities of solid state lighting were realised.

All of these developments would require enhanced thermal and power management capability from the interconnect and the printed circuit industry would respond with an expanding range of solutions going beyond established metal-base and metal-core technologies to provide cost-effective solutions to the challenges of thermal and power management, enabling new applications and market opportunities.

Pete Starkey,
May 2014

13th Electronic Circuits World Convention : "Connecting the World"

The Embedding Technology Session

a Review by **Peter Starkey**

The 13th Electronic Circuits World Convention in Nuremberg provided an exceptional diversity of information and knowledge, through 123 presentations in 26 sessions. The Embedding Technology session on the second day attracted an enthusiastic audience, keen to learn about PCBs with embedded RFID and embedded magnetic cores, interposers with embedded thin-film capacitors, and flexible microsystems with ultra-thin embedded silicon chips. The session was introduced and moderated by **Dr Eric Maiser** of VDMA Productronic.

Martin Cotton

The first presentation was delivered by **Martin Cotton,** long-standing expert in embedded RFID, who demonstrated the scope offered by the technology beyond basic identification and product tracking.

Reviewing the fundamental benefits of RFID, and its advantages over bar-code labelling, he stressed that he was describing a process for creating a wireless communication portal within the structure of, and if necessary electrically connected to, the PCB, which could achieve very much more in functionality than simply acting as a traceability device and could effectively become part of the "internet of things". Read ranges of 9-10 metres were now attainable, at up to 200 devices per second, and line-of-sight was not a necessity. Bar codes, by comparison, could hold only limited data, could not be written-back to and could only provide a reference to be used with a database.

Embedded RFID devices could be connected to various sensors to enable additional functional features regarding safety, traceability and working environment, and could be activated when a device was powered-up, for example to lock the device against unauthorised use.

Cotton listed and discussed many applications including reporting of performance data for maintenance planning and failure prediction, providing a complete cradle-to-grave information pipeline and enabling the best security and anti-counterfeit strategies.

Chun Chen

Next to speak was **Chun Chen** from Shenzen King Brother Electronics Technology, describing a method of manufacturing multilayer PCBs with embedded magnetic cores. He explained that embedded core technology was an effective route to achieving miniaturisation of power modules, but that certain fabrication difficulties had to be overcome.

In order for the core to function effectively, it was necessary to position it precisely within the multilayer construction, then to form insulated plated-via-hole conductors through the core by drilling clearance holes, vacuum plugging with resin, drilling concentric holes leaving insulating resin sleeves, then metallising these holes to become part of the windings of the inductor, with printed circuit features taking the place of wires. Chen explained the details of the lay-up and laminating technique and how the positional tolerances and bond strengths had been achieved. The magnetic cores were very fragile and the through-drilling of clearance holes was a critical operation for which drilling parameters had been optimised by serial DOE procedures.

Problems of micro-cracking of the resin fill had been overcome by careful choice of materials and an enhanced vacuum lamination process. Other processing challenges which had been addressed included step-etching of asymmetric copper thicknesses.

The result was a process by which the customer's design requirements for electrical insulation, inductor and electromagnetic loss

had been satisfied, and which demonstrated a practicable route for the manufacture of embedded magnetic products.

Masumitsu Yoshizawa

From embedded inductors to the effects of parasitic inductance in external decoupling capacitors on power supply quality. Masumitsu Yoshizawa from Noda Screen Company explained how thin-film decoupling capacitors embedded in organic interposers could achieve better noise reduction than PCB-mounted ceramic chip capacitors and effectively act as if they were on the chip itself, but without taking-up space on the silicon.

He described a patented process for manufacturing stable thin-film strontium titanate capacitors by aerosol chemical vapour deposition at atmospheric pressure, with the advantages of flexibility in size, shape and location. Capacitors could be located very close to LSI pads, with optimised electrode positions. He reviewed the observed differences in characteristic performance between on-chip and on-PCB decoupling capacitors, believed to be related to the very low inductance between IC and embedded capacitor. Further studies to gain a more precise understanding of IC internal noise were being carried out in cooperation with the University of Tokyo.

The final paper of the session was presented by **Jürgen Wolf** from Wurth Elektronik, reporting the outcome of a government-funded collaborative research project on ultra-thin silicon chips in flexible microsystems, which had many potential applications in medical electronics, wearable electronics and automotive electronics.

A growing demand for mechanically flexible electronic systems and increasing levels of integration had led to the development of hybrid build-ups combining polymer substrates and ultra-thin silicon chips which could maintain their functionality under bent conditions.

