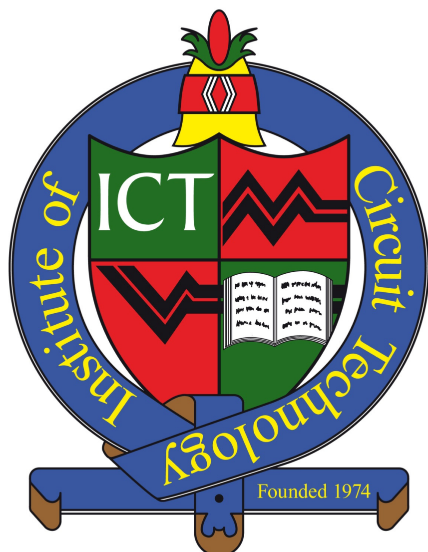

Journal of the Institute of Circuit Technology

2012 Events

15/16th October Graphene Conference - National Physical Laboratory,Teddington,TW11 0LW
Monday & Tuesday
events@npl.co.uk

6th November **17.30 ICT Evening Seminar**
Tuesday
There will be four papers , followed by a buffet bill.wilkie@InstCT.org
Historic Quay, Hartlepool
www.hartlepoolsmaritimeexperience.com
supported by Falcon Group

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

2013 Events

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

5th March **17.30 ICT Northern Evening Seminar**
Tuesday
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 **ICT Annual Foundation Course**
Tuesday - Friday
at Loughborough University
bill.wilkie@InstCT.org

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

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Vol.6 No.1 February 2013

Editorial

As we welcome in 2013, it is also with the hope that the New Year will bring business cheer as well as health and happiness to all.

For many UK companies, fabricators and their suppliers, 2012 has been a struggle. Nevertheless, technology advances, and with the arrival of new technologies, materials and processes, PCB fabricators must keep up to keep their company in the game. ICT can do little to help with business conditions but does its best to keep members abreast of the latest technologies.

This quarter's journal covers a raft of interesting topics from printed electronics to embedded optical waveguides to the exciting development of a maskless lithographic process. Tin whiskers continue to be a cause of concern and therefore a subject of much investigation. The 6th Annual Symposium on Tin Whiskers was held on 27/28th November and is reported on in this issue. A particularly hot topic at the moment is graphene which could provide a new platform for cheap, flexible and also transparent electronics. Deposition of graphene films has been demonstrated using different methods including inkjet printing and vapour deposition.

Europe has earmarked a billion euros over the coming decade to fund research into graphene. In the UK, the chancellor has allocated 50m pounds to graphene research.

The ICT has as usual planned a series of informative seminars throughout the year starting with the seminar and AGM in Arundel on 6th February. Make a note in your diaries now of the Annual Symposium to be held at the Heritage Motor Museum on 5th June. We hope that you will be able to attend at least one of these events, and benefit from the talks and to network with business colleagues and acquaintances.

Francesca Stern - 1st Jan. 2013
Council Member

Council Members 2013/4 Martin Goosey (*Chairman*), Andy Cobley (*Deputy Chairman*), John Walker (*Secretary*), Chris Wall (*Treasurer*), William Wilkie (*Membership Secretary & Events*), Bruce Routledge (*the Journal*), Richard Wood-Roe (*Web Site*), Maurice Hubert, Lawson Lightfoot, Tom Parker, Steve Payne, Peter Starkey, Francesca Stern, Bob Willis.

Membership

New members notified by the Membership Secretary

10267 Steve Lloyd M.Inst.C.T
10268 Ian Kenyon M.Inst.C.T
10269 Steven Crawford A.Inst.C.T
10270 Martin Blackstone M.Inst.C.T
10271 Chris O'Brien M.Inst.C.T
10272 Bill Burr F.Inst.C.T
10273 Mark Munley M.Inst.C.T
10274 Jonathan Kennett M.Inst.C.T
10275 Les Browne M.Inst.C.T.
10276 Daljit Basra M.Inst.C.T
10277 Marc Holloway M.Inst.C.T.
10278 Robert Gibson M.Inst.C.T.
10279 David Wylie M.Inst.C.T.
10280 Pete Hill M.Inst.C.T.
10281 Greg Hawkins M.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
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ICT Members feedback on the Journal - August 2012

In August 2012 at the request of the Journal Editor, Bill Wilkie wrote to the last 30 New Members who joined starting on the 18th July as follows:-

As a relative newcomer to the Institute, I would appreciate your opinion on our on-line journal.

1) Do you read it - is it interesting?
2) Is it good enough?
3) Is it up to date and relevant?.
4) Any comments, on content or format - anything at all would be useful in planning for future editions.

Bill had 7 replies.

Not deterred, he then sent the enquiry to 30 'old hands' and had 4 replies.

Bill and the Editor were still not deterred, so they published in the last issue the following Editorial :-

> This issue of the *Journal* is accompanied by two additional .pdf files, which contain lists of the 'topics' and the 'authors' which have appeared in the first 3 issues and the last 4 issues, both in the form of reviews and papers.
> Topics have been worded so that its' main subject is contained in the first word of the 'topic'.
> Each record gives, 'topic', authors name, vol no, and page. (and in future links to more information)
> Members can then refer to the appropriate *Journal* , either their own copy or the .pdf's that appear on our Web site.
> The 'authors' list is intended for further research on the same author.
>
> Members are requested to make a trial search, and to send their findings and comments to the editor :-
> Bruce Routledge bruce.rout@btinternet.com
> before the arduous task of compiling the data from Vols 2,3 and 4 is begun.

As yet **NO** replies have been received.

From the 11 replies received from Bill's original 60 enquiries two valuable points stood out.

a) An easy way to research a particular subject was essential, BUT no one has responded to the last two paragraphs of the above editorial.

b) Some of the "subjects" are at an advanced level - it is our opinion that Journals should reflect today and foresee tomorrow.

To assist some of the new Members to our Industry, part of a long list of relevant text books, - available on request from your Public Library, - is alongside. Any ICT Council Member will be willing to help.

This Issue of the *Journal*

We have adopted a single column layout, The right hand column now contains all the subject matter and reads down one page directly to next page. All subsidiary matters such as, topic reference, pictures and diagrams are contained in the left column. - when practical.

Again, we welcome your comments.

A Comprehensive Guide to the Design and Manufacture of Printed Board Assemblies
by William Macleod Ross,
Published by Electrochemical Publications Ltd.(1996)
Vol. 1 "Components and Assembly
ISBN 0 901 150 32 0
Vol. 2 "Manufacture, Quality Assurance and the Environment"
ISBN 0 901 150 33 9

The Printed Circuit Board Handbook,
by Clyde E. Coombs Jr
Published by McGraw-Hill Professional; 6th Edition (1 Oct 2007),
ISBN-10: 0071467343,
ISBN-13: 978-0071467346

Modern Circuit Technology Metal Finishing processes in printed circuits and electronic assemblies
by W Macleod Ross
Portcullis Press
ISBN 0 90199420 0

An Introduction to Printed Circuit Board Technology
by J. A Scarlett
Electrochemical Publications
ISBN 0 90199420 0

Dry Film Photoresist Processing Technology
by Karl H. Dietz
Publisher: Electrochemical Publications Limited, 2001
ISBN 0901150398,
9780901150394

Large Area Electronics: addressing the applications challenge

18th December 2012

The Hauser Forum, Cambridge, UK

Cambridge Integrated Knowledge Centre (CIKC)

The Cambridge Integrated Knowledge Centre (CIKC) held its large area electronics event at the Hauser Centre, Cambridge on the 18th December 2012, with the objective of providing a showcase of recent progress towards the commercial application of large area electronics. With leading experts from both industry and academia, the event covered the opportunities and challenges for new low temperature manufacturing techniques in photonics and electronics as they made the transition from laboratory to market place.

