Journal of the Institute of Circuit Technology

2013 Events

6th February *Wednesday*
17.00 Registration
17.30 ICT Evening Seminar & AGM.
bill.wilkie@InstCT.org
Norfolk Arms Hotel, Arundel.
http://www.norfolkarmshotel.com

5th March *Tuesday*
17.30 ICT Northern Evening Seminar
bill.wilkie@InstCT.org
Glynhill Hotel,169 Paisley Road,
Renfrew, Glasgow PA4 8XB
Phone: 01418 865 555
This event is supported by
Rainbow Technology Systems

2nd /5th April *Tuesday - Friday*
ICT Annual Foundation Course
at Loughborough University
bill.wilkie@InstCT.org

5th June *Wednesday*
ICT Annual Symposium
at the Heritage Motor Museum,
Gaydon, Warwickshire
bill.wilkie@InstCT.org

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

November
ICT Evening Seminar
at Hartlepool
bill.wilkie@InstCT.org

2014 Events

February or March
Proposed **ICT Evening Seminar & AGM**
at Winsford

7th - 9th May
ECWC13 (13th Electronic Circuits World Convention)
at Nuremberg

Vol.6 No.3 July 2013

Editorial

John Walker F.Inst.C.T.

It must be years since I was invited to write the Editorial for the *Journal.* In fact it was 6 years, in 2007, since the first copy was published jn which I was privileged to introduce our then new enterprise. For these many years our Editor has been Bruce Routledge who has regularly produced 4 issues a year sometimes of 32 pages each and copies of all his *Journal* works can be found on our Website. He must be congratulated.

I would like to think that todays' PCB Technology is a far cry from that of 25 or more years ago. But is it ?. I refer to two important text books on the subject of Printed Circuits published in 1996 , namely "A Comprehensive Guide to the Design and Manufacture of Printed Board Assemblies" by William Macleod Ross published in two volumes. It would appear that many of todays' problems such as Tin Whiskers, Nickel/Gold plating and a host of other current difficult technologies were well known to our predecessors which could suggest that we are at times re-inventing the wheel.

Taking a laymans' view, how do our Far Eastern Printed Circuit manufacturers, producing many millions of high quality square feet of boards per annum, appear not to be plagued with difficulties? How do they do it? Perhaps they are but it appears to have little impact on their success.

Finally I hope that our Membership, which now exceeds 300, will continue to support our *Journal* by submitting material for publication. Articles are its life blood. There is not a better way of becoming known in the Industry.

John Walker
Hon Sec ICT

Membership

New members notified by the Membership Secretary

10283	Matthew Keller M.Inst.C.T.	10291	Charlotte Beck A.Inst.C.T.
10284	Craig McAdam A.Inst.C.T.	10292	Steven Garratt A.Inst.C.T.
10285	Chris Matthews A.Inst.C.T.	10293	Charles Bolas A.Inst.C.T.
10286	Elsa DeGabbey A.Inst.C.T.	10294	Mike Burgess A.Inst.C.T.
10287	Ivan Shaw A.Inst.C.T.	10295	Jamie Rowsell A.Inst.C.T.
10288	Chan Singh A.Inst.C.T.	10296	Greg Eaton A.Inst.C.T.
10289	Thomas Webster A.Inst.C.T.		

Members Reinstated

9943	Keith Bryant M.Inst.C.T.
9951	Tony Ridler M.Inst.C.T.

Re-grading Member to Fellow

10204	Ian Mayoh F.Inst.C.T.

Corrections and Clarifications

It is the policy of the Journal to correct errors in its next Issue.
Please send corrections to : -
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.***
4 Burnhams Field, Weston Turville, HP22 5AF. Tel:01296 394 383
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ICT 39th Annual Symposium

Gaydon, UK, 5th June 2013

Insulated metal substrates (IMS)

Ian Mayoh

The Institute of Circuit Technology Annual Symposium has become a must-attend conference and networking event for the UK printed circuit industry.

Technical Director Bill Wilkie had chosen a splendid venue for the ICT 39th Annual Symposium – the Heritage Motor Centre in Gaydon, Warwickshire, in the Midlands of England, home to the world's largest collection of British motor cars from the classic, vintage and veteran eras.

The UK PCB industry was remarkably well represented, with an impressive collection of fabricators and suppliers (including a few personalities from the industry's classic, vintage and veteran eras...) gathered together to absorb up-to-date knowledge from eminent presenters, to renew acquaintances and to share information, gossip and opinion with their peers.

ICT Chairman Professor Martin Goosey welcomed the gathering and remarked upon the continuing growth of the Institute's membership, now well into the 300's, and the wide and increasing range of services to members: annual symposium, evening seminars, foundation course, technical journal and website as well as collaboration in research projects such as ASPIS, coordinated by ICT and now in its final stages.