Wolf described a proprietary process for wafer-scale fabrication and subsequent “pick, crack and place” singularisation and handling of integrated circuits less than 20 microns in thickness, and explained their physical characteristics. He went on to detail methods of mechanically and electrically connecting them to flexible substrates, and discussed design issues such as the influence of piezoresistive effects and the layer- and structure-dependent management of mechanical stress.

Several build-up techniques for embedding ultra-thin chips into flexible polymer substrates had been realised and characterised, and the technology represented another step in the evolution of flexible printed circuit assemblies.

Pete Starkey,
May 2014

13th Electronic Circuits World Convention : "Connecting the World"

The Metal-Base PCB Technology Session

a Review by **Peter Starkey**

At the 13th Electronic Circuits World Convention in Nuremberg, the session on Metal-Base PCB Technology was well-attended, with delegates interested to learn about life cycle cost optimisation, latent short circuit failure and a particularly innovative alternative approach to manufacturing electronic assemblies. The session was introduced and moderated by EIPC Chairman **Alun Morgan**

Dr Viktor Tierderle

Dr Viktor Tierderle from RELNETyX Consulting discussed the optimisation of life cycle cost by selection of PCB laminates, including metal-based materials, using physics-of-failure methodology.

In order for printed circuits to perform reliably under harsh conditions of thermal and mechanical stress, it was important to choose the appropriate laminate from the many available in the market, and to select the best balance between cost and performance to fulfil the requirement.

Dr Tierderle demonstrated a procedure which began with a CAD data input and took into account all of the relevant issues: temperature cycling, sustained temperature, humidity, corrosives, power cycling, electrical loads, electrical noise, mechanical bending, random vibration, harmonic vibration and mechanical shock, using a series of simulation and three-dimensional modelling techniques to predict reductions in life cycle costs.

The outcome was the ability to reduce field failure rates and the number of testing cycles required, and to enable the selection of an adequate-for-purpose material with an optimised cost-performance relationship.

Stan Heltzel

Stan Heltzel from the European Space Agency emphasised the critical importance of cleanliness in processing PCBs to avoid latent in-service short circuits.

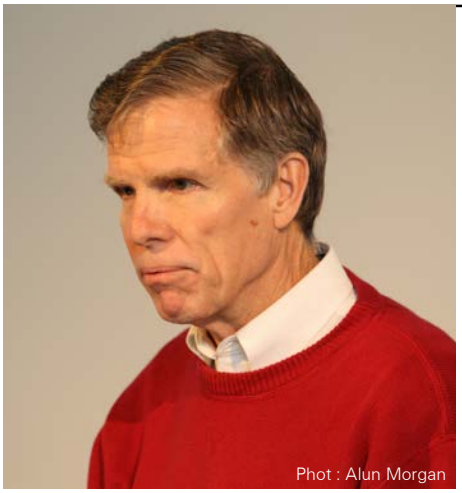
A consortium of space agencies, ESA-qualified PCB manufacturers and leading European aerospace OEMs, had worked on revision 12C of the ECSS-Q-ST-70 Space Product Assurance specification, shortly to be published, which would define new design rules for printed circuit boards.

Lack of cleanliness in PCB laminates had been demonstrated in several case studies to be a cause of failure due to electromigration, and Heltzel described the inspection procedures used by ESA on materials, manufacturing processes and finished PCBs.

He discussed risk mitigation strategies, cleanliness control plans and test methods that could detect reduced insulation due to contamination and electromigration, and presented proposals to tighten the requirements on base materials for the manufacture of high-reliability PCBs for space applications.

The presentation that attracted most interest and provoked plenty of interactive discussion came from **Joe Fjelstad** of Verdant Electronics who described an alternative approach to the manufacture of electronic assemblies, which used aluminium as a substrate and eliminated the soldering process.

Aluminium had many attributes which made it attractive as an alternative circuit substrate: abundance, low cost, thermal conductivity, light weight, dimensional stability, thermal expansion



Joe Fjelstad

comparable with copper, ease of processing, and capable of being anodised or electrophoretically coated. Ironically, the main reason aluminium had not been considered for traditional PCB applications was its high thermal conductivity and heat-sinking ability, which limited the practicability of the soldering process.

Except in applications such as LED substrates, designers had preferred to specify resin-based laminates and then deal with thermal management issues after completion of assembly. And even in the knowledge of the thermal issues and intrinsic reliability problems associated with the introduction of lead-free soldering, human inertia – *"better the devil you know"* attitudes – had tended to preclude the consideration of radical alternative concepts.