The meeting was opened by **Chris Rider**, Director of the CIKC, who welcomed the attendees to the Hauser Centre and who said that large area electronics was at last beginning to take off, with companies now at the stage where they were producing large quantities of prototype materials and devices.

He also gave an overview of the CIKC, its structure and activities. The CIKC was interested in electronics and photonics that incorporated new materials and related areas where there were multi-billion pound opportunities. Its mission was to facilitate the commercial exploitation of early stage university technology, especially where there were challenges of bringing disparate technologies together. Example technology areas included printed organic photovoltaics, transparent microelectronics, polymer waveguides and colour displays on plastic.

Manufacturing - High value of low cost electronics.
***Scott White** of PragmatIC Printing Ltd*

The first formal technical presentation was then given by **Scott White** of PragmatIC Printing Ltd, who discussed the high value manufacturing of low cost electronics.

He began by explaining why there was an interest in printing electronics and dispelling some of the myths around low cost printing. In many cases improving printing processes sufficiently for electronics deposition made it expensive, and controlling quality and consistency of functional inks was also very challenging. Sometimes, subtractive processes could be more efficient and lower cost than additive approaches. For example, high speed roll to roll printing offered economies of scale, but starting and stopping a roll to roll process wasted material. Each application needed to be considered on an individual basis.

A big benefit of printed electronics was its ability to be automated, thereby maximising the utilisation of equipment and minimising labour costs. PragmatIC Printing produced printed logic circuits on plastic substrates, ie that were thin, flexible, transparent, robust and disposable. By using an imprint process, it was possible to integrate large numbers of transistors in a small area. Feature sizes were typically 50 nm to 5 microns and they built thin film transistors with novel architectures using a two dimensional approach.

Scott concluded by outlining the company's business model and their pilot production activities, which were being undertaken in collaboration with CPI in Sedgefield.

Graphene and 2D materials - inkjet printing
Felice Torrisi
Depart. of Engineering at Cambridge University

Felice Torrisi from the Department of Engineering at Cambridge University then covered the inkjet printing of graphene and 2D materials which could provide a new platform for cheap, flexible and transparent electronics. He began by introducing the various methods that could be

used for making graphene. An approach called liquid phase exfoliation had been employed in this work to produce graphene inks and these had been characterised using Raman spectroscopy. A centrifuge-based process was employed to separate the graphene monolayers and the subsequently produced inks had been utilised for a number of electronics applications. The deposition characteristics of the inks had been optimised and the properties of the deposited inks studied in ink jet printed devices. Films had good optical transparency and the mechanical flexibility was superior to indium tin oxide, which had allowed flexible smart windows to be fabricated.

Liquid crystal lasers - Printable ***Damian Gardiner*** *from the Inkjet Research Centre*

The final presentation of the first session was then given by **Damian Gardiner** from the Inkjet Research Centre, which was part of the Centre for Molecular Materials for Photonics and Electronics at Cambridge University and he covered printable liquid crystal lasers.

Current tuneable lasers were typically large, complex and expensive and this had tended to restrict their application. A potential alternative was to use liquid crystals and, in particular, to exploit photonic band gaps in chiral nematic liquid crystals. High efficiency band edge lasing could be achieved over continuously tuneable wavelengths from 450 to 850 nm Inkjetting and bar coating could be used to produce these lasers on a variety of substrates and the deposition processes were described.

Portable printable laser demonstrators had been produced and some of the large number of potential applications for these low cost tuneable lasers were discussed.

Displays - Flexible Applications ***Guillame Fichet*** *of Plastic Logic*

Following a networking break there were three more presentations before lunch. **Guillame Fichet** of Plastic Logic gave a presentation on new applications of flexible displays.

He began by presenting an overview of Plastic Logic and its operations. R&D was undertaken in the UK with production being in their Dresden facility, which was now producing thousands of displays per week and operated on a true optimised industrial scale.

Examples of the qualification tests required for organic thin film transistors and display modules were described. The company produced the lightest and most durable backplane technology that was currently available. Displays up to 10.7 inches (diagonal) size with 16 grey scale levels were available with a pixel density of 225 ppi and thicknesses down to 400 microns.

A colour display architecture was also described and this had 640 by 480 pixels. Plastic Logic had developed a method for dealing with overlay distortion and the process had been qualified in their production facility. An example was also shown of a colour display with 1280 by 960 pixels in a 10.7 inch (diagonal) display. Flexible displays could easily be cut and bonded together to make larger displays. The company was interested in working with partners to help develop markets and applications for their display technology.

Waveguide interconnects - in high performance polymer. ***Richard Penty*** *Depart.of Engineering at Cambridge University*

Richard Penty from the Department of Engineering a Cambridge University then gave a presentation on high performance polymer waveguide interconnects.

The work reported in his presentation had used a proprietary Dow Corning siloxane-based material. He explained the recent evolution of optical interconnects and the need for very short distance optical interconnects. Optical interconnects enabled the shortcomings of electrical interconnects to be overcome as data rates increased.

Advantages were reduced losses and cross talk, power savings and reduced size possibilities. The cross over point to optical interconnects varied with distance and data rates but, as the cost of optical

interconnects was coming down, the crossover points were changing. The use of optical interconnects allowed the power consumption to be significantly reduced over conventional copper interconnects. Board level optical interconnect approaches were described and the three key approaches used free space interconnects, waveguides and embedded fibres.

A board design based on low cost FR4 substrates was shown in which the optical layers were sequentially built on the bottom layer of the board. This board integrated 10 Gb/s optical functionality and subsequent work had concentrated on a 40 Gb/s design. Other work had focused on a wave guide based regenerative optical architecture that allowed connection of multiple bus segments and which was compatible with VCSEL/PD arrays. A proof of principle four channel, three card bus module had been produced and data was shown to confirm that error-free transmission had been achieved at 40 Gb/s. This work had been carried out in collaboration with Dow Corning and Xyratex and a proposal (PHLARE) was currently under consideration by the European Commission for a project that would help to build the supply chain.

Printable Electronics – work undertaken at the CPI National Printable Electronics Centre in Sedgefield ***Tom Taylor***

The final presentation of the session was by **Tom Taylor** of CPI Ltd and he detailed work undertaken at the CPI National Printable Electronics Centre in Sedgefield to take industrial innovation to market in printed electronics.

It was part of the first UK Technology Innovation Centre which had almost 250 employees and had received £75 million in funding to date. CPI covered a range of technology areas around printed electronics and it had two clean rooms for prototyping, fabrication and testing. One of these was used for scale up and yield improvement ie for companies to get proof of manufacture before getting further investment.

CPI owned a multi-functional printing pilot line which offered unique combinations of print processes and it could be used for novel types of integration. This was combined with a component pick and place facility. Thin film transistor arrays and OLED lighting tiles could be produced. The example of a tuneable OLEDs for low cost medical applications was described and this had progressed towards production on the millions per year scale. The CPI had wide experience across formulation, coating, encapsulation, testing and process engineering and it was available as a UK resource to help take new technology forward to production.