Professor Goosey introduced a well-chosen programme of technical presentations, commencing with an up-to-the-minute review of PCB substrate materials for thermal management from Ventec Europe Technical Support Manager **Ian Mayoh.**

He explained that, besides general trends to miniaturisation, higher density and embedded technologies in multilayer circuits, a major driver was the continuing growth in high-power LED lighting applications. Insulated metal substrates (IMS) enabled the reduction of system costs through the reduction in size or elimination of cooling fans and heat sinks. Compared with standard FR4 laminate, which had a thermal conductivity around 0.25 Watts per metre Kelvin (W/mK), IMS materials were currently available with thermal conductivities between 1 and 5 W/mK, and 7 W/mK materials were in development.

Mayoh stressed the importance of understanding that the actual thermal impedance of a material, which was a function both of its thermal conductivity and its thickness, was the meaningful practical consideration in determining the suitability of an IMS for a particular application, and a cost-effective solution could often be found without having to use the highest thermal conductivity (and most expensive) material. He discussed the relative attributes of glass-reinforced and non-reinforced materials in terms of thermal and mechanical performance, formability and cost/reliability trade-offs, and advised against specifying a material purely on data-sheet information without carrying out proper trials.

Technology routes - "sustaining" or "disruptive"

Stuart Hayton

Next to speak was **Stuart Hayton**, Sales and Marketing Director for Mutracx, with a thought-provoking discussion of the dilemma faced by companies choosing whether to pursue "sustaining" or "disruptive" technology routes, with some sobering examples of big names with successful histories who had concentrated on putting too much emphasis on customers' current needs, had failed to adopt new technologies or business models that would meet customers' unstated or future needs and had lost their leading position as a result.

Quoting Clayton Christensen, he commented that in their efforts to provide better products than their competitors and earn higher prices and margins, suppliers often "overshot" their market and gave customers more than they needed or were ultimately willing to pay for. Hayton illustrated this with his own mobile phone, which he said had many more functions than he ever wanted and some which he had not even known existed.

For established companies it was easier to rationalise the decision not to invest aggressively in disruptive technologies because these tended to have a lower initial profit margin for the supplier than contemporary technology and were often conceived and commercialised in different market areas. Indeed, in most cases failure could be attributed to classical "good management".

A specific case in point was Kodak's failure to realise the opportunity presented by digital photography, and to cling to film whilst their technology was effectively obsoleted by their digital competitors. And film had a particular relevance to PCB imaging – Hayton described how the technology had progressed from hand-laid artwork and process cameras, through vector and laser plotters to laser direct imaging (LDI). He did not consider LDI to be a truly disruptive technology, since it still involved the wasteful use of photoresist and its associated processing. And although LDI had been commercially available for over 15 years, it still only represented 5% of the world PCB imaging market, the remaining 95% relying on silver halide film.

The real disruptive technology presently emerging was ink-jet primary imaging, which eliminated 11 of 15 process steps in the imaging of inner layers, and only placed resist where it was actually needed. The technology itself was not new – it had been developed to a high level in the graphic arts industry – but it brought a new value proposition to the printed circuit industry and offered the capability for inner layers be ready for etching within 5 minutes of the image data being output from the CAM station.

ASPIS project ENIG - final stages

Prof. Karl Ryder

The ASPIS project, mentioned by Professor Martin Goosey in his introduction, was in its final stages and **Professor Karl Ryder** described how his research group at University of Leicester had evaluated immersion gold processes based on ionic-liquid chemistry as a potential means of overcoming the hyper-corrosion effects observed when aqueous gold chemistries were used in the ENIG process.

A series of immersion gold formulations had been prepared using Ethaline 200, an ionic liquid composed of ethylene glycol and choline chloride in 2:1 molar ratio, and gold in the form of gold chloride, gold cyanide and potassium cyanoaurate , and these had been used to deposit gold on a standard electroless nickel surface. Quartz crystal microbalance techniques had been used to study plating rates, scanning electron microscopy and atomic force microscopy to study surface morphology, and wetting balance measurements to test solderability.

The roughness of deposits from ionic liquids was less than the equivalent from aqueous solutions, and there was less evidence of corrosion of the electroless nickel. Soldering tests had indicated that coatings from ionic liquids wetted faster and more reliably than those from aqueous processes. Spun out of the ASPIS work, a current project supported by IeMRC was exploring applications of ionic liquids as soldering fluxes, where their ability to readily dissolve metal oxides without the use of acids potentially offered significant advantages.

Functionalisation of copper nanoparticles

Dr John Graves

Another IeMRC-funded project was concerned with the functionalisation of copper nanoparticles for applications in electronics manufacturing.

Dr John Graves described work being carried out at the Universities of Coventry and Loughborough together with industrial partners with the objective of substituting commercially-available nano-copper powder for tin-palladium catalysts in electroless plating processes.

It was necessary to coat the nanoparticles to improve dispersion stability, inhibit oxidation and to promote adhesion to surfaces. The chemistry of self-assembled monolayers (SAM), of which there was in-depth experience at Loughborough, was being evaluated as a means of achieving an appropriate functional coating, and remarkably good initial results had been observed in the catalysation of glass and polymer surfaces. A particular challenge was

the successful dispersion and de-agglomeration of the SAM-functionalised nano-powder, and Dr Graves demonstrated how Coventry University's expertise in sonochemistry had helped overcome this problem using high-power ultrasonics,

High-aspect-ratio blind microvias - megasonic agitation

Dennis Price

From ultrasonics to megasonics, a related technique mainly used in the silicon industry, which operated in a higher frequency range (typically 0.8–2 MHz compared to 20-200 kHz for ultrasonics) and gave less-aggressive cavitation effects.

Dennis Price from Merlin Circuit Technology reported his work with Heriot-Watt and Greenwich universities on the ASPECT project, studying the effects of megasonic agitation in the fabrication of high-aspect-ratio blind microvias. Their objective was to reduce the number of sequential bonding operations required to build complex multilayer microvia PCBs, by carrying out a single bonding operation then controlled-depth mechanical drilling to various levels to achieve interconnection to several layers in a single plating operation, rather than through a series of drill, plate, and build-up stages.

The metallisation and electroplating of high-aspect-ratio blind holes presented particular challenges and conventional agitation could not guarantee consistent results. Ingenious methods had been developed for modelling, observing and measuring solution flow in and around via holes, and megasonic agitation had been demonstrated to facilitate the break-up and extraction of entrapped air bubbles. On a micro scale, acoustic streaming could give an enhancement effect in through vias although its influence was small compared with diffusion. Improved performance was achieved due to the high level of bulk concentration next to the mouth of the via, supported by acoustic streaming along the board. Price concluded that, within microvias, megasonic agitation gave improved ion transport, mainly due to the presence of resonant bubbles rather than by acoustic streaming.

High frequency signal integrity - design considerations

Martyn Gaudion

The focus moved from high-frequency sound waves to design considerations for high frequency signal integrity in the presentation by **Martyn Gaudion**, CEO of Polar Instruments, who began by saying "Don't always trust the data sheet" when considering impedance and loss.

Regardless of whether impedance was modelled or measured, a multiplicity of factors needed to be taken into account when frequencies higher than 100MHz were involved, and results were likely to be inaccurate unless specialised 2D field-solver programmes were used for the calculations.

A range of loss mechanisms came into play as data-rates moved into the multi-GHz range. Skin depth became a serious consideration and the surface roughness of copper conductors, particularly that resulting from bonding treatments, became a crucial factor. Solder mask could have a dramatic effect on impedance, and this could be further influenced by moisture absorption.

It was preferred to route critical traces on inner, rather than outer layers. Even then, the natural dielectric inhomogeneity of woven-glass reinforced laminates was a limitation, although this could be mitigated to an extent by non-orthogonal routing. In general, losses could be reduced by the use of short traces, as wide as possible, and the smoothest copper consistent with adequate adhesion to resin.

Gaudion discussed how to minimise crosstalk and explained mode conversion and field distribution in differential pairs.

Finally, he demonstrated how to properly document modelled results into meaningful stack-up specifications and technical reports.

Drilling and routing tools - latest developments

Chris Serre

Back to practical aspects of PCB manufacture, as **Chris Serre**, Managing Director of Union Tool, described current technology and latest developments in drilling and routing tools, and discussed the technical and functional details of tool geometry, materials and coatings.

Another advocate of being careful what to believe in data sheet statements, he listed the attributes and benefits of single-flute drills, which were capable of better registration accuracy, higher capacity for swarf removal and longer life than their conventional 2-flute counterparts and certain "parallel-flute" offerings.

Furthermore, single-flute drill bits could be re-pointed on existing machinery. Proprietary lubricant coatings further assisted in swarf evacuation, and Serre illustrated their effect using high-speed video. Taking the example of a 0.1mm single-flute drill, an uncoated tool was capable of 6000 hits and one re-point, giving an effective total of 12,000 hits, whereas the coated equivalent could be used for 16,000 hits before re-point and re-pointed twice, giving an effective total of 48,000 hits.

Flute design was not the only physical consideration: the drill shank was a critical component in its own right. Traditionally, tools had been made from solid tungsten carbide. New composite tools were becoming popular, with the shank made from stainless steel. This offered not only a significant material cost benefit over tungsten carbide, but was better at absorbing spindle vibrations and run-out.

Diamond-based wear-resistant coatings on routing tools gave significant improvements in life and resistance to breakage, and with the increasing requirement to machine aluminium-backed IMS substrates, lubricant coatings substantially reduced the tendency to clogging of tools with aluminium.

When the symposium drew to a close, and Bill Wilkie had thanked presenters for their contributions, delegates for their attention, and Ventec Europe for their generous sponsorship, there seemed a certain reluctance for attendees to rush off home – many took their time to browse the spectacular selection of museum exhibits on their way out of the conference area. A very satisfying and informative day all round.

Pete Starkey.
I-Connect007.
June 2013

Author's note: I am grateful to Alun Morgan for kindly allowing me to use his photographs.

Book Review by Martin Goosey

Raspberry Pi for Dummies

Sean McManus and Mike Cook
Published by John Wiley & Sons Inc, Hoboken, New Jersey, USA
ISBN-10: 1118554213
ISBN-13: 978-1118554210
26 March 2013

Having begun my scientific research career in 1973 when slide rules were still the order of the day and four function calculators cost over a month's salary, I have spent more than a little time learning how to operate, programme and interface a range of early computers in order to make them do something useful. However, although they have now been widely available for many years and possess vastly greater capabilities, the need to undertake such tasks has largely disappeared, leaving new generations of users with little understanding of how computers operate or the programming languages and operating systems that bring them to life. (This has been confirmed by the year-on-year decline in the numbers and skills levels of students applying to read computer science at university in each academic year). There is clearly a strong need to encourage the broader adoption of computer skills in new generations of users. Fortunately, this is one of the key objectives of the Raspberry Pi Foundation, a UK-based charity that has developed the credit card sized and very low cost, Raspberry Pi computer.

The Raspberry Pi is a UK developed computer built on a small printed circuit board that is specifically aimed at promoting the teaching of basic computer science. In fact, this bare board computer, which requires a case, power supply and various other additions to make it of any use, has already developed something of a cult following, with over 1 million units shipped to eager users since its launch early in 2012. It has encouraged a new generation to take an interest in computing and to see what can be done with this unique and fascinating little device.

Having been aware of the various 'for dummies' publications that have appeared over the years, but never actually having read one, I was pleasantly surprised by the 'Raspberry Pi for Dummies' easy to use and approachable style of writing, which was augmented with many illustrations and examples. The book has the clear objective of helping users of this novel computer to get to grips with the device, and to learn how to use it in both work and leisure applications, even if the reader has little experience of programming, hardware or circuit design.

This 19 chapter, 412 page book is divided into six key sections, the first comprising three chapters giving an introduction to the device itself and detailing how to connect the computer up and get it running, including the important prerequisite of downloading and installing an operating system which runs from an SD card. (The Pi doesn't have a hard disc drive built into it, so it uses an SD memory card as its main storage, although external external hard drives can also be connected via a spare USB port.) The desktop environment that is used to run programs, manage files, browse the web and view images is detailed and there is also coverage of how to connect the Raspberry Pi to other devices, such as a keyboard, mouse, monitor and speakers etc. The book is full of useful tips with valuable information that might not be immediately obvious to all but the most informed users. Tips such as ensuring that the power supply used with the computer has sufficient current capacity (up to 700 milliamps) and that any additional USB hubs added have their own power supplies, will be useful to first time users during set up and help to ensure reliable operation.

The next section has a focus on Linux and getting started with this widely used open source operating system, although it should be noted that

the Pi can also use an operating system called RISC OS, which has a graphical user interface and which is also available as a free download. Specific information is given on how to download the operating system and to create an SD card with the operating system on it. (Another option is to buy an SD card with the OS preloaded, but that defeats the object of learning how to do such things.) There then follow four chapters on using the Raspberry Pi for both 'work' and 'play' applications. For work applications, the free to download Libre Office Suite is recommended, as it is fully compatible with the Pi and has a very similar feel to its Microsoft equivalent. Other examples of what are covered here include the editing of images, creating web pages and playing music. The software that is recommended for editing images is called GIMP, another free to download programme and one which is both highly sophisticated and compatible with other operating systems as well. There then follows a section on how to write programmes for the computer. The first chapter of the section gives an introduction to programming with Scratch, a free graphical, drag and drop style, programming language developed by MIT (Massachusetts Institute of Technology) and that was designed to specifically appeal to elementary and middle school children aged between seven and twelve. Following an introduction to Scratch, the next chapter describes how to use the language to create a simple arcade game. Python is another programming language covered in the book and chapter twelve introduces the basics of writing programmes with this powerful and commercially used language, before it is used to create a simple arcade game in the following chapter.

In section 6 the book moves on to explore the use of electronics with the Raspberry Pi and there are four chapters that begin with an explanation of circuitry and soldering. The following chapters then cover a specific project that demonstrates the use and control of the computer's input and output signals in a simple way to create a game. The next two chapters take this approach further by covering the fabrication of electronic circuitry on to a breadboard and even going as far as requiring the assembly of surface mount componentry. The book then introduces the use of discrete logic levels, with the final chapter of the section covering analogue aspects and applications. This gives the reader/user the opportunity to indulge in some more soldering and circuit board assembly in order to build one of a number of interesting and useful devices, including a so called 'Steve Reich Machine' that generates interesting musical patterns. The book concludes with a couple of useful appendices. The first covers trouble shooting and configuring the Raspberry Pi, including software and networking issues. The second appendix covers the pin configuration of the general purpose input/output (GP10) pins of the computer.

In summary, the recent publication of 'Raspberry Pi for Dummies' by John Willey and Sons is a most welcome event, as it covers all of the key aspects of this unique device from first set up and software installation through to interfacing and making the little computer do something useful. 'Raspberry Pi for Dummies' is the perfect guide for getting started with this exciting new device and I am happy to recommend it to anyone who is purchasing the computer itself. Sean McManus and Mike Cook are to be congratulated for producing such a valuable and useful work and I am sure that the book will prove to be just as successful as the Raspberry Pi itself. As the preamble to the book states, this user friendly guide seeks to make 'mastering this cool, compact computer as easy as pie!'

Martin Goosey
May 2013

Raspberry Pi for Dummies

Sean McManus and Mike Cook

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Design, Manufacture and Test of High Reliability Electronics.

SMART Group Seminar
Aero Engine Controls,
Birmingham, 19th June 2013

The UK Aerospace and Defence industry has global significance and relies heavily upon the design and manufacture of high-reliability electronics. And high reliability is also a key factor in the automotive and medical electronics industries.

Orchestrated by Technical Committee members Ian Fox and Bob Willis, and hosted by Aero Engine Controls in Birmingham, England, this SMART Group Seminar on design, manufacture and test of high reliability electronics proved to be a truly international event, attracting a sell-out crowd with delegates from Denmark, Netherlands and Italy, as well as from Ireland, Scotland, Wales and England.

Ian Fox reflected upon the 70-year history of Aero Engine Controls, now part of Rolls Royce, in designing, making and supporting control systems for gas turbine engines, in the introduction to his presentation on expansion control in printed circuits.

Controlled-expansion PCB's - Why are they necessary.?

Ian Fox

Why were controlled-expansion PCB's necessary? Fox began by listing typical expansion coefficients of materials and component packages: 16 ppm/°C for FR4 multilayer PCBs, 6.5ppm/°C for leadless ceramic chip carriers and chip resistors, 10-14ppm/°C for chip capacitors and 10-12ppm/°C for plastic SOIC packages depending on the volume fraction of silicon within the package. The expansion mismatch due to variations in expansion coefficients generated strain on solder joints during thermal cycling, and repetitive application of strain led to fatigue and eventual failure of joints. In high reliability assemblies, expansion control was necessary to reduce the cyclic strain to acceptable levels.

Aero Engine Controls had many years' experience of designing and building controlled-expansion PCB assemblies, and copper-invar-copper incorporated into an all-polyimide multilayer build had historically been their preferred material, giving finished PCBs with expansion coefficients of 6-7ppm/°C or 10-11ppm/°C, depending on the intended component mix.

There were certain issues to be considered, including exposed copper-invar at the edges of PCBs, the need to ensure the complete filling of clearance holes with ceramic-loaded resin and to carefully control drilling parameters to avoid cracking in plated-through holes. However, provided they were manufactured by competent fabricators, copper-invar-copper PCB constructions had proved extremely reliable over 20 years' service history, particularly in assemblies with large leadless devices.

For certain applications, aluminium/silicon carbide metal-matrix composites had been used as central core between two thin PCBs, giving an expansion coefficient of 7.2ppm/°C.

Under evaluation at Aero Engine Contols was a proprietary copper-clad carbon fibre composite material known as StablCor, which offered some interesting properties. Initial testing has shown that incorporating this material into a multilayer PCB gave an extremely robust structure, although it did little to reduce the coefficient of expansion of FR4 constructions.

Looking to the future, Fox answered the question "Will we still need expansion control?" with reference to trends towards reduction in active component size such that the package effectively contained a higher proportion of silicon, and the increasing use of large multi-chip modules based on high-temperature co-fired ceramic packages. He believed that expansion control would continue to be a requirement and left the audience to speculate upon ways in which this might be achieved.

Semblant's SPF nano-material

Tim Gee

Second presentation was by **Tim Gee**, Technical Director of Stevenage Circuits, with an overview of Semblant's SPF nano-material, which he believed brought a totally new perspective to the solderable finishing and long term protection and preservation of printed circuit boards. SPF was a low-cost plasma polymer process which yielded a patented solder-through finish on metal surfaces.

The material was RoHS & REACH compliant and the dry, room temperature process involved no hazardous waste or conflict metals, required no water and consumed minimal energy. The finish was an unreactive, highly cross-linked fluoropolymer which coated the entire surface area and gave unprecedented environmental protection and corrosion resistance. Gee explained the principles of the plasma deposition process and the use of Fourier-Transform infra-red spectroscopy to measure the deposit thickness, typically 40 nanometres.

He showed many examples of independent test results which demonstrated how SPF dramatically improved the corrosion resistance of copper, immersion silver and ENIG surfaces under a wide range of conditions, whilst maintaining excellent solderability through multiple reflow cycles.

A particularly desirable attribute of SPF was its performance in RF applications. Final finishes applied over transmission lines could have profound effects on insertion loss, and could significantly downgrade the overall performance of high frequency designs.

There were particular issues with ENIG and ENEPIG plated finishes due to skin effect in the nickel. In instances where high density RF designs required a finish which could not only minimise signal loss but also withstand multiple soldering operations, immersion silver was popular, but tended to corrode if unprotected. Immersion silver coated with SPF offered an ideal solution.

Conductive anodic filamentation, (CAF)

Martin Wickham

Martin Wickham from the National Physical Laboratory discussed a new approach for studying CAF, conductive anodic filamentation, an increasingly significant failure mechanism in printed circuit assemblies.

He explained CAF as an electrochemical process, initiated by corrosion of copper at an anodic site within the PCB and resulting in corrosion products growing along interfaces between laminating resin and glass-reinforcement filaments towards a corresponding cathodic site. CAF formation required electrical charge carriers to be present to form an electrochemical cell, typically ionic species inside the PCB: hydrogen ions and hydroxyl ions from water, which must also be present to dissolve the ionic species and sustain them in their mobile ionic state, an acid environment around conductors to initiate copper corrosion, delamination between glass fibre and resin to form a pathway, and an electrical bias to act as a driving force for ion transport.

With the support of a group of industrial partners, NPL had devised a technique for observing CAF effects under controlled conditions and studying the individual effects of a range of variables including different resin chemistries, glass fibre sizes, surface conditions and finishes, and the effects of drilling, desmear and reflow. Their Simulated Test Vehicle enabled CAF to be monitored in real time with an optical microscope and backlighting. It consisted of an copper lead-frame etched on a polyimide flexible substrate, across which glass fibre filaments were placed and embedded in a solution of laminating resin which was subsequently dried and cured, as it would be in a laminate manufacturing process. The test vehicle enabled ionic material, in the form of copper plating electrolyte, to be brought into contact with the glass filaments, and an anode-cathode bias voltage to be applied.

The technique had been successfully used to evaluate the effects of different resin systems, different glass fibres, desmear process, reflow

process and glass fibre bundle size on CAF failure. It had been observed that heat-cleaned and loom-state fibres formed CAF more easily than finished fibres, with loom-state fibre having the highest propensity. Phenolic cured resin appeared to promote more CAF than DICY-cured resin; the desmear process did not increase CAF formation to any great extent, although the reflow process caused significant increase. And large glass bundle size increased CAF formation, but not significantly. The project was ongoing and the next phase would study actual PCB build parameters.

Reliability improvement using a - "Design-Test-Analyse-React " approach.

Anthony Jackson

Not surprisingly, actual PCB build parameters were fundamental to the following presentation, from **Anthony Jackson**, Product Assurance Manager at Invotec, specialist manufacturers of complex PCBs for military and aerospace applications.

His topic was the improvement of the reliability of a 16-layer 3-stage bonded flex-rigid board using a "Design-Test-Analyse-React" approach. He explained that, because of the variety of materials used in the construction of flex-rigid designs, they were more susceptible to thermal expansion stresses and less robust than rigid PCBs.

The product in question was required to perform with high reliability in a harsh environment and the customer had specified that it withstand a minimum of 400 cycles of interconnection stress testing (IST) before failure. The interconnection stress test an accelerated test method that measures the integrity of the printed circuit interconnect structure by thermally cycling a representative test coupon electrically whilst monitoring changes in resistance, revealing specific areas of weakness in a particular construction.

Although Jackson's example was required to pass 400 cycles of IST, the initial samples failed at between 258 and 289 cycles. The point of failure, identified by thermal imaging and microsectioning was cracking of the copper plating at the centre of a plated-through hole, corresponding with an area of no-flow prepreg.

Improvement in drilling parameters, a reduced plasma desmear cycle and increased plating thickness increased the cycles-to-failure to between 387 and 446, but it was clear that with the construction as designed, the product would remain close to the limit of acceptable reliability.

So the next step in the "Design-Test-Analyse-React" procedure was an engineering review with the customer, which resulted in a modification of the build such that four single-sided flex layers were replaced by two double-sided layers. This reduced the amount of no-flow prepreg in the build and enabled a further reduction in the severity of the plasma desmear cycle, and resulted in a dramatic increase in IST cycles-to-failure to more than 1000.

Jackson remarked that all of the failures seen during the different iterations were linked to protrusions and notches within the hole wall acting as stress risers. His observation led to a lively discussion around the merits of the old MIL-SPEC requirements for heavy etch-back to give three-point contact between inner layer copper and through-hole plating. The consensus was that heavy etch-back probably did more harm than good in terms of the reliability of PCBs under thermal cycling conditions.

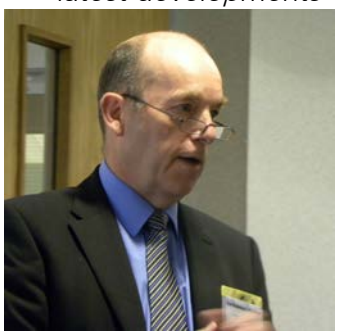
Loughborough research

Prof Andy West

The afternoon session began with **Professor Andy West** reviewing electronics research at Loughborough University. With great gusto, he listed an impressive range of projects including Electronics Manufacturing Process Enhancement Towards High Yields (EMPATHY), Embedded Enhanced RFID (RFIX) for Printed Circuit Board Manufacture and Added Value, Design and Simulation of Complex Low Volume Electronics Production (DISCOVER), Complex Low Volume Electronics Simulation (CLOVES), Life-cycle Tracking (INBOARD), and Design for Increased Yield in the Electronics Manufacturing Supply Chain 2012-2014 (DIY).

Of the many examples he described, two had particular relevance to the "High Reliability" theme of the seminar. One was the modelling of vibration modes in printed circuit assemblies to facilitate the optimisation of component placement, and the second was an analysis of the multitude of factors which determine the consistency and precision of solder paste placement in the stencil printing process. He showed how information was identified, gathered and incorporated into a DoE, how experimental models were developed, utilised and studied, how observations were analysed and how rules were designed which could then be applied to physical models, with an end objective of getting intelligence into shop-floor operations.

Press-fit connections. - latest developments



Andy Longford

From university research to the practical aspects of achieving high-reliability electrical interconnection without recourse to soldering, as **Andy Longford** from PandA Europe discussed latest developments in press-fit connections.

Press-fit technology exhibited a number of advantages over soldering methods. It involved no thermal stress on the PCB, no fumes, gases or cleaning fluids, no cold solder joints, no solder shorts and, in the case of press-fit connectors, the elimination of the need for mounting screws.

Two classes of press-fit were available: "solid pin" did not deform in the insertion process, and "compliant pin" compressed as a result of insertion into a PCB through hole. "Eye of the needle" compliant pin connectors had been developed to meet automotive requirements as defined by IEC, EIA and SAE, and were already qualified for operational temperatures of 125°C and 150°C and moving towards 175°C.

Of the material options available, copper-tin alloys were the most popular for general-purpose applications, whereas copper-chromium-silver alloys gave best conductivity for power applications, and compliant pins were compatible with various PCB plating types.

Additionally, press-fit technology offered complete repairability and ease of dis-assembly, enabling "green" system development

Longford discussed typical automotive performance and test requirements for press-fit technology: mechanical properties including insertion, withdrawal and retention force, vibration in temperature, thermal shock, electrical contact resistance and through-hole integrity after various environmental and corrosive-atmosphere conditions.

Solder - low-silver SAC alloys

Richard Boyle

Back to soldering! Henkel's technical specialist **Richard Boyle** reported the latest lead-free developments in a review of low-silver SAC alloys.

Were they useful for high-reliability? "In a word, no, but they do have some interesting properties. In particular, they give much better resistance to mechanical shock". Why use silver at all? "Metallurgically, it inhibits the dissolution of silver from the printed circuit and the components".

Although the cost of solder represented a relatively small proportion of the overall value of a PCB assembly, cost reduction was the main driver for reducing silver content to less that 1% compared with the 3-4% silver in near-eutectic SAC alloys, where silver could represent more than 50% of the material cost, and was subject to dramatic metal-market price fluctuations.

The improvement in shock resistance in low-silver alloys resulted from their lower modulus such that their greater elastic compliance reduced the stress transmitted to interfaces upon mechanical shock.

Reducing silver content resulted in an increase of up to 10°C in melting point. Wetting speed was slightly slower, although this was unlikely to cause any significant difference in the reflow process. And because low-silver alloys were non-eutectic, joints had a duller appearance.

Other issues were reduced reliability due to poorer low-cycle fatigue performance compared with near-eutectic SAC alloys, and lower mechanical strength

But all was not lost – there was a lead-free alloy specifically designed for high reliability! An innovative formulation developed by a consortium of

research institutions and solder manufacturers for high-temperature under-the-hood automotive applications was a 6-component alloy known as InnoLot, based on SAC 387 with the addition of bismuth, antimony and nickel as grain refiners. InnoLot alloy had a high tensile strength, yield stress and shear strength at both low and high operating temperatures, and performed remarkably well on thermal cycling and drop testing. Its reliability under vibration testing compared well with traditional tin-lead solders and was superior to other lead-free alloys.

Conformal coating - PCB design considerations

Jon Anderson

Final presentation of a long and technically intensive day came from **Jon Anderson** of Humiseal, with an interesting discussion on PCB design considerations for conformal coating.

In his definition, a conformal coating was a thin plastic protective film which conformed to the varied profile of an electronic circuit assembly, acting as a membrane to protect the assembly from water vapour, solid debris and corrosion in harsh environments.

Typical solvent based coatings gave coating thicknesses between 25 and 75 microns; 100% solids formulations gave thicknesses of 75 to 200 microns. IPC- HDBK - 830, Guidelines for Design, Selection, and Application of Conformal Coatings, the main industry standard, together with IPC 2221B and IPC-A-610A for generic design and acceptability. But these standards were not particularly definitive, and tended to throw most of the responsibility on to the designer.

Along with the change to lead-free soldering had come higher reflow temperatures, low VOC fluxes with higher solids content, new solder paste chemistries, new solder mask chemistries, new solderable finishes on PCBs, and PCBs now increasingly came from distant, rather than local, manufacturing locations. Current technology trends were towards ultra-fine component pitch, higher frequencies and higher operating temperatures.

From the perspective of conformal coating, reduction in overall dimensions and tighter limits on keep-out zones demanded greater selectivity to achieve coverage, and VOC-free materials often required specialist dispensing techniques.

It was important for the PCB designer to consider at the outset the application method, the surface area of PCB to be coated, the types of components to be coated, the keep-out areas to be defined and the inspection level required. Anderson gave valuable practical advice on design for selective coating, with particular reference to shadowing effects of tall components and constraints on keep-out zones.

The attentiveness of the audience was impressive. The well-chosen seminar programme delivered an enormous amount of relevant information on many issues associated with the design and manufacture of high-reliability electronics, and provoked plenty of interactive debate and discussion. Another excellent SMART Group event and a great credit to those who organised and hosted it.

Pete Starkey,
June 2013

Head in Pillow, Pad Cratering, Cleaning, Selective Soldering & SMT Audit **Webinars** *with Bob Willis*

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Practical Handling Moisture Sensitive Devices & PCBs - Without Failure	Tuesday	11th June	10:00
Pad Cratering Failure & Test Methods	Monday	11th July	14:30
Auditing & Troubleshooting PCB Assembly Suppliers - On or Offshore	Tuesday	3rd Sep.	10:00
Selective Soldering Design & Process Setup	Monday	16th Sep.	14:30
Guide to PCB Surface Finishes & Process Defects	Tuesday	22nd Oct.	14:30
Crimping Inspection & Quality Control	Monday	25th Nov.	14:30

Organisation	*Address*	*Communication*
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The Membership Secretary's notes - July 2013

The last 10 years have seen major changes in the way the Institute handles applications for membership. Prior to 2003, all applications were in writing, and were discussed at the next suitable council meeting, so the process could take many months. An on-line grading committee, drawn from council members, and headed by Prof, Martin Goosey was set up, and although we still handled written applications, most forms were being sent out electronically.

As Council Member Richard Wood-Roe refined our website, he was able to add a page for application forms, delivered automatically to the Membership Secretary and the era of written forms disappeared forever. When the application is approved, and the Members name added to the Members Listing page, it triggers a welcome message to the new member, who is then able to access and update his information and the electronic loop is completed.
Membership Certificates together with a list of the Objectives of the ICT still wing their way via the Royal Mail, but as the use of 3D Printing continues, we may yet find members printing out parchment paper and a wax seal!

Our thanks go to Members Dennis Price and Ian Mayoh for helping us out with presentations at our Annual Symposium this year (reported elsewhere in this journal)

OBITUARY

Members will be saddened to learn that Ian Molynuex passed away last Tuesday at a Dublin Hospital. Ian had a technical role with Nelco, Skelmersdale before joining Taconic where latterly he headed their European Industrial Products Division. Ian would have been 49 next month and he leaves two daughters and a younger son.

13th Electronic Circuits World Convention

ECWC13 7th - 9th May 2014 Nuremberg

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CALL FOR PAPERS -

The **13th Electronic Circuits World Convention** (ECWC13) will take place from 7 - 9 May 2014 in conjunction with the SMT Hybrid Packaging exhibition in Nuremberg, Germany. The conference is organized every three years alternately by the members of the **WECC**. In 2014, for the first time in eleven years the conference will be hosted in Europe. Participants from all over the world will meet in Nuremberg and benefit from extensive networking and knowledge transfer.

Become a part of **ECWC13** as a speaker or poster presenter. Take the chance to present your know-how to an audience of qualified specialists. The deadline for the submission of abstracts is **13 September 2013**.

We are looking forward to your submissions.

Topic range

Management

- M1 Global Market Trends and Outlook
- M2 Supply Chain Management
- M3 Enviroment, Health and Safety
- M4 Business Models and Safety
- M5 Certification and Qualifications
- M6 Total Cost of Ownership and Overall Equipment Efficiency (OEE)

Technology

- T1 Design and Development Tools
- T2 Materials, Components and Traceability
- T3 Manufacturing
  - T3.1 Equipment
  - T3.2 Technology
  - T3.3 Process Development
  - T3.4 Automation
- T4 Quality and Life Cycle Management
- T5 PCB Processes
  - T5.1 Chemical Technology
  - T5.2 Mechanical Technology
  - T5.3 Optical Technology
- T6 Surface Mounting, Assembly and Interconnection
- T7 Packaging Technology
  - T7.1 System in Package
  - T7.2 Wafer-Level Packaging
  - T7.3 Panel-Level Packaging
- T8 Energy and Resource Efficiency
- T9 Application Specific Areas
  - T9.1 Automotive Electronics and Electromobility
  - T9.2 Industrial and Power Electronics
  - T9.3 Aerospace and Defence
  - T9.4 Medical Electronics
  - T9.5 Consumer Electronics
- T10 Advanced and Emerging Technologies

There are two opportunities for presenting your expertise:

Oral presentation

These will be held within conference sessions addressing key elements of the same topic. Each presentation should last 20 minutes. An extra 5 minutes will be permitted for discussions and questions from the audience.

Poster presentation

Authors will have the chance to present their posters during a special poster session.

The working language for all presentations and discussions is English.

Abstract Submission

Those who wish to offer a technical paper should send their abstract/synopsis by using the online submission form, which should be fully completed. The synopsis should not exceed three pages and should follow the format, as detailed here: word or pdf. Click _ http://www.mesago.de/en/ECWC/The_Conference/Welcome/index.htm for the submission form.

Selection Process

All submitted abstracts will be presented to the committee for selection. The acceptance of your abstract depends on the following criteria: the content, the preparation, the substance and the relevance of the conference themes. Punctuality and completeness are also a criteria. The committee reserves the right to allocate abstracts to a different topic when suitable.