Fjelstad advocated reversing the assembly process to eliminate the solder issue, by positioning and bonding all the components on an aluminium carrier with leads facing up, encapsulating the components in place, exposing the terminations and interconnecting them by additive or semi-additive PCB fabrication techniques or alternative direct interconnection methods.

Because solder lands were not required, conductor routing density could be higher so that fewer layers would be required.

The basic manufacturing infrastructure was already in place, semi-additive fabrication processes were well-established, and the concept was appropriate for all classes of products including flex.

The benefits of solderless assembly were many: no PCB was required, no soldering was required, component concerns were reduced, circuit design layout was easier, design security was increased, thermal management was integral, reliability was enhanced and multiple novel structure options were possible – modular array assemblies, aluminium-core rigid-flex, direct-write prototyping.

The limits were more likely to be defined by the imagination of the designer than by the fundamental limitations of the technologies that Fjelstad had described. *"Change may happen slowly, but change always comes..."*

Pete Starkey,
May 2014

13th Electronic Circuits World Convention : "Connecting the World"

The Drilling and Routing Session

a Review by **Peter Starkey**

Notable amid the vast array of information and knowledge shared at the 13th Electronic Circuits World Convention in Nuremberg was the highly informative session on advances in drilling and routing, with a focus on the technology of cutting tools. The session was introduced and moderated by EIPC Technical Director **Michael Weinhold.**

Johann Schmidt

Growth in applications of high-power LEDs had created an increasing demand for substrates with high thermal conductivity, and resulted in the development of a wide range of insulated metal substrates heavily loaded with ceramic fillers in the dielectric. Consequently, the dielectric layer of these composite laminates tended to be very abrasive, causing rapid wear of conventional tungsten carbide routing cutters. **Johann Schmidt** of CGT GmbH discussed how diamond coated tools could significantly increase dimensional accuracy and reduce production cost.

He described a proprietary process for diamond coating of tungsten carbide drills and routers, based on hot-filament chemical vapour deposition. A particular feature of this proprietary coating was that it was built up as a multi-layered combination of different crystalline and nano-crystalline layers. Typical coating thickness was 12 microns, although this could be varied depending on tool geometry and diameter. The multi-layered structure gave the benefit of resistance to crack propagation, a major limitation of single-layer coatings, and a very smooth surface with low friction and excellent chip-removal characteristics. Hardness of the coating was approximately 9000VPN, compared with about 2100VPN for standard tungsten carbide grades, and coated tools could be used at higher feeds and speeds.

Schmidt showed many comparative examples: on a typical IMS substrate, routing feed could be increased from 4 mm per second to 15 mm per second with tool life extended from 7.5 metres to 60 metres. And a coated drill could complete 1000 hits with no clogging, whereas a conventional drill was clogged with aluminium swarf after only 150 hits.

Diamond coated tools offered greater dimensional accuracy and cost and productivity benefits from increased production speeds and significantly improved tool life resulting in less machine down-time for tool changing. Clearly, even with the most advanced cutter technology, good tool management, machine maintenance and operating discipline were essential, with minimal spindle run-out, rigid fixturing of the work and powerful vacuum extraction if the best results were to be realised.

Some applications, such as using a 2-flute end-mill on IMS, benefited from wet lubrication.

Dr Lianyu Fu from Shenzen Jinzan Precision Technology gave an interesting presentation on the optimisation of drilling parameters by investigation of drilling temperature, and how the outcome contributed to the development of an innovative single-edge tool geometry. He commented that although laser drilling played an increasingly significant role in PCB micro-via drilling, mechanical drilling was still a dominant technique for micro-hole

Dr Lianyu Fu

formation, and ultra-small mechanical drilling was increasing in popularity.

Drill temperature had been demonstrated to be an effective process monitor for characterising and optimising drilling parameters and hole quality. Dr Fu showed a video illustrating how a high-speed infra-red camera had been mounted on a fixture adjacent to the drill-head to make real-time temperature measurement as the drill bit was withdrawn from the stack. The output from the camera was stored and analysed for different tool geometries and drilling conditions.

Comparison of the performance of standard and single-edge micro-drills indicated that the single-edge tool generated less heat for a given set of drilling parameters. This design featured a unique cutting edge, with increased effective cutting length and improved chip-breaking performance, and an increased rake angle near the centre improved cutting performance. The result was more accurate positioning and a reduction in drilling force.

Pete Starkey,
May 2014

The 40th Anniversary Institute of Circuit Technology Dinner and Annual Symposium

A Review by **Pete Starkey**

The Institute of Circuit Technology celebrated its 40th Anniversary with an evening dinner attended by Fellows, Members and Associates old and new, welcomed by Technical Director Bill Wilkie and given a review of the history of the Institute and some of its notable events and personalities by Chairman Professor Martin Goosey.

The following morning, delegates assembled in the Daniel Gooch Room of the Great Western Railway Museum of Steam in Swindon, Wiltshire, UK, for a diverse conference programme with topics encompassing management of human resources, market trends and developments in technology.

Keynote presentation came from **Kim Hayton** of HaytonHeyes, offering motivational advice on energising business by harnessing the power of people, with emphasis on leadership and focus on the customer.

She defined the attributes of a good leader: creating confidence, setting a vision and communicating effectively with team members, using the analogy of dating, engagement, marriage, family life, and the possibility of break-up and divorce, to illustrate and explain employment relationships, then detailed a management strategy for structuring a team and getting the most out of it.

In conclusion, she reflected: "*When it comes to your people, you get what you deserve!*"

Dr Chris Hunt

Investigation of the phenomenon of conductive anodic filamentation (CAF) continues at the National Physical Laboratory, with the cooperation of a number of industrial partners.

Dr Chris Hunt gave a progress report on studies of the mechanism of CAF formation using simulated test vehicles, and introduced a new approach for detecting its presence.

The established method was to use an optical microscope with backlighting, but since CAF was effectively an electrical short circuit there was on opportunity to measure resistance heating effects by thermography. Thermal cameras were now available with sensitivity better than 0.1 degree Kelvin, and a new technique known as lock-in thermography (LIT) was capable of detecting CAF at the sub-0.5 Megohm level, with the prospect that further development could extend the sensitivity into the Gigohm region.

A complex rigid PCB was currently undergoing a range of tests.

Francesca Stern

Market research specialist **Francesca Stern** gave an outlook on the UK PCB and electronics industry. (*see also Pages 7-10*)

Excluding components, world electronic equipment production in 2013 was $1.4 trillion. Compared with 2012, production had declined 2.4% in North America, 3.7% in Europe and 24% in Japan, but the overall figure remained the same.

In 2012, European electronic equipment production was □136bn, of which UK was □10bn.

Looking specifically at PCB production, the world overall was down 4% from $57.7bn in 2012 to $55.7bn in 2013. Forecasts for growth in PCB production (in Sterling) between 2013 and

and 2017 were from □35.7bn, of which Europe 5%, North America 5% and China 45%, to □40.7bn, of which Europe 4%. North America 4% and China 47%. UK PCB production in 2013 was □136m, of which the major sectors were military and aerospace together with industrial controls and instrumentation.

Demonstrating how leading indicators were used by forecasters as tools for predicting trends, she advised caution about spurious correlations. Some bizarre examples were how the divorce rate in Maine followed exactly the same trend as the per capita consumption of margarine and how US spending on science, space, and technology correlated closely with suicides by hanging, strangulation and suffocation!

Demë Mulaj of Nelco gave an interesting view on the changing needs of OEM companies and the need for new materials, but for reasons of commercial confidentiality preferred that the details of his presentation were not published.

Professor Martin Goosey

ICT Chairman **Professor Martin Goosey** was optimistic that the reporting of his presentation would be free from ironically amusing typographical errors, as he gave an update on the TSB-funded STOWURC project, entitled "Recovery of Copper from PCB Manufacturing Processes using Crab Shells", (*see also Pages 5-6*) describing the development of a sustainable process of using waste products from the seafood industry to recover metals from PCB manufacturing effluent. Chitin, a natural component of the shells of crustaceans, had the ability to adsorb heavy metals from dilute solution, and a simple chemical modification of chitin, by alkaline deacetylation to form chitosan, significantly improved the efficiency of adsorption.

Professor Goosey summarised the results of initial experiments. The effects on adsorption rates of parameters such as temperature, pH, initial concentration, rate of mixing, specific metal ions had been studied, over a range of chitosan parameters including the amount of adsorbant, the degree of deacetylation and the particle size. It was possible to reduce copper concentration in effluent to the 0.1 ppm level. Having captured the metal, it was possible to desorb it with sulphuric acid and recover it by straightforward electroplating.

A key issue was the residual adsorption efficiency of the chitosan after stripping of copper. There was a tendency for absorption ability to decrease with each cycle, and conditions were being optimised to minimise the effect. There were additional opportunities to optimise the chitosan adsorption process for metals other than copper in the general metal finishing industry, as well as recovering rare metals, including platinum, palladium, rhodium, osmium, iridium, mercury, and gold, from low concentration solutions.

Dr Andy Cobley

Specialist in chemical process applications of ultrasound, ICT Deputy Chairman **Dr Andy Cobley** reported progress on two collaborative projects: Susonence and Mesmoproc. Susonence was a three year multi-partner project aimed at producing industrial scale ultrasonic equipment for sustainable surface modification in metal finishing and printed circuit manufacture. The objectives of the project were to reduce the use of toxic and hazardous chemicals, and at the same time to minimise waste and reduce energy and water consumption. Initially, two applications for ultrasonic technology in PCB manufacture had been identified:

low temperature, reduced strength permanganate desmearing and persulphate etching, and extensive laboratory work had been carried out. Field trials in an ultrasonic pilot line at Merlin Circuit Technology had demonstrated that a 50% reduction in permanganate concentration, a 10 ºC drop in temperature and a 76% reduction in process time could be achieved, with freedom from interconnection defects and hole-wall pullaway. Pilot trials on persulphate etching were due to start second week in June 2014.

The objective of the Mesmoproc project was to develop innovative electrochemical processes for the maskless patterning of materials by combining electrochemical reactor engineering with ultrasound agitation to enable selective metallisation of microscale devices, components and printed circuit boards whilst eliminating repetitive conventional photolithography.

A proprietary technology known as EnFace – Electrochemical Patterning by Flow and Chemistry – was characterised by a low metal concentration electrolyte and very small anode to cathode spacing, with the 'mask' placed on the anode, and advanced ultrasonic agitation.

A laboratory-scale reactor had been constructed and was being used for optimisation of ultrasonic and electrochemical parameters and for the production of patterned samples.

Bill Wilkie has consistently demonstrated a remarkable talent for selecting memorable venues for Annual Symposia, of recent years on themes of transportation. This year's choice, the Great Western Railway Museum of Steam, was extremely popular. The museum is housed in a restored building that was part of the old Swindon Works of the Great Western Railway, which operated from 1843 to 1986 and in its heyday could turn out three locomotives per week. Delegates made the most of the opportunity to check out the exhibits before heading home.

Pete Starkey,
May 2014

The Membership Secretary's notes - July 2014

Bill Wilkie

At our 40th Anniversary dinner, held at the Wiltshire Golf and Country Club at Wooton Bassett this month, Martin Goosey, our chairman gave a presentation covering the history of the ICT from its inception in 1974 up to the present day. We had a memory table at the event, with some literature on the Institute and the PCB Industry going back to 1974, including the very first copy of Circuit World, which was the Journal of the Institute at that time. This copy was kindly lent by Steve Jones, one of our members and had a foreword by our first Chairman, Doug Taylor of CR Circuits, who was the business partner of Bruce Routledge, the present Journal editor – a real link to the past.
It was interesting to look at the Transactions of 1974, which consisted of articles on the de-wetting of Tin/Lead Boards, the Thickness Measurement of Gold Deposits and the Troubleshooting of Electroless Copper plating Solutions and compare them with some of the papers presented at our 40th Annual Symposium, which followed the Anniversary Dinner.

At our Symposium in the Great Western Railway Museum, we had presentations on the Formation of Conductive Anode Filaments, the Removal of Copper from Waste Solutions using Chitin from Crab shells, the Development of Ultrasonic Research for PCB Manufacture and Electrochemical Maskless Patterning of Materials.

On the face of it, we have bottomed out the basics and are conducting research on ideas and materials which would not have seemed possible in those heady days of the mid 1970's.

Volume manufacture may have gone east, but we still have a bedrock of companies and people who continue to take us forward with the same principles imbued in the Institute by Doug Taylor and the other founders.

At the 2014 Annual Foundation Course, Dennis Price was given an inscribed tankard on the occasion of his proposed retirement as a lecturer on the course. The tankard was presented by Iesha Mossman, who is also a Merlin Employee at Deeside and was a delegate on the course.

Dennis has given both the IPC Standards and Embedded devices lectures since the course started at Loughborough in 2005, but has been involved in the course since its inception in 1980, when the course was run as a two week event alongside a thriving local apprenticeship scheme in the Scottish Borders.

We had another modern-day record turnout for this years' course, with 30 delegates, who came from companies based from Antrim in the North to Portsmouth in the South, all of whom showed their appreciation of Dennis's dedication, but at the age of 70, he has decided to call it a day and we hope the tankard comes in useful!

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