Organic photovoltaic modules -development for off- grid applications. ***Michael Niggemann*** *from Eight19 Ltd*

The afternoon session began with a talk on the development of organic photovoltaic modules for off-grid applications. This was given by **Michael Niggemann** from Eight19 Ltd, which was a spin out company that came out of the Cavendish Laboratories. The company developed technology for the manufacturing of organic photovoltaics.

Organic PVs had shown a rapid increase in attainable efficiency over the last ten years and they were now well above 10%. However, the high efficiencies had largely been achieved on non-scaleable devices.

New materials and advanced device architectures were needed to get the efficiency above 10%, eg such as by stacking cells on top of each other. The current costs for thin film PVs were around $0.62 per Watt peak compared to $0.78 for silicon-based PVs. OPV would be adopted in off grid applications before they were used in on grid ones.

Roll to roll production of organic solar cells had been around for some time and typical traditional device architectures were compared with those for OPVs in terms of cost. Eigth19 were focussing on cell/module architectures that could be transferred to a roll to roll process and hence these were typically on flexible substrates. The designs had been iterated to be chlorine-free and also not to use indium tin oxide.

Further technology challenges would continue to be around efficiency and lifetime, coupled with the need to utilize large areas, to reduce costs to below $40/square metre and to be fully roll to roll processable. The company had a model for providing solar lighting at low cost to people that currently did not have access to conventional electricity supplies.

Printed organic transistor circuits.
Henning Sirringhaus

Henning Sirringhaus then gave talk on the CIKC's high performance printed organic transistor circuits programme.

He began by giving an overview of the fundamental aspects of organic transistors. They were typically made from abundant, low temperature processable materials and there had been significant improvements made in their mobilities in recent years. They also exhibited excellent mechanical properties which enabled them to be bent and rolled etc.

The project had integrated high performance OFETs with sensors and displays. Circuit applications of OTFT technology included RFIDs and in integrated device driver circuits.

An 8 bit microprocessor similar to an Intel 4004 device had been demonstrated. For many applications it was necessary to integrate both n and p type devices into a CMOS format and this was a challenge with organic transistors. However, some devices were ambipolar ie they were capable of n and p type operation and a key development had been the development of new ambipolar materials with high mobilities.

Example gate structures were shown and capacitance reduction had been achieved by using self aligned gates. Ring oscillators had been produced that could operate in the 300 kHz range. An overall objective of the project had been to produce silicon-free integrated smart label displays that incorporated a sensor, battery, logic and display.

Demonstrator circuits had been produced in collaboration with Plastic Logic.

Laminated electroactive foils.
Daping Chu
Depart.of Engineering at Cambridge University

The third paper of this session was on laminated electroactive foils for the built environment and it was given by **Daping Chu** from the Centre for Advanced Photonics and Electronics (CAPE) in the Department of Engineering at Cambridge University.

He began by outlining the needs for radiation control and sustainability in the built environment. Smectic liquid crystals could be used to provide dynamic light scattering in buildings. They were switchable between the clear and scattering states and were stable in these switched states without the need to apply a continuous field. Switching was achieved by applying varying frequency AC fields.

Customised formulations had been switched many millions of times and there had been no change in the switching voltages required. The devices were normally white in the scattering state but the use of colourants had also been investigated and these had shown no degradation in colour over several years of testing. 64 by 64 element switchable displays had also been fabricated.

The ultimate aim was to have the displays used in the windows of buildings.

Biosensors – new developments
Andrew Flewitt
Depart.of Engineering at Cambridge University

The penultimate talk was given by **Andrew Flewitt** from the Electrical Engineering division of Cambridge University and it was called 'how to detect a single virus'.

The presentation was on a collaborative project with the Universities of Bolton and Manchester to develop new biosensors. There was growing interest in the use of 'lab on chip' devices for early diagnosis of diseases.

These devices typically needed to be very sensitive, easy to use low cost, robust and disposable and there were a range of potential detection methods.

The approach used in this work was based on acoustic biosensing but traditionally this had been limited in sensitivity. However, surface acoustic wave devices operating with a resonant frequency of 200 MHz had a sensitivity of 10^{-11} grammes, however the target sensitivity was 1000 times lower at 10^{-14} grammes. A method for increasing the sensitivity was to increase the device resonant frequency even further ie into the GHz range. Zinc oxide was one of the preferred materials for this type of sensor application and it could be sputtered to give suitable low stress, piezoelectric films. Devices had been fabricated and shown to be capable of detecting species of interest. If the electrodes were fabricated using carbon nanotubes, the sensitivity increased even further via a much larger frequency shift. The result was that the mass sensitivity that been achieved was now down to 10^{-14} to 10^{-15} g. Interestingly, the surface acoustic wave feature might also be used to move the sample liquids around the sensor devices if required.

*Printed electronics for print, packaging and point of sale. **Chris Jones** of Novalia*

The final presentation was given by **Chris Jones** of Novalia and he talked about printed electronics for print, packaging and point of sale applications.

Novalia was a small Cambridge–based company whose aim was to seamlessly integrate print with electronics.

Examples of their work were shown and these included a tissue box with a piano keyboard on the side for entertaining children, a music playing poster and an interactive pharmacy package which reminded the user when to take medication.

The print processes used by Novalia were those that were already used in volume in the printing industry and based on conventional printing equipment.

***Ian White** of the CIKC*

Ian White of the CIKC closed the event with words of thanks to the speakers who had taken time to give presentations at the event, as well as to all of the staff and researchers that had undertaken the work that had been presented during the day.

This meeting provided a valuable update on some of the excellent work that has been undertaken in the UK to take large area electronics from research forward towards commercialisation. The potential areas of use are broad and disparate, but it seems that in many of these there is beginning to be more of an application specific pull because traditional routes are unable to provide the performance required. This is an exciting area that seems, at last, to be on the verge of significant application and commercialisation and it will be interesting to see how things progress in the coming years. Overall, this was an excellent and well organised event that was attended by a large number delegates from industry and academia. The CIKC is to be congratulated for organising such a successful event.

The presentations from the event were to be made available on the CIKC website (http://www-cikc.eng.cam.ac.uk) in due course.

Martin Goosey

18th December 2012

6th International Symposium on Tin Whiskers

Henry Ford College
Loughborough University, UK
27/28th November 2012

Loughborough University's Henry Ford College was host to the 6th International Symposium on Tin Whiskers.

The Symposium was opened with a welcome by Dr Geoff Wilcox from Loughborough University and Mike Osterman from CALCE. Mike highlighted how the RoHS Directive was evolving to include new categories of equipment that would have to be lead-free and how there were major concerns about tin whiskers across a wide range of industrial sectors.

He then gave an introduction to tin whiskers and how they caused problems.

Tin whisker - risk management ***Bob Gregory*** *of Rolls Royce*

Bob Gregory of Rolls Royce gave the first paper and it was on tin whisker risk management for high reliability systems. He stated that industry best practice was to implement formal tin control plans and that the aerospace and defence sector used GEIA-DTD-0005-2 which was initially issued in 2006.

There were various levels of tin control that needed to be employed and these varied by product type and the degree of reliability required. The use of component level mitigation did not count toward required mitigation, but preference must be given to lower risk finishes during the component selection process. Bob also stated that the use of barriers was a mitigation strategy rather than a cure. However, replacing tin with tin-lead could provide a cure and one such approach was to apply a hot tin-lead finish.

Tin whisker - mitigation strategies. ***Mark Ashworth*** *from Loughborough University*

Mark Ashworth from Loughborough University then presented 'manufacturing and in service tin whisker mitigation strategies; the co-deposition of particulates and conformal coating'.

He began by covering the co-deposition of particulates and the ones used in this work had been silver and silica. Two sizes had been selected and the aim was to evaluate the effect of particulate size and type on whisker formation.

Deposition conditions had also been evaluated and this included the use of pulse plating. Pulse plating and reverse pulse plating had been used with silica deposition and these gave a more uniform distribution of the particles within the deposit.

The influence of both 0.5 and 5.0 micron silica particles on whisker formation was also evaluated and compared to pure tin samples. It was found that the incorporation of silica particles into the deposit actually accelerated whisker growth.

Tin whisker - conformal coatings ***Mark Ashworth*** *from Loughborough University*

The second part of the presentation was on the use of conformal coatings. A number of commercially available organic coatings had been benchmarked on bright tin deposited on brass substrates. Examples of tin whiskers penetrating acrylic conformal coatings of different thicknesses were shown. Sometimes the whiskers were actually covered by the coating material. Further work was planned where particulates would be incorporated into the coating materials. To date, no whiskers had been observed when silicone and UV cured materials were used.

Tin whisker - development of shape variants ***Barbara Horvth*** *from Budapest University*

The effect of electrochemically oxidised films on whisker growth had also been investigated and this had reduced whisker growth compared to samples with naturally formed passive oxides.

Barbara Horvth from Budapest University then presented work on the development of shape variants of whisker formations on bright tin layers. Tin whiskering was a major risk when electroplating tin because the smaller grain size in brighter tin could cause greater residual stresses. Examples of whiskers were shown and these had been divided into

different whisker types such as filaments, hillocks and nodules. The steps defining whisker growth in bright tin samples were then discussed in detail for each type. In the case of hillock/nodule fragments, additional impurity atoms created sub-grains with large abnormal grains. The mass migration of copper into whiskers was also reported and this was related to the development of voids beneath the whisker grains. Voids appeared in the Cu_6Sn_5 intermetallic due to the diffusion of tin into the forming whiskers. The copper, and tin, then moved up along the grain boundaries of the tin into the whiskers.

Tin whisker - Grain Boundary ***Pylin Sarobol*** *from Purdue University.*

The second session began with a paper on 'tin whisker and hillock growth via grain boundary sliding coupled with shear induced grain boundary migration' and was given by **Pylin Sarobol** from Purdue University.

This was a summary of work on tin whisker growth from lead-free solder and electroplated films. Whiskers and hillocks had been studied and they both grew from surface grains as a mechanism of stress relaxation. The mechanism of compressive stress formation and its relief were then described and sources of stress included the plating process, the formation of intermetallics and expansion coefficient mismatches.

A key factor influencing whisker growth was thought to be grain boundary sliding and a proposed steady state growth model was reviewed. The model was used to explain the formation of different types of whiskers.

Hillock growth was then discussed in terms of grain boundary formation, shear and migration. Grain orientation effects were reviewed in terms of the hypothesis that crystallographic orientation had a significant role in the nucleation and growth of whiskers and hillocks.

Tin whisker - Thermal cycling and the influence of atmosphere. ***Katsuaki Suganuma*** *from Osaka University.*

The next paper was on the thermal cycling of whiskers and the influence of atmosphere and this was given by **Katsuaki Suganuma** from Osaka University.

There was a difference in whisker formation after 500 thermal cycles between samples in air and those in a vacuum. A possible mechanism for whisker growth during thermal cycling was then described. The influence of plating thickness on whiskers had also been investigated. With thinner coatings (2 µm) the whiskers were longer and thinner than those growing from a thicker deposit (5 µm) after 1000 cycles between -20°C and 80°C in air. The thicker deposits also had a larger grain size (1.94 versus 4.69 µm) and grain size coincided well with whisker width for both air and vacuum grown samples. It was also noted that grain boundary cracking was more severe in air. Another interesting finding was that whisker growth in vacua was faster than in air.

Tin whisker - Shorting in tin whiskers. ***Barrie Dunne*** *from the European Space agency and* ***Martin Wickham***

Barrie Dunne from the European Space agency then began a presentation on increased shorting in tin whiskers due to electric fields and contact pressure.

He showed some early examples of tin whiskers found in the 1970s on relays used in aerospace applications. A lead-free control plan working group had been established and ESA guidelines had recently been published.

Martin Wickham then continued the presentation. A special plating chemistry had been used that enabled the relatively rapid formation of whiskers. Whiskers had been harvested and their electrical properties determined; larger whiskers had higher resistivities due to defects. Whiskers were known to deform in an electric field and thus the likelihood of shorting between adjacent conductors increased if the whisker moved under the influence of an electric field.

*Tin whisker - Growth in low and high stress environments: metallurgical and statistical analysis Part 1 - **Polina Snugovsky** from Celestica,*

The first presentation of the afternoon session was entitled 'whisker growth in low and high stress environments: metallurgical and statistical analysis'. **Polina Snugovsky** from Celestica, Toronto gave part 1 of the presentation.

She began by outlining the typical occurrences of whiskers in lead-free solder joints. The rougher surfaces of lead-free solder joints were an important factor in whisker formation. Other well-known factors were the presence of compressive stress in the tin and impurities.

A specific four year tin whisker testing and modelling research project (WP1753) was then described. This had looked at wide number of variables including contamination, different solders and board designs and a range of accelerated testing conditions. The use of clean components, boards and post-assembly cleaning significantly reduced the propensity for whisker formation in lead-free products.

It had been found that RoHS compliant tin plated components may have microstructural characteristics that could affect whisker formation. A key conclusion from this work was that whisker growth was particularly pronounced on SAC305 alloy fillet edges. In summary, Polina presented a huge amount of information and data related to the dependence of whisker growth on component type and lead material, component defects and solder joint microstructure.

*Part 2 -**Stephan Meschter** from BAE Systems in Endicott, New York*

The second part of this presentation was then given by **Stephan Meschter** from BAE Systems in Endicott, New York.

This part of the presentation had a focus on the statistical analysis aspects of the project. It was shown that the most significant factor was the lead material and this was followed by the contamination level. Alloy 42 had greater whiskering than copper and rework flux residues also encouraged whisker growth.

*Tin whisker - A solution for tin whiskers by hot solder dipping. **Mark Walmsley** from Micross Components*

Mark Walmsley from Micross Components then gave a talk entitled 'A solution for tin whiskers by hot solder dipping'.

The main theme of the presentation was to give an overview of the commissioning, testing and qualification of an automated hot solder dipping process for non-hermetically sealed components. A seven axis multifunction robot-based automatic hot solder dipping process had been developed which met the requirements of GEIA. The equipment offered control of depth, dwell, entry and exit speed, solder angle and exit angle.

*and **Stoyan Stovanov** from University of Greenwich*

Two projects related to this process had been undertaken with the University of Greenwich and with NPL. The Greenwich project undertook a modelling assessment of the impact of the hot solder dip process and was carried out by **Stoyan Stovanov.** The study was able to confirm that the refinishing process did not have a significant impact on the electrical performance of the ten different types of components tested.

The work undertaken with NPL was to develop a methodology for process qualification. The overall findings were that solderability was equal to or better than the original components and ball shear test results for BGAs were also acceptable. Additionally, thermally cycled solder joint reliability was improved for re-terminated components compared to tin finished originals.

*Tin whisker - A cure for tin whiskers by re-passivation **Mike Swanick** from Rolls Royce*

Mike Swanick from Rolls Royce then presented 'a cure for tin whiskers by re-passivation'.

He began by giving an overview of the problems associated with pure tin finishes. It was important to remove all of the original tin and to provide 100% coverage of the new solder while ensuring that there was no damage to the parts. Components needed to be dipped for around three seconds to ensure that there was a full exchange of the tin coating.

Qualification was by package type and by electronic technology type for the specific package. The qualification had two parts; package

damage and reliability assessments which included cycling for aerospace and steady sate high temperature testing for submarine systems. Testing was carried out with devices biased in simple circuits.

Tin whisker - Effectiveness of photosintering in mitigating tin whisker formation. ***Michael Osterman***

The final paper of the first day was given by **Michael Osterman**, and he talked about the 'effectiveness of photosintering in mitigating tin whisker formation'. Photosintering used a high energy pulse from a flash lamp to rapidly heat and melt the device surface. Due to the rapid nature of the exposure the penetration of the heat was very shallow and limited. A typical pulse would be for 0.5 ms and 1.4 MW.

For a thin electroplated tin layer on copper the photosintering induced an even IMC layer. The ability of photosintering to mitigate whisker formation had been evaluated via whisker growth studies and XRD stress measurements.

The test coupons were crested using an acid electroplating process and the subsequent whiskers formed were characterised by scanning the coupon surfaces at 400x magnification and counting the whiskers.

Interestingly, the stress after annealing was low but after about a year it was highly compressive. One of the key findings was that photosintering at elevated temperatures indicated a long term reduction in film stress but, without elevated temperatures, it did not reduce the compressive stress in tin films plated on copper.

Tin whisker - Electrical aspects of zinc and tin metal whisker induced failures in electronic equipment. ***Michael Osterman***

The second day of the symposium began with a presentation on electrical aspects of zinc and tin metal whisker induced failures in electronic equipment and this was also given by **Mike Osterman**.

Mike began by giving an overview of tin and zinc whiskers and he described where they could be encountered. Zinc whiskers were similar to tin whiskers, as were those from cadmium. Zinc whiskers were often found on the zinc coated raised floor tiles used in computer data centres.

The electrical failures caused by whiskers were then detailed and the electrical breakdown of whiskers was related to the thickness of the dielectric layer, contact resistance and surface roughness of the whiskers. The results of work to measure the breakdown voltages of whiskers were detailed and zinc whiskers were found to have higher breakdown voltages than tin whiskers. The effect of contact force on breakdown voltage had also been measured by using harvested tin and zinc whiskers attached to a copper substrate. The ability of tin whiskers to induce a vapour arc was also discussed and it had been found that, at reduced atmospheric pressure, the voltage required to strike an arc was lower than in a normal air atmosphere. Conditions were described under which it was possible to strike and sustain an arc. The proposed arc metric and arc threshold information would be useful for providing a guide for circuit designers and to minimise the vapour arc propensity of whiskers.

Tin whiskers - On novel nanoparticle enhanced conformal coatings. ***Stephan Meschter*** *from BAE Systems*

The next paper was given by **Stephan Meschter** from BAE Systems and was on novel nanoparticle enhanced conformal coatings for whisker mitigation.

The aim of the project was to develop and assess nanoparticle filled conformal coatings designed to improve whisker penetration resistance and coverage on tin-rich metal surfaces prone to whiskering. The coating materials used were based on polyurethane and polyurethane-acrylate resins, because they possessed a range of required properties such as jet fuel resistance, coupled with toughness and flexibility. Methods had been developed to assess whisker penetration and these had included the addition of rare earth elements to tin in order to facilitate whisker growth. A key part of the project had been the development of the nanoparticle suspensions and the integration of the nanoparticles within each coating solution.

An example shown had a 12% nanosilica content, homogenously dispersed in a polyurethane resin. Coatings had been characterised using dynamic nanoindentation and nanoscratch techniques.

The project had started in 2012 and was due to continue until 2015.

Tin whiskers - Mitigation of tin whiskers by optimisation of electroplating process methodologies. ***Mark Ashworth*** *from Loughborough University*

The third paper was given by **Mark Ashworth** from Loughborough University, UK and was on the mitigation of tin whiskers by optimisation of electroplating process methodologies.

The effect of current density on metal deposit characteristics had been evaluated using current densities from 5 to 50 mA.cm $^{-2}$. As current density increased, there was a reduction in whisker length and a decrease in whisker density, but there was an increase in the size of the eruptions that did form. It was also found that there was a reduction in whisker growth as the thickness of the deposit increased.

Whisker growth on copper substrates was much lower than on brass. As part of the project, pulse plating had been investigated as a potential whisker mitigation strategy. The technique offered the possibility of manipulating the grain boundaries and orientation of the tin deposit to promote improved whisker resistance.

The results of a study of the effect of duty cycle and pulse frequency on deposit properties were reported. It was found that whisker growth on pulse plated deposits increased as the duty cycle was reduced and pulse frequency increased. Whisker growth on initial pulse plated samples was greater than for those plated using DC. However, whisker mitigation could be achieved by using a combination of increased deposit thickness and high current density. Low whisker growth rates had been achieved for tin deposits on copper, even after 4000 hours storage at 55°C and 85%RH.

Tin whiskers - Lead as a suppressant for tin whisker growth ***Jacob Wang*** *from Loughborough University*

The penultimate presentation was given by **Jacob Wang**, who reported more of the work undertaken at Loughborough University on tin whisker growth as a part of the IeMRC supported Whiskermit project.

The focus was on an investigation into the role of lead as a suppressant for tin whisker growth and work to help guide research for effective replacements for lead by modifying the tin deposition process and by substituting other elements for lead. The ability of lead additions to mitigate against tin whisker growth had been established in the 1950s but the underlying mechanisms were still not fully understood. The effect of plating bath composition on deposit lead content had been studied, along with an assessment of the effect of lead co-deposition on deposit grain structure. It had been found that the grain structure transitioned from a columnar to an equiaxed structure, which was considered better for suppressing tin whisker formation. The addition of lead also resulted in a more uniform and planar IMC formation, which had been reported to have a lower strain generating ability and which enabled more uniform creep.

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Tin whiskers - Elimination of whiskers from electroplated tin ***George Milad*** *of Uyemura, Southington, CT*

The final presentation was by **George Milad** of Uyemura, Southington, CT, and was on the elimination of whiskers from electroplated tin. George reviewed the factors that led to tin whiskers.

The mechanism for tin whisker formation under ambient conditions was considered to be the most serious one. An approach for reducing the likelihood of tin whisker formation was then detailed and this included control of the tin crystal structure and controlling the substrate surface roughness in order to decrease the internal stress. Work had been carried out on tin plated copper lead-frames and the surface roughness measured using laser profilometry. The influence of surface roughness on whisker formation had been studied and it had been found that tin deposits on rough copper had reduced whisker formation at ambient conditions.

Three different tin plating solutions had been used to give different types of tin deposit crystal structures. Whisker length versus storage time data for tin films from these three solutions was shown. Compared with large grain size tin deposits, those with smaller grain sizes had reduced tin whisker formation under ambient conditions. The crystal structure in the tin deposit was found to be one of the most important factors for restraining tin whisker formation.

One of the solutions studied had been shown to effectively prevent whisker formation; this was the one that deposited tin with a columnar and equiaxed mixed crystal structure rather than the conventional columnar structure alone.

*Tin whiskers - **Martin Goosey's** Summing up of this successful International Symposium.*

This symposium had an excellent combination of presentations which covered all aspects of tin whiskers, from fundamental research to a better understanding of the science and mechanisms of whisker formation, through whisker prevention to mitigation strategies.

There was a large number of factors, often with complex interactions, that played an important role in the formation of tin whiskers. Although much good work has been undertaken to develop the knowledge base and to solve the problem of tin whiskering, there still remain many issues to be resolved.

There will thus be a need for this work to continue for some time to come. Overall, this was an excellent international symposium with top quality presentations detailing progress in the global effort to overcome the problem of tin whiskers.

Martin Goosey
November 2012

ICT Northern Seminar,

Hartlepool, 6th November 2012

A new venue for the Institute of Circuit Technology's Northern Seminar: Hartlepool's Historic Quay, with the three masts of Britain's oldest warship afloat, HMS Trincomalee, a classic British frigate dating from 1817, dominating the skyline.

ICT Chairman Professor Martin Goosey welcomed over 60 delegates to the Northern Seminar, now an established annual event which continues to increase in popularity year-on-year, and gave an update on ICT activities and member benefits with special mention of the recently upgraded website and the quarterly *Journal*. The ASPIS FP7 project, now entering its third year, was contributing greatly to the understanding of failure mechanisms and the development of process improvements in ENIG technology.

Professor Goosey introduced a well-chosen programme of four papers from eminent speakers, the first of whom was Martin Cotton, Director of Technology Europe for SCI-Sanmina.

Panelisation - Cost benefits of intelligent layout. ***Martin Cotton****, SCI-Sanmina.*

Renowned for his stylish and provocative presentations, Cotton developed a very convincing argument around the cost benefits of intelligent panelisation, with apologies to the laminators present for encouraging their customers to use less material. And in the context of a multinational EMS provider employing 22.000 people and turning over $6billion annually, he nominated panelisation as the number one parameter for cost avoidance and demonstrated with many actual examples how a small cost saving per unit could add up to hundreds of thousands of dollars.

In order of precedence, the PCB designer usually occupied a position downstream of the mechanical designer. Instead of having the opportunity to optimise panel layout for best utilisation of material and most efficient manufacture, he was too often constrained by a fait-accompli mechanical design, and had to fit his PCB into metal and plastic components and enclosures whose dimensions had already been committed. Mechanical issues had a huge effect on PCB cost; therefore it was important to design the PCB first, and then design the enclosure around it. It was essential for design and manufacturing to work together with marketing to carry out proper value analysis at the earliest stages of the design cycle, and certainly before the mechanical design was frozen.

"If you think the PCB designer has a challenging job, put yourself in the position of a shoe-maker panelising a hide for cost-effective shoe production."

A particular area of unnecessary waste in PCB design was the incorporation of supporting rails for transporting circuits through assembly equipment. By straightforward rationalisation of panel sizes, Cotton demonstrated that rails could be eliminated and that the investment cost of re-usable carriers could be recovered very rapidly through material savings.

Designers were notorious for being stubbornly resistant to change. How to overcome that resistance? "Let their bosses know how much money can be saved!"

PCB materials - High-frequency laminates and thermal reliability. ***Alun Morgan****, of OEM Marketing*

A resolute supporter of ICT events besides his duties as Chairman of the EIPC, **Alun Morgan**, Director of OEM Marketing for Isola's European operation, gave an elegant and articulate presentation on high-frequency laminates and thermal reliability, beginning by discussing the causes of signal losses, where they occurred and ways in which the laminate manufacturer could help to reduce them. He explained the concept of the

skin effect: the tendency of a high frequency signal to distribute itself so that the current was carried near the surface of the conductor, the higher the frequency the greater the effect, the closer to the surface, and how this contributed to conduction losses in copper foil, exacerbated by the roughness of the bonding treatment. Consequently, the choice of copper foil treatment could be critical when specifying laminate. "Low-profile" (LP) foil had a surface roughness of less than 5 microns and even lower-profile materials were in development. "Don't forget the oxide!" was a reminder to PCB fabricators that their own in-process bonding treatments could have significant effect on impedance, and that proprietary chemistries from alternative suppliers did not necessarily give similar results.

Considering the dielectric losses associated with the glass and resin components of laminate, Morgan demonstrated how heat was generated, and hence energy consumed, by applying an alternating signal to a polarisable material. The action of a microwave oven was a familiar example. Because the dielectric constants of glass and resin were different, the effect on impedance and signal integrity varied according to whether a conductor was passing over microscopic resin-rich or glass-rich areas of the laminate, according to the weave of the fabric. The effect was much reduced by using fabrics where the yarns and filaments were more uniformly distributed.

Standard FR4 laminate typically had a bulk loss factor of 0.015, whereas non-polarisable materials like PTFE and certain ceramics could be as low as 0.002. New-generation laminates were becoming available with loss factors approaching 0.003 without the use of PTFE or ceramic, which offered cost savings and easier processing. It was significant that water had a loss factor of 0.06, so moisture absorption in laminates could dramatically increase its loss characteristics. It was now practicable to manufacture laminates with resin systems that exhibited very low moisture absorption, good thermal stability and low thermal expansion, which showed a favourable combination of low loss and high thermal reliability.

PCB materials - characteristics of and developments in flexible laminates ***Roger Jamieson*** *of DuPont*

Alun Morgan having described characteristics of and developments in rigid laminates, it was appropriate that the following presentation should discuss corresponding aspects relating to flexible materials.

Roger Jamieson, Account Manager for Circuit and Packaging Materials with DuPont, gave an authoritative review of polyimide materials for flexible circuit applications. Flexible laminates could be classified into two distinct groups: adhesive-based and adhesiveless. Adhesive-based materials relied on a layer of acrylic or epoxy resin to bond the copper foil to the polyimide core, whereas in adhesiveless materials, the bond was directly between the foil and the core, either by sputtering copper onto polyimide film or by casting polyimide resin on to copper foil.

Foil for flexible applications could either be electrodeposited (ED), as used in the manufacture of rigid laminates, or rolled-annealed (RA), which was generally preferred because of its better flex-fatigue properties and high-temperature performance. Jamieson presented a chart of recommendations and guidelines for flexible materials to suit a range of particular applications.

Although it exhibited many desirable properties, a shortcoming of polyimide film was its natural tendency to absorb moisture.

There had been some interesting recent developments in flexible materials for high frequency applications, where the polyimide film was sandwiched between two layers of fluoropolymer, resulting in dielectric constant about 2.4 which enabled controlled impedance circuits to be made with wider conductors and thinner cores.

Impedance control - considerations for flex and flex-rigid design ***Neil Chamberlain*** *of Polar Instruments*

Mention of controlled impedance flexible circuits led logically into the final presentation, entitled: "Impedance control considerations for flex and flex-rigid designs" from **Neil Chamberlain**, Signal Integrity Product manager with Polar Instruments. Accurate modelling was vitally important for effective impedance calculation, and there had been significant advances in numerical field solving techniques. 2D field solvers could now be successfully applied to the mixed dielectrics found in flex-rigid constructions.

After declaring: "All models are wrong, but some are useful!" Chamberlain discussed recent developments that enabled the modelling of transmission lines on flexible circuits with meshed or crosshatched ground return planes, which had previously presented some difficult challenges. He remarked that solder masks and coverlays could have large effects on impedance, and needed to be taken into account in the modelling process. The tendency of polyimide to absorb moisture introduced further complication into the modelling process.

Regarding the local effects of glass fabric reinforcement in rigid materials, as Alun Morgan, had discussed, he remarked that some designers even resorted to routing their transmission lines at a 12½^{o} angle to the weave in order to even-out microimpedance variations. Again, with reference to the effects of copper surface roughness, where historically it was normal practice to specify core layers for critical dielectric spaces, there was now a trend to design such spacings between etched layers to avoid the treated sides of the copper.

Customers were developing an awareness of loss as well as impedance, and factors such as trace geometry, via dimensions, material characteristics and conductor quality were of increasing significance. Chamberlain predicted that laminate selection would become more and more important.

ICT Technical Director Bill Wilkie brought proceedings to a close and extended his thanks to Falcon Group and Merlin-Flexability for supporting an excellent event.

Pete Starkey
PCB007

November 2012

Essential updates on RoHS and REACH; an Electronics Yorkshire (EY) Seminar

Mid Yorkshire Golf Club, Pontefract,, Yorkshire, UK

20th November 2012

Introduction

There are a number of pieces of European legislation that have global ramifications for the electronics industry. Two of these are the RoHS Directive and the REACH Regulations; both of which have had a major impact on electronics manufacturers, not only in Europe but across the world. Whilst this legislation has been in place for some time, RoHS and REACH are both still evolving. Electronics Yorkshire's 'Essential Updates on RoHS and REACH' seminar was aimed at providing up to date information on these important pieces of legislation and the recent changes that have been implemented.

Electronics Yorkshire
Roger Gibbeson

The seminar was opened by **Dr Leigh Holloway** from Eco3 Environmental Consultancy who welcomed the attendees to the Mid Yorkshire Golf Club. **Roger Gibbeson** of Electronics Yorkshire then gave a brief overview of EY and the services and courses that it could offer around training, inspection and testing.

RoHS Recast and Beyond
***Gary Nevison**,*
Head of Legislation and Compliance at Premier Farnell

The first presentation of the seminar was from **Gary Nevison**, Head of Legislation and Compliance at Premier Farnell and his presentation was on 'RoHS Recast and Beyond'.

He began by giving a comparison of the differences between the original RoHS Directive and the new RoHS 'Recast' version, outlining the deadline dates for the changes to be implemented. In addition to the inclusion of medical electronics, there would also be a new 'Category 11' to cover many other types of products including wardrobe interior lights and heated clothing! There were also new definitions of equipment, which would mean more products were subject to the legislation. Cables would now be specifically included in the scope of the new directive.

There was still a list of exemptions and this included military equipment, equipment designed to be sent into space and R&D equipment etc.

Non-compliant electrical and electronic equipment that was outside the scope of RoHS 1 could still be made available on the market until July 2019. However, the entire supply chain must be 'cleansed' by July 2019.

There would also be a RoHS 2.1 version and a planned review of restricted substances by July 2014.

RoHS Recast applied to finished products and needed compliance with material restrictions, a CE mark, a declaration of conformity and a technical file.

At this time, components were not directly in scope but obviously needed to be compliant if used in equipment that was to comply with the legislation.

The current plethora of RoHS compliant symbols had to be replaced by the CE mark, although basic RoHS symbols were still allowed. All exemptions to the directive would expire after five years, unless there was an application for renewal. There had also been 34 new requests for exemptions, mainly from the medical sector. Manufacturers were now responsible for a single declaration covering all CE mark directives that applied to a product and this had to be to a format described in Decision 768/2008 and as also described in Annex VI of Recast 2011/65/EU. There were various voluntary standards that could be used eg EN50581 and EN62474 and these were available from BS.

REACH Regulations
Dr Leigh Holloway
from Eco3 Environmental Consultancy

The second presentation of the seminar was given by **Dr Leigh Holloway** of Eco3 and this was on the REACH Regulations. He began by presenting an overview of the raft of EU legislation that included WEEE, RoHS, EuP and several other directives in addition to the REACH regulations. He also outlined the objectives of the regulations. The REACH regulations came into force in June 2007 and there were

legal implications for manufacturers of products, which were the same across all European member states. It applied to substances, preparations and articles, but there were also a number of substances that were specifically excluded, such as waste, radioactive materials and non-isolated intermediates.

He then gave definitions for what was impacted by REACH and also detailed substances of very high concern (SVHCs). There were currently 84 of these substances on the European Chemical Agency's list of SVHCs and it was important to know if these were present in the products that a company produced. There were various obligations under REACH for substances in articles and these varied depending on a company's activities. There may also be a need to register substances for use in specific applications. It was important to have a good understanding of what substances and preparations were present in articles and to know at what levels they were there. There were specific legal obligations if an article contained a SVHC from the candidate list in a concentration above 0.1% by weight (in terms of the weight of the whole product). This obligation applied as soon as a substance appeared on the candidate list. Companies should be in a dialogue with their suppliers and seek to understand what chemicals were likely to be present in their products.

RoHS and REACH'
- Legislation impact on the electronics industry.
Prof. Martin Goosey
Industrial Director of IeMRC

The final presentation was given by **Professor Martin Goosey**, Industrial Director of the UK's Innovative Electronics Manufacturing Research Centre (IeMRC), and he covered the impact of legislation on the electronics industry.

He began by giving an overview of the IeMRC and the research work it supported for the benefit of the UK electronics industry. The focus then moved on to the RoHS Directive and the REACH Regulations and he covered the estimated costs of complying with these two pieces of legislation. These costs had undoubtedly been huge and were likely to have major global implications for manufacturers. Example data from various reports was shown. However, although these costs were a burden on manufacturers, the key question was whether there were any real benefits from compliance, bearing in mind that there was no option but to comply. The example of moving to lead-free electronics assembly and the use of brominated flame retardants in circuit boards was given. The transition to RoHS compliant lead-free assembly had resulted in a number of reliability issues that were still causing concern and a lot of on-going research. The examples of tin whiskers and conductive anodic filament formation were cited. The RoHS Directive had generated a lot of pressure for brominated flame retardants to be proscribed and this had resulted in PCB laminate suppliers now offering halogen-free laminates, even though the brominated flame retardants used in circuit board materials were not yet banned. Examples of the benefits possible from compliance were then presented and discussed. The European Commission had estimated that there were substantial health benefits occurring from the implementation of the REACH Regulations and the value of these could be valued at as high as 50×10^6 Euro over the next few years. Martin concluded his presentation by giving examples of the research work the IeMRC was supporting on sustainable electronics manufacturing and which was aimed at benefiting the UK electronics industry.

The large number of questions that were asked by the audience about these two important pieces of legislation gave a good indication of the real level of concern that companies still had regarding compliance and Electronics Yorkshire are to be congratulated for organising this timely and apposite seminar. More information about Electronics Yorkshire can be found at http://www.electronicsyorkshire.org.uk.

Martin Goosey ,
20th November 2012

Editor's Note

These papers has been submitted to ***Len Pillinger*** *the ICT representative on RoHS Directive and the REACH Regulations , who reports that all the implications have already appeared in previous issues of the Journal.(as below) Excluding of course the impact of the legislation on the electronics industry.*

Vol/No.	Page	Topic
1/1	05	REACh - EU Legislation
1/2	05	REACh - Enforcement & Registration
1/2	05	REACh - Exemptions
1/2	05	REACh - Impact on the supply chain
1/2	03-6	REACh - What exactly is it ?
1/3	03-4	REACh Regulation
1/2	04	REACh is 'No Data - No Market'
1/3	03-4	RoHS-46 New Materials

(These references all appear in INTOPIC.pdf available on ICT web site,)

ICT Arundel Seminar

6th February 2013

The Annual General Meeting of the Institute of Circuit Technology was held in the historic market town of Arundel, in the South Downs of West Sussex, England, famous for its castle and its cathedral.

The AGM was followed by a very well attended evening seminar, which included updates from two RTD partners in the ASPIS FP7 project, a look at developments in re-usable electronics, and a user-view of a revolutionary solderable finish.

After a welcome and introduction by ICT Chairman Professor Martin Goosey, who commented that the Institute, now in its 39th year, had seen its membership exceed 300, despite the contraction of the UK PCB industry and its supply chain over the past decade.

SPF nanofinish -

***Tim Gee**,*
of Stevenage Circuits

The first presentation was given by **Tim Gee**, Technical Director of Stevenage Circuits. Stevenage Circuits was the first European PCB fabricator to install Semblant's innovative SPF nanofinish, and were cooperating in Semblant's Premier Partner programme, to facilitate quick-turn evaluation, prototyping and production for OEMs in high-reliability product segments.

Gee considered that SPF brought a totally new perspective to solderable finishing and long-term protection of PCBs. It was applied by a dry, room temperature plasma polymer deposition process, which resulted in microscopically thin coating of an unreactive, highly cross-linked fluoropolymer. The process was pervasive and coated the entire surface area, giving unprecedented environmental protection and shelf life. The process was capable of high volume operation at low unit cost, involved no hazardous waste or conflict metals, consumed no water and had minimal energy requirements

He explained the principles of operation of the plasma deposition system, commenting that the equipment was ready for use only one minute after switching on. Deposit thickness was between 40 and 50 nanometers, and was measured using a Fourier Transform infra-red spectrophotometer.

SPF could be used as a protective solderable finish in its own right by applying it directly over bare copper, or could be applied over existing metallic finishes such as immersion silver, electroless nickel and immersion gold to enhance their shelf life. The finish had "solder-through" capability – it was displaced as the solder wetted the underlying metal – but was robust enough to maintain solderability through multiple reflow operations.

Gee showed the results of a wide range of third party corrosion tests, which demonstrated the remarkable protective capability of SPF.

Several of Stevenage Circuits' customers specialised in RF work and were particularly concerned with minimising signal losses through the "skin effect". Electroless nickel, immersion gold finishes did not perform well in RF applications. Immersion silver had more suitable characteristics, but its corrosion resistance was limited. However, immersion silver coated with SPF gave very favourable performance.

Although Stevenage Circuits' primary interest in SPF was as a solderable finish, Semblant had also developed a range of associated products for conformal-coating applications, applied by the same plasma-ploymerisation process with no masking required, which had many advantages over traditional coatings.

ReUSE project - TSB-supported

***Dr Chris Hunt** of the National Physical Laboratory*

Dr Chris Hunt, who leads the Electronics Interconnection Group at the National Physical Laboratory, discussed a novel application of printed electronics principles to improve electronics sustainability, reporting the progress of the TSB-supported ReUSE project. The project needed little justification, considering that an estimated 100 million electronic units were discarded annually in the UK alone, that 85% of scrap PCB assemblies ended up in landfill, and that most of this was non-metallic substrate material that offered little opportunity for recycling.

The ReUSE project aimed to develop reusable, unzippable, sustainable electronics interconnection technology, with circuits based on recyclable thermoplastics and rigidisers, with special polymer layers and binders designed to allow straightforward, end-of-life disassembly with easy reuse and recycling.

One of several demonstrators that had been constructed was an inverter assembly for an electroluminescent lamp, which consisted of a thin flexible circuit assembled with standard tin-finished components by normal SMT techniques using an isotropic conductive adhesive and bonded to a rigid base. This assembly had been extensively tested for reliability, with satisfactory results.

Dr Hunt showed a video illustrating how, at nominal end-of-life, a simple immersion in hot water allowed the assembly to be "unzipped", the components removed without damage to leads or terminations and the flex circuit separated from the rigid base. He believed that recovery levels in typical assemblies would be improved to at least 90%, and that the ReUSE technology would lend itself readily to rigid, flexible and 3D structures.

Ionic liquids - Immersion gold processes, used in the ENIG process.

Dr Andy Ballantyne
University of Leicester

Dr Andy Ballantyne from University of Leicester gave the first of the two presentations on the ASPIS project. His research group specialised in exploring applications for ionic liquids and were evaluating 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.

Ionic liquids were typically composed of organic cations with halide anions. They differed from molecular solvents, particularly with metal salts, where they exhibited unusual solvation properties and changed their electrochemical behaviour. The ionic liquid used in this investigation was known by the proprietary name Ethaline 200, made from ethylene glycol and choline chloride in a 2:1 molar ratio. The components were environmentally benign and readily available.

A series of immersion gold formulations had been prepared, using Ethaline 200 and gold in the form of gold chloride AuCl, gold cyanide AuCN and potassium gold cyanide $KAu(CN)_2$. These had been used to deposit gold on electroless nickel plated from a standardised laboratory formulation. Plating rates had been measured using a quartz crystal microbalance technique, and surface morphology studied with scanning electron microscopy and atomic force microscopy. The deposits had been examined visually and tested for solderability with a wetting balance. Nickel corrosion effects had been studied and compared with the equivalent effects when gold was deposited from aqueous chemistries.

The gold chloride based solution had not given good results, but results from the cyanide-based solutions were more encouraging. It had been observed that AuCN gave bright uniform coatings, $KAu(CN)_2$ gave comparatively thin coatings and that increasing cyanide content improved coating quality but decreased deposition rate. 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 the aqueous reference process. It had been shown that certain additives designed to activate electroless nickel surface could have a dramatic impact on coating morphology, and this was being studied further.

Electroless nickel deposition - fundamental aspects

Chris Fisher *from ITRI,*

The final presentation came from **Chris Fisher**, a specialist corrosion scientist from ITRI, who had been studying some fundamental aspects of electroless nickel deposition in order to determine the causes of the hyper-corrosion effect in ENIG processing. Proprietary electroless nickels all had a tendency to deposit with a cellular morphology, and the intercellular regions were points of weakness.

For purposes of development work, non-proprietary formulations had been selected, and these had been verified against commercial PCBs produced by SME partners in the ASPIS project. The absence of unidentified additives allowed changes to be made more easily and effects of individual modifications to be isolated. Several variations had been produced to control certain parameters such as deposit chemistry, plