Journal of the Institute of Circuit Technology

2012 Events

27/28th November 6th International Symposium on Tin Whiskers
Tuesday & Wednesday Loughborough University
bill.wilkie@InstCT.org

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

Late September
ICT Evening Seminar
at Hayling Island

November
ICT Evening Seminar
at Hartlepool

Vol.6 No.2 April 2013

Editorial

With this second issue of 2013 we should be well advanced into Spring, unfortunately the Gulf Stream has been deflected to the South West and left us still in Winter Conditions,

It is rather like the position of the New Materials and Processes that we have been considering lately - such as Graphene, DNA memory, ASPIS and Susonence, they are all listed in 'Topics' - where progress is slower than we would wish. Lack of a steeper progress curve is considered by some to be a result of the National and Worldwide recessions and Nationally a political issue; which of course we don't formally discuss within the Institute.

The way forward within the Institute must therefore be for individual and company wide pursuit of the Aims and Objectives established over 40 years ago by the Institute founders, one of these objectives was the provision of facilities for discussion and debate by its Members.

At present, the Institute organises four Technical Seminars, an Annual Symposium and the Annual Foundation Course, together with four issues of this Journal.

If Members would give serious consideration to writing publishable Papers or News Items about their achievements, which could be used by our current facilities, progress in our Industry could be more rapid.

Please e-mail your comments for publication in the July Corrections and Clarifications column.

Bruce Routledge Hon.F.Inst.C.T.
Membership No.27
Editor

Corrections and Clarifications

It is thle policy of the Journal to correct errors in its next ssue.
Please send corrections to : -
bruce.rout@btinternet.com

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IeMRC 7th Annual Conference

Loughborough, UK,
5th September 2012

Pyroelectric materials - Recent advances

Prof. Roger Whatmore

Henry Ford College at Loughborough University was a popular and appropriate venue for the 7th Annual Conference of the Innovative Electronics Manufacturing Research Centre, the UK's internationally recognised provider of world-class electronics manufacturing research.

IeMRC Coordinator Dr. Darren Cadman made the opening remarks, gave a brief update of the status of passed, current and future projects and introduced keynote speaker **Professor Roger Whatmore** from the Tyndall National Institute in Cork, Ireland, whose topic was "Recent advances in pyroelectric materials and their applications: People Counting, Cooling and Energy Harvesting".

The pyroelectric effect was the change in polarisation of a polar material with temperature, which had been recognised over a century ago and had led to the discovery of the piezoelectric effect. From the basic physics of pyroelectric and related electrocaloric effects, derived from interactions among electric displacement, electric field, temperature and entropy, Professor Whatmore explained the construction and operation of pyroelectric infra-red detectors and how they were sensitive to very small changes in infra-red flux, which made them particularly suitable to sensing and monitoring the movement of people.

Performance and cost were a function of the materials used and, from a wide range of candidate materials, pyroelectric ceramics offered advantages in array fabrication and could be chemically doped to modify their properties. Professor Whatmore discussed tape-casting methods for producing functionally gradient Lead Zirconate Titanate (PZT) ceramics, then described low-temperature sol-gel processes for depositing ferroelectric thin films direct on silicon ASICs to make integrated arrays and fabricate MEMS-based structures. Arrays of thin-film pyroelectric detector elements could be combined with three-dimensional radiation collectors to improve their efficiency.

In an alternative application, pyroelectric energy harvesting had been shown to be significantly higher in efficiency than thermoelectric methods. Converse of the pyroelectric effect was the electrocaloric effect: the change in temperature which occurred when an electric field was applied to a pyroelectric material, and the electrocaloric effect in thin films offered potential for solid state refrigeration

Cost Estimating

Paul Green

Dr Linda Newnes

It seemed the business of supplying aircraft to the military had undergone a radical transformation. No longer did manufacturers simply supply a product; they were now required to provide an availability of the product. In a two-part presentation, **Paul Green** from BAE Systems and **Dr. Linda Newnes** from University of Bath described how a collaborative of universities and industrial partners, representing the supply chain from concept design through to manufacture and disposal, was working to provide a set of modelling tools to enable the manufacturer to estimate the cost of providing a long-term availability contract.

Paul Green began by outlining the differences between traditional and modern support solutions. Effectively, all the military now wanted to do was fly the aircraft and it was the responsibility of the industry to keep the aircraft available. "What are the cost relationships we need to understand?" he asked, and added: "Can you give me a crystal ball?"

Dr Newnes listed and examined cost estimating relationships and described the challenges of acquiring quality data for through-life costing: a paradigm shift was necessary and one of the first questions to ask was what should be done differently now if designing for service. emphasised the need to provide evidence-based decisions in terms of identifying a

She emphasised the need to provide evidence-based decisions in terms of identifying a methodological approach that could be utilised to model a true representation of cost of availability that encompassed the factors influencing the cost of providing a service. Taking as an illustrative example a very simple scenario of a hand dryer on an availability contract to dry one hundred pairs of hands per day, she demonstrated the enormous number of factors involved, questions to be asked and decisions to be made, in particular how would success and performance be measured, and how would the provider would be paid for providing the service – would it be on the basis of performance or availability? She advocated "system thinking" in an operations-based approach and gave an indication of how the CATA (Costing for Avionic Through-life Availability) team of academic and industrial partners was addressing its extraordinarily complex task.

Power modules - high-performance - low-cost

Prof. Mark Johnson

Theme of the second conference session was assembly and test, and the first speaker was **Professor Mark Johnson** from University of Nottingham with a presentation on high-performance low-cost power modules for energy smart network applications.

Predicting that by 2050 the UK would be supported by an integrated smart energy infrastructure, he discussed the role of power electronics in the conversion of electricity from one form to another, and the control of energy flow to provide for grid quality and security, whilst underpinning the low-carbon energy supply chain. Against this background, he focused on the characteristics and limitations of power modules, specifically voltage source converters for high-voltage DC transmission. These converters were typically based on insulated-gate bipolar transistor switches, connected in series or in chain-link modules to withstand voltages in excess of 11kV.

It was necessary to build-in a degree of redundancy, but preferable that in the event of a switch failing it should fail to a short-circuit condition. Historically, this requirement had been addressed by complex "Press-Pack" or "StakPak" devices which were expensive and had limited flexibility.

The challenge was to develop a low-cost alternative which would still fail-to-short-circuit, using existing die technology, existing PCB processes and appropriate high-reliability bonding processes. Planar modules offered many potential advantages, particularly the elimination of weaknesses associated with bond wires and the opportunity for more efficient cooling, and work was under way to simplify the assembly process.

Sintered silver nano-particle pastes were the preferred bonding medium, with polyimide flexible PCB interconnects using nano-paste filled vias providing alignment and circuit functions.

Interconnects - ultra-fine pitch

Prof. Changqing Liu

The requirement for ultra-fine pitch interconnects for micro-BGAs and flip-chip devices presented major challenges, particularly in achieving acceptable yields on large-format devices such as high-resolution sensors.

Professor Changqing Liu from Loughborough University reported the progress of a project investigating the feasibility of using metal-coated polymer microspheres to replace traditional solder joints and achieve interconnection at pitches as fine as 10 microns.

The capability already existed to manufacture mono-sized microspheres and to coat them with nickel-gold, and these materials had been used in anisotropic conductive adhesives.

The objective of the project was to find a way of selectively depositing controlled quantities of these particles directly onto the bond pads of integrated circuits. Various routes had been considered: physical, chemical, mechanical, electrical, electromagnetic and electrochemical.

Chemical methods using self-assembled octanethiol monolayers had been evaluated but yields were low. Electrophoretic deposition appeared to be a viable method, but required the microspheres to carry an ionic charge and a process had been developed to acid-etch the surface of the nickel-gold coating. This resulted in a positive surface charge through the formation of Ni^{2+} ions and hence enabled the microspheres to be deposited electrophoretically.

Once conditions were optimised it had been demonstrated that 100% deposition yield could be achieved on full 6″ wafers with pads as small as 40 microns on 75-micron pitch, and low-temperature thermocompression bonds had been successfully formed between bumped devices and gold substrates.

Flip-chip solder joints - through-life non-destructive monitoring

Ryan Swee How Yang

Through-life non-destructive monitoring of flip-chip solder joints in automotive electronic systems was the subject of the presentation of **Ryan Swee How Yang** from Liverpool John Moores University.

He began by stating that 20% of the value of a typical automobile was in its electronics, and 80% of automotive innovation involved electronic systems. Flip-chip-on-board assemblies were widely used in automotive electronics, which were expected to operate reliably in harsh environments, and flip-chip solder interconnections tended to be the weak link because of thermal expansion mismatch between silicon die and organic substrate potentially resulting in fatigue failure.

The project objective was to track the condition of solder joints from manufacture to failure using non-destructive techniques, and to assess how reliability was influenced by joint position. Acoustic micro-imaging was most effective in detecting gap-type defects, but was not sensitive to volumetric defects, where X-ray was the preferred method. Using the two techniques in combination offered the basis of a complementary method for automatic inspection and non-destructive monitoring of solder joints. An FR4 test board with double-sided flip chips had been used as a test vehicle in a 96-cycle accelerated thermal cycle test, with samples checked at 8-cycle intervals by ultrasound, X-ray and microsectioning.

Analysis and feature extraction from individual and combined ultrasound and X-ray images had yielded information about the characteristics of good joints and fractured joints and enabled discrimination between fracture and voids. It was possible to plot 3-dimensional failure distribution to determine how reliability was related to the position of the flip chip on the board.

Interconnection reliability - wire-bond

Maria Mergkizoudi

Another aspect of interconnection reliability was addressed in the presentation of **Maria Mergkizoudi** from Loughborough University on wire-bond reliability under extreme environments.

She explained that qualification tests for wire-bonded devices were typically carried out in separate environments, for example: temperature storage, temperature cycling and vibration, and this approach could fail to detect the effects of combined parameters.

Her work was aimed at testing gold-wire-bonded components under a combination of thermal loading up to 180ºC and mechanical loading in the form of high frequency vibration. The investigation covered bond strength and mechanical integrity, electrical resistance changes, microstructural defects induced, the role of wire orientation on wire degradation and the effect of applied conditions on loop geometry, using wire-pull and ball-shear testing, electrical resistance measurement, and metallographic examination.

The results had revealed significant differences between thermal testing without vibration and testing in thermal-vibration combination.

Observations on gold-wire ball-bonded devices indicated an appreciable decrease in electrical resistance after testing, which could be attributed to annealing of the wire, a reduction in the shear force to failure of the ball bonds, particularly at higher temperature and low frequency vibration, and a more severe distortion of wire loops when testing at low frequencies. Future work would focus on extending the vibration-temperature regime and examining the effect on wire bond pull strengths.

PCB materials - Applications and limitations of low-loss, - high-speed materials.

Alun Morgan

Printed circuit boards was the theme of the afternoon conference session and the keynote presentation was given by **Alun Morgan**, Chairman of EIPC and Director of OEM Marketing with Isola Europe. Noted for his ability to present complex technical issues in plain language, he gave a detailed insight into the characteristics, applications and limitations of low-loss, high-speed PCB materials, starting with an explanation of the causes of signal losses and where they occurred, and what could be done by the laminate manufacturer to reduce them.

Losses fell into two major categories: conduction and dielectric. Conduction losses occurred in the copper and, as signal frequency increased, were increasingly associated with the surface of the copper because of a phenomenon known as the "skin effect". This was the tendency of an alternating current to distribute itself within a conductor such that its current density was highest near the surface. As a result, current flowed mainly at the "skin" of the conductor, and the depth of the skin varied enormously with frequency. For example for copper it was 9.3mm at 50Hz, 6.6 microns at 100MHz and 0.66 microns at 10GHz. The skin effect effectively reduced the current carrying capacity of the conductor and increased its resistance at higher frequencies.

Copper foils for PCB laminates were "treated" during manufacture to give a rough surface to promote good bonding to resin : standard foil had a treatment depth of about 10 microns. At low frequencies, the treatment had little effect on signal loss but because of the skin effect it could have a dramatic effect at high frequencies, which was why low-profile foils were available for high-frequency applications.

Dielectric losses resulted from alternating signals causing polarisation and molecular vibration within the glass and resin components of the laminate, generating heat, a familiar example being the microwave oven. The dielectric constants of glass and resin were different, which meant that in a glass-fabric reinforced laminate the microimpedance effects of filament distribution could cause problems with signal integrity at high frequencies. Laminate manufacturers had begun to use square-weave fabrics with spread fibres to minimise this effect.

Morgan listed loss factors for a range of PCB substrate materials. Standard FR4 had a loss factor of 0.015 at 1GHz, compared with 0.002 for PTFE and 0.003 for certain ceramic-filled materials. New-generation, non-PTFE, non-filled PCB substrate materials were becoming available with loss factor around 0.003 at 1 GHz as a lower-cost, easier-processing alternative to traditional solutions.

Traceability - Manufacturing history

Axel Bindel

Axel Bindel from Loughborough University stressed the importance of clear and easy-to-access information about the manufacturing history of a product in supporting traceability requirements and decision making at end-of-life, as well as providing scope for re-use and re-manufacturing.

He explained that information could be stored in an electronic product by embedding an RFID tag within the structure of the PCB, with the facility to read or write data wirelessly, and described how this had been successfully achieved. During the manufacture of a multilayer PCB, the RFID chip was assembled on to an inner layer by a flip-chip process, and became fully encapsulated within the epoxy resin during the laminating process.

The only significant modification to the PCB layout was the incorporation of an antenna in the periphery of the design.

The embedded RFID had been shown to withstand harsh environments and multiple thermal shocks. Product information could be stored from the very beginning of the manufacturing supply chain and during subsequent production processes for each individual product, and accessed with a hand-held reader even when the PCB assembly was enclosed within a piece of equipment.

Ultrasound - electroless copper plating

Amirah Kassim

The effect of ultrasound on electroless copper plating was the subject of the presentation by **Amirah Kassim** from Coventry University, who reported the progress of the IeMRC-funded ULTIEmet project.

Using a commercially available EDTA-based self-accelerating electroless copper process, initial studies had examined the effect of ultrasound of different frequencies on the stability of the bath, and 40KHz had been chosen as the working frequency for plating-rate experiments as it caused no spontaneous precipitation of copper.

Plating rates were measured over a range of operating temperatures, with and without ultrasonic agitation, and only slight increases were observed when ultrasound was applied from the start of the process. It had been shown that, in the early stages of deposition, ultrasonic agitation was tending to scrub the palladium activator off the surface and reduce the plating efficiency. When a delay was introduced to enable complete initiation before the application of ultrasound, a significant increase in plating rate was observed. Ultrasonic agitation also appeared to yield a finer-grain deposit with improved mechanical properties.

Ionic liquids - immersion gold processes

Dr Karl Ryder

The final presentation was given by **Dr Karl Ryder** from University of Leicester, a partner in the EU Framework 7 funded ASPIS project.

His department specialised in developing applications for ionic liquids and as part of the ASPIS project was investigating immersion gold processes based on deep-eutectic solvents as an alternative to aqueous processes which were known to have been contributed to "black pad" effects on traditional electroless nickel – immersion gold solderable finishes. Immersion gold had been deposited on a standard aqueous electroless nickel surface from solutions in a deep eutectic solvent based on readily available choline chloride and ethylene glycol.

Three different gold salts had been used: gold chloride, gold cyanide and potassium cyanoaurate, and their electrochemical behaviour had been studied A standard aqueous solution based on citric acid had been used as a control, and plating rates had been measured with a quartz crystal microbalance. Immersion gold deposited from the gold cyanide – ionic liquid formulation was bright and uniform in appearance, and gave faster and more reliable solder wetting than the deposit produced from the aqueous control formulation. Addition of cyanide to the ionic liquid formulation had been observed to improve plating rate and deposit appearance. Future work would include further investigation of the effect of additives other than cyanide, and the effect of ageing on solderability.

The 7th Annual Conference was yet another outstanding IeMRC event and a great credit to the team at Loughborough.

If I might steal a few words from the IeMRC mission statement to capture the spirit: "....focus on sustaining and growing high value manufacturing in the UK by delivering innovative and exploitable new technologies...", and reflect upon a statement attributed to Henry Ford, displayed on a wall in the conference venue: "If I had asked people what they wanted, they would have said faster horses"

Pete Starkey
I-Connect007

Novel Solder Flux Project - February 2013

A project investigating the development of a new solder flux for electronics using special types of ionic liquids called "deep eutectic solvents" (DES) has been started at the University of Leicester by Professor Karl Ryder and Dr Andrew Ballantyne.

The IeMRC-funded project aims to cause a technology change in the solder flux industry by replacing the harmful, expensive rosin based systems, used currently, with a lower cost, sustainable and environmentally friendly DES-based flux.

Additionally, the current approaches often require different fluxes to suit the type of metal, whereas DES has the potential to be a universal flux.

A kick-off meeting was held at the University on the 14th February, 2013 when presentations were given by Professor Ryder detailing the background to the project, and Dr Ballantyne discussing the structure of the research to be carried out.

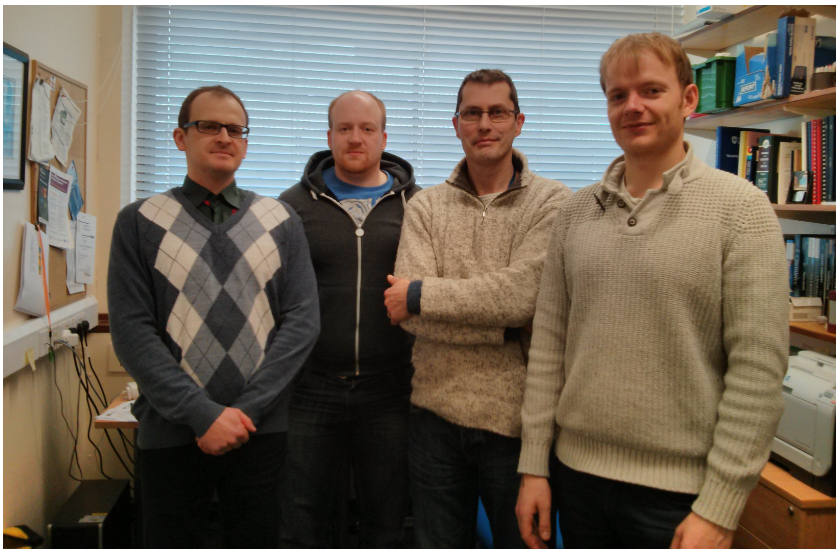
Active partners in the research are:-

International Tin Research Institute (ITRI) and Merlin Printed Circuit Boards (Merlin PCB) to fully characterise the nature of the solder bonds and provide a critical assessment compared to those of conventional methods.

The project has a wide impact potential and is supported by:-

European Institute of Printed Circuits (EIPC)
iMAPS group.
Institute of Circuit Technology (ICT)
National Physics Laboratory (NPL)
Manufacturing Technology Centre (MTC)
SMART group

More information from Dr Andrew Ballantyne at ab27@dleicester.ac.uk.



Dr Rob Harris Prof. Karl Ryder
Christopher Zaleski Dr Andrew Ballantyne.

Pulse Plating

Wolfgang Hansal and Sudipta Roy
Eugen G. Leuze Verlag KG D-88348 Bad Saulgau, Germany
ISBN: 978-3-87480-265-9
Published in 2012

Although electroplating has been in industrial use since the 19th century, the technique known as pulse plating is a more recent development. The first interest in pulse plating began during the 1970's and since then there has been a huge amount of work reported, both on the fundamental science and in terms of bringing the technology to commercial application through use in industrial production.

Following the initial fundamental work carried out around 35 years ago, the development of new and increasingly sophisticated electronically controlled rectifiers, along with computer aided process simulation techniques, has enabled pulse plating to become a valuable production tool in numerous high technology applications including printed circuit board fabrication.

Although there have been many papers and several earlier books published on the subject, this new work by **Wolfgang Hansal** and **Sudipta Roy** provides a more up to date compilation of the basic science coupled with details of the latest developments, possibilities and applications associated with this powerful technology.

The main body of this substantial work is prefaced by forewords from three well known experts in the field. The first is by Peter Farr who gives a review of a sample of relevant papers published in recent years on pulse plating in a foreword entitled "Pulse Plating in the Third Millennium". The second foreword, "Past and Future of Pulse Plating: An Introduction", is then provided by Wolfgang Paatsch, an expert who has been active in this field for a great many years. The final foreword is by Sudipta Roy and Wolfgang Hansal, who have not only edited this major work but also contributed to virtually all of the chapters, either individually or in collaboration with four other authors.

Following these useful introductions, the book then moves on to a series of individual chapters covering all aspects of pulse plating, from the fundamentals to the equipment and processes for the deposition of a range of metals. Conveniently, the book is arranged in four sections that start with the fundamentals and then move through implementation to applications and, finally, special systems.

The first section on fundamentals comprises seven chapters beginning with an overview of pulse deposition and then taking in chapters on thermodynamics, reaction kinetics, nucleation and morphology, current distribution, mass transfer and modelling of pulse plating. This section thus provides a detailed review of all of the underlying scientific aspects that need to be understood by anyone working in this area who desires to gain a deeper knowledge of the subject.

The second section on implementation then covers the key aspects that will be of importance to those engaged in the actual utilisation of pulse plating and its three chapters cover pulse rectifier systems and the technical implementation of pulse plating processes, along with energy and material considerations. Rectifier designs and their associated performance capabilities have advanced significantly in recent years, giving much more versatility in terms of pulse waveforms, duty cycles and a number of other key factors and these are all covered in some detail in this section.

Pulse plating of copper in printed circuit board fabrication.

High aspect ratio holes and vias.

The third section on applications has six chapters detailing the use of pulse plating to deposit a range of important metals and alloys. The section begins with a chapter on the pulse plating of copper in printed circuit board fabrication. Interestingly, this was the first significant commercial application for pulse plating and it continues to provide a valuable approach for the deposition of copper in complex circuit boards. In particular, it enables the plating of high aspect ratio holes and vias that could not successfully be deposited using traditional conventional electroplating techniques. This chapter will be one that is of particular interest to those involved in the manufacture of printed circuit boards and it offers a broad coverage of the key subject matter that will be of interest to such readers. The chapter covers not only the historical development of pulse plating techniques for use in printed circuit fabrication but also the reactions that take place and which influence the overall efficiency. The demands on copper deposited in printed circuit boards are broad and challenging and are their attainment is fundamental to the performance of all of the modern electronic goods upon which society increasingly relies. As boards increase in complexity and interconnect density, a key demand is for enhanced throwing power and this subject is also covered in detail, from the basics of current distribution and Wagner numbers to surface distribution, plating of through holes and blind vias. The copper deposits used in PCB interconnects require a very specific set of properties and associated structures and morphologies and the chapter covers these aspects before concluding with a brief introduction to the more complex approach of superimposed pulse reverse plating and some information on recommended pulse plating parameters and settings.

The following five chapters cover nickel and its alloys, tin and its alloys, chromium, precious metals and zinc and its alloys. The chapter on the pulse plating of precious metals includes gold, silver, palladium, platinum, rhodium and various alloys.

The final section of the book is on special systems and its three final chapters discuss pulse polishing, machining and anodising, the deposition of nano-structured metal multilayers and pulse plating in combination with particle dispersion.

With a total of three forewords, nineteen actual chapters, a list of over 800 references and a very extensive index, this work of almost 400 pages provides a comprehensive compilation of all of the important subject matter that comes under the umbrella of pulse plating. Rather unusually for a book of this type, the final pages following the index are dedicated to advertisements from a number of organisations active in the field of pulse plating and who will doubtless be good sources of further information for readers interested in implementing the technology.

The book covers the basic science, the equipment needed and the use of pulse plating to deposit a wide range of metals and alloys. For those with an interest in electrodeposition, this book contains a wealth of information and it provides an excellent work with which to learn more about this extremely interesting and relatively new electroplating technique.

The authors are to be congratulated for preparing such a valuable and important new work that will be of use to both academics and industrialists.

Martin Goosey
December 2012

ICT Northern Seminar

Glynhill Hotel, Renfrew, Glasgow, 5th March 2013

Reviewed by Pete Starkey

Pete Starkey

Not since the golden days of the Northern UK Circuit Group had such a gathering of the great and the good of the British printed circuit industry been seen north of the Scottish border. But the combined attractions of an excellent technical programme and a visit to Rainbow Technology Systems headquarters for a working demonstration of their innovative primary imaging process brought a capacity crowd to the Institute of Circuit Technology seminar in Glasgow on 5thMarch 2013. Welcoming delegates, ICT Technical Director Bill Wilkie commented that membership of the Institute continued to grow, and now exceeded 300.

Micro section preparation - Broad Ion Beam (BIB) machining

Stewart McCracken

The first presentation of the seminar programme came from **Stewart McCracken**, Managing Director of MCS, with a description of a game-changing technique for micro section preparation. Many members of the audience, author included, had spent long hours at the laboratory bench, cutting, mounting, grinding, polishing, etching and examining sections of circuit boards or assemblies, conscious that critical details could be distorted or obscured as a consequence of the mechanical stresses involved.

McCracken was an expert in the application of Broad Ion Beam (BIB) machining to the micro sectioning process. In principle, the technique involved masking-off the functional area of the sample and machining away the rest with a beam of energised ions in the form of an argon gas plasma. Material was removed at the atomic level, there was absolutely no mechanical damage – no smearing or deformation – and the true structure of the material was revealed. No potting resin was required, so an additional benefit was that, as well as the cut face of the cross-section, the adjacent surface could be examined, whether by optical or scanning electron microscopy.

He showed several examples of sections prepared by BIB, and clarity of detail and sharpness of edge definition were amazing. The technique allowed the critical examination of thin surface layers, such as immersion tin and immersion gold, and, when combined with scanning electron microscopy and energy-dispersive X-ray spectroscopy, the compositions of surface and sub-surface structures could be determined by superimposing elemental maps on the micrographs. In cross-sections of BGA joints, the copper-tin intermetallic phases were clearly seen and extremely fine Kirkendall voids could be readily detected in aged solder joints. BIB machining could be used to reveal otherwise hidden damage at interfaces and to identify failure mechanisms. Sections up to 5mm in width could be prepared by BIB alone, or up to 30mm diameter for encapsulated samples if hybrid methods were employed. In all cases, the machined surface was perfectly preserved to nanometer scale.

The techniques that Stewart McCracken described brought a whole new dimension to the field of defect investigation and failure analysis of PCBs and assemblies, and generated enormous audience interest. The equipment cost was probably beyond the means of smaller PCB fabricators, but subcontract services were available.

High frequency - the future

Jim Francey,

Next to speak was **Jim Francey**, Sales Manager for Optiprint, who quoted Professor William Scanlon, Head of Wireless Communications Research Group at Queen's University Belfast: "Take my word for it Jim, the future is high frequency!" as he began his discussion of the trends in millimetre-wave applications that would proliferate demand for bandwidth, and the impact they would have on the PCB technology required for backhaul infrastructure. The "need for speed" was being driven by exponential growth in mobile communications devices, and network operators were responding with implementation of 3G and 4G networks to meet demand for wireless internet access. Access to fibre-optics was not always possible, and network operators were looking to millimetre-wave radio solutions to satisfy bandwidth demand. The Wireless Gigabit Alliance "WiGig" protocol, operating in the 60GHz waveband, was designed to allow wireless communication of data, display and audio over short distances at multi-gigabit speeds. Antenna-in-package devices were available for use in many consumer electronics applications, and it was forecast that, by 2017, 1.6billion smart-phones would be WiGig compatible.

What did this mean for the PCB? For 60GHz short-distance applications, the functionality was in the packaged devices, consumer products would continue to use conventional PCB technology, as would short-haul radio links with silicon-germanium chipsets, whereas longer-distance E-band radio would use architecture based on monolithic-microwave-integrated-circuit components mounted on low-loss substrates. It was attractive to use conventional PCBs rather than ceramics for millimetre-wave radios because of the global supply base, low tooling costs and assembly economics, but the problem remained how to achieve the tolerances that such frequencies demanded.

Francey explained that when frequency increased, everything had to shrink. Below 20-30 GHz, the designer had a lot of freedom and could be assured of good production yield, but at higher frequencies everything was about manufacturing tolerances and producibility. "Being a microwave designer is a completely different job at 77 GHz compared to 1 GHz." He discussed design rules for millimetre-wave to explain what factors were driving the tolerances. For a transmission line to work, substrate thickness could not be more than about 5-10% of the wavelength, and many designers were specifying 0.1mm thick dielectrics, such that a 50ohm microstrip on a material of 4.0 dielectric constant was only 0.2mm wide, with the consequence that critical control of etching was required, even if lower-Dk materials could be justified. From the PCB fabricator's point of view, millimeter-wave demanded expertise in working with small-form, high-precision components, and a manufacturing capability that included thin liquid-coated etch resist, laser direct imaging, vision-assisted drilling and machining, IR and UV laser ablation and gold wire bondable finishes.

High Frequency - Suitability of Available Laminates

Geoff Layhe

Jim Francey having set the high-frequency scene, it was appropriate that **Geoff Layhe**, Technical Manager at Lamar, should step forward to give a presentation on the suitability and availability of laminates for high frequency applications. "Why isn't FR4 good enough?" he asked. "Because we want to know as much as possible as soon as possible!" in reference to the relentless demand for increased computing power and faster communications. With Moore's Law references to petaflop rates and gigahertz clock speeds, and the increasingly high frequencies used in radio communications, he focused on the need for flawless high-speed transmission of "Big Data", and discussed the laminate parameters influencing signal speed and signal loss. In general terms, signal speed was closely related to the dielectric constant of surroundings, and signal loss to the dissipation factor of surroundings.

Beginning with conductor losses, he explained the "skin effect", where at gigahertz frequencies the signal is carried not in the body of the copper but in a progressively thinner surface layer – 0.37 microns at 30GHz for example – much less than the surface roughness of the bonding treatment on the copper foil. To reduce signal degradation, foils were available in low-profile, very-low-profile and reverse-treated grades. Then considering woven glass reinforcement: traditional glass cloth had a pronounced weave profile, such that signals experienced significant local variations in dielectric constant depending on the presence or absence of glass yarns in the weave construction. Modern grades of "flat glass" fabric had glass filaments more evenly distributed, reducing the local dielectric constant variation. He then considered laminate effects, and the dielectric constants and loss factors of different high-frequency materials, quoting data for various proprietary laminates, stressing the importance of values remaining consistent through ranges of frequency, temperature and humidity, and concluding that there was a range of processable laminates commercially available using flat glass as reinforcement, with very-low-profile or reverse-treated copper which were suitable for modern high frequency circuits.

Jonathan Kennett

Jonathan Kennett, Chief Executive of Rainbow Technology Systems, brought proceedings to a close, thanking all who had taken the opportunity to visit his facility, and inviting delegates to join him and his colleagues in the convivial and interactive networking session which nicely rounded-off the evening.

The Glasgow Audience of ICT Members at the

ICT Northern Seminar

The event was sponsored by :-
Rainbow Technology Systems

Pete Starkey

I-Connect007
March 2013

The Rainbow Process: I've seen it ! It works!

Pete Starkey, I-Connect007

Pete Starkey

I have followed the evolution of the Rainbow Technology Systems primary imaging process ever since a conversation with CEO Jonathan Kennett at Productronica 2009, when he took me to one side and described to me confidentially the principles of his current development project, although he was not in a position at that time to disclose substantial details.

The project continued behind closed doors until Rainbow unveiled their process line at Productronica 2011, although only part of the hardware was exhibited and certain key elements of the system appeared, in my opinion at the time, to exist predominantly in the form of elegant computer animations. Despite my scepticism, Jonathan Kennett, together with chief chemist John Cunningham and chief engineer Robert Gibson, went to a lot of trouble to answer my questions about the workings of the process and I continued to follow the development over the next 18 months through their presentations at exhibitions and conferences.

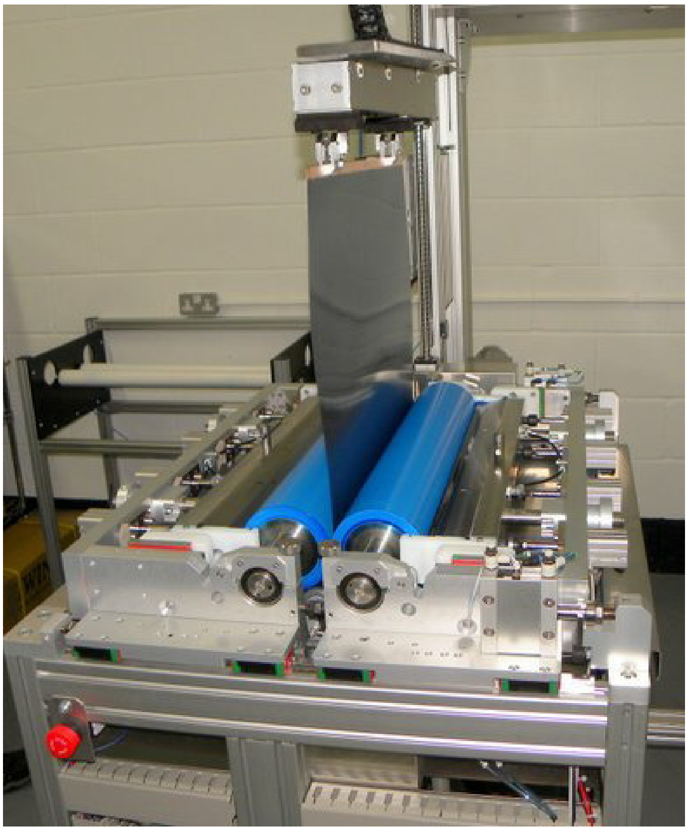
Phot 1 Complete Rainbow demonstration line without its clean air enclosure.

But I wanted to see the system in real-life, and an impromptu meeting with sales and marketing manager Chris O'Brien at an ICT seminar late last year resulted in an invitation to visit Rainbow's facility in Glasgow, Scotland, to see the complete process line in full operation.

The Rainbow process is built around a solvent free 100% polymerisable negative-working liquid photoresist with a very fast photoinitiator, which is extremely resistant to oxygen inhibition, and a unique feature of the concept is that the resist is contact-exposed without drying, phototools being placed directly on to the wet material. A protective coating on the photo tools prevents the resist from sticking to them, so that they can be peeled off clean after UV exposure, leaving the resist selectively polymerised in the areas which have been exposed but still liquid in the areas corresponding to the opaque features of the phototool, and therefore very readily removed in the developing process.

So what of the reality? For reasons of accessibility and visibility the demonstration line (*phot. 1*) stood in an open shop environment (the production version will be contained in a clean air enclosure) and consisted of four modules connected by an overhead transport mechanism, in the process sequence: coat, expose, develop, rinse. And the whole line stood within a very compact $12 m^2$ footprint.

Entry and exit stations were horizontal conveyors, but each active process step was carried out with the panel suspended vertically from its upper edge.



Phot.2 Double-sided grooved-roller resist coater.

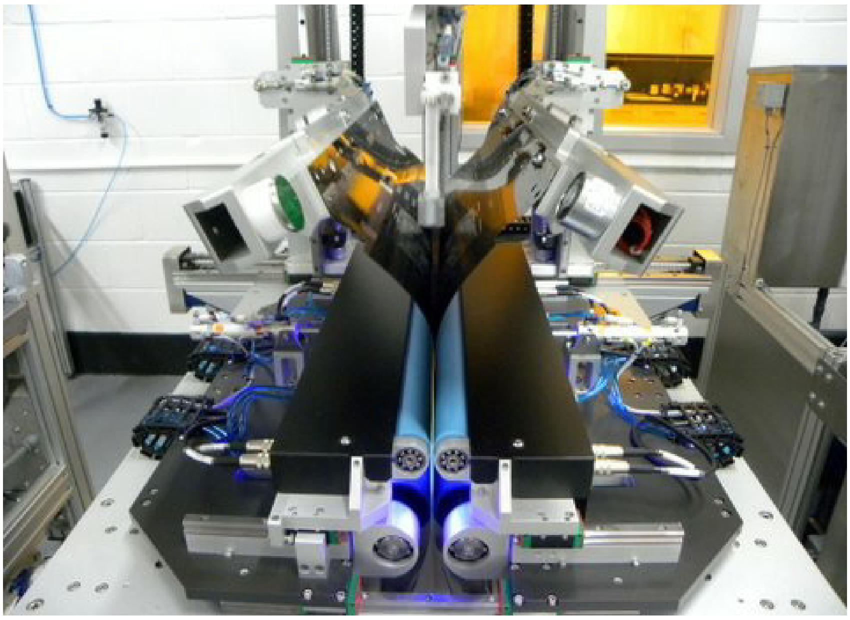
Entering the coating unit (*phot.2*) horizontally, the panel was turned through 90° and fed upwards through a double-sided grooved-roller coater, each roller being independently driven and fed from its own resist reservoir. Because the resist was solvent-free, there was no worry about rollers drying out. The groove geometry was calculated to give a wet coating thickness of 5 microns.

The rollers closed on the panel just after the leading edge emerged and a gripper first matched its speed to the panel then closed, supported the panel at it exited the coating rollers and lifted it clear before presenting it to a traverse mechanism which carried it to the next process station: the exposure unit. *(phot. 4 on next page)*

Phot.3 Showing the traverse mechanism in its raised position carrying (from R. to L.) a panel,
(I) coated with wet resist,
(Ii) exposed,
(iiI) resist developed, and
{iv) rinsed.

This was the really clever bit: the operation I had waited a long time to see: the wet panel was lowered between the open jaws of the exposure module and, at the bottom of its travel, a pair of tool bars closed above it and locked on to the carrier in exact side-to-side register. Pre-aligned photo tools were positively edge-located on these tool bars.

Then a lot of things happened in quick succession. Nip rollers closed to bring the photo tools into hard contact with the wet resist, below a pair of narrow horizontal arrays of UV-LEDs, and there was a brief glow of purple light as the carrier and tool-bar combination began its travel upwards, drawing the sandwich of panel and photo tools smoothly past the light sources.



Phot.4 Showing the photo tools being peeled off the upwards moving exposed panel.

Once the panel had moved a few inches, a pair of guide-rollers closed on the sandwich and the tool bars parted from the carrier and literally peeled-off the photo tools, (*phot.4*) which detached cleanly from the panel as its withdrawal progressed.

It really was poetry in motion as the panel continued to move upwards and the photo tools continued to peel away. The panel still had a complete covering of blue resist although now a latent image was clearly visible.

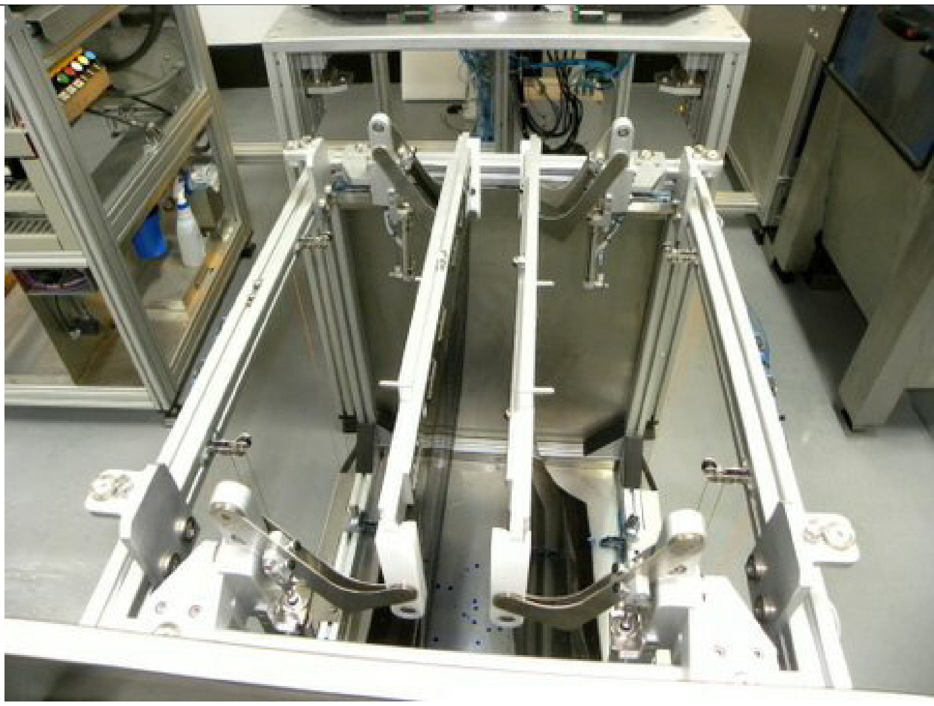
There was *No* resist on the photo tools!

As the bottom edge of the sandwich cleared the upper rollers and the photo tools had completely detached, the rollers retracted, the photo tools were lowered back into the body of the exposure module ready for the next cycle, and the panel proceeded to the next station to be developed.

Developing was an almost instantaneous operation, for two reasons: the resist layer was only 5 microns thick, and the material to be removed was still in its original liquid state. The panel was lowered into a spray chamber with a dilute carbonate developer and withdrawn within a couple of seconds, a pair of squeegee rollers closing on it to remove dragout. The final process station was a water rinse, in a module similar to the developer, after which the panel was carried to an exit conveyor that rotated it back to horizontal ready for etching.

Mesmerizing to watch in continuous operation with panels at every station, the line is designed to process 120 double-sided 21″ x 24″ panels per hour. Changeover between designs is quick and easy - a simple matter of unlocking and wheeling-out a self-locating cart and wheeling-in a second cart with the next job pre-aligned on its tool bars ready for immediate use, a two-minute operation. *(phot.5 on next page)*

I spent a long time discussing and debating process details with John Cunningham. Suffice it to say that the system has extremely high resolution capability as a consequence of the thin-ness of the coating and the intimate contact with the phototool. 20 micron lines are routine, and 10 micron lines are well within the capability of the system.



Phot.5 Looking down at a self locating photo tool cart,

And at remarkably high yield, even though the demonstrator is presently operating in an open environment – a major area of customer interest in the Rainbow system is for yield improvement. The operating principles: wet coating and automated vertical operation, eliminate problems associated with film adhesion and physical damage from handling and conveyor systems. The compact footprint and very low power consumption – no drying ovens or high-intensity UV sources are required – are additional advantages.

Best word to describe the design of the system is "elegant". The concept is simple but a lot of creative engineering and precision mechatronics has gone into bringing the concept to physical realisation. Construction is robust, all the working parts are easily accessible and there appears to be nothing that would be beyond the scope of a competent maintenance engineer to keep in good order.

I admit to being a bit cynical about "revolutionary" technologies – over the years I've seen too many bright ideas over-hyped, never achieving their claimed performance and quietly fading out of sight.

But this one achieves what it claims! It's a remarkable process at a very mature stage of development and, as Jonathan Kennett remarked, "the principles we have established give lots of possibilities for alternative applications such as additive circuitry, flat panel displays, touch screens and chemical milling, but our initial objective is to establish our presence in inner-layer production"

http://rainbow-technology.com

Pete Starkey
January 2013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This is the Certificate referred to in **The Membership Secretary's notes - April 2013** on the next page.

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The Membership Secretary's notes - April 2013

With Easter just around the corner, it is time once again for the ICT/NUKCG Annual Foundation Course at Loughborough University. This course has been running since 1980, when it was founded under the auspices of the Northern UK Circuit Group. This group has now been disbanded, but the course retains the title to show and remind us of its origins.

The course has changed over the last thirty two years, whilst maintaining its essential premise - that of encouraging Industry experts to deliver the presentations to delegates. Initially, the course was a two-week residential course at Borders College (part of Heriot Watt University) with a factory visit - usually Exacta or Bepi, practicals and a multi-choice examination at the end accompanied by a book prize for the top scorer.
It has been running at Loughborough University since 2005 and the first day is now hosted by Invotec Group so that we can take in facility visits of both their Tamworth facility and the Printed Electronics Manufacturing Area.

At our recent Seminar in Glasgow, one of the speakers, Jim Francey showed a slide of the certificate he received, when he attended the course in 1982 – prompting a comment from one of the other speakers, Geoff Layhe that he had also attended the course in the Eighties – reinforcing the concept of the course as pre-eminent in the PCB Industry.

Event

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Institute of Circuit Technology 39th Annual Symposium

The 39th Annual Symposium will be held at the Heritage Motor Museum at Gaydon in Warwickshire on the 5th June 2013

Event Info
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Symposium begins at 10:00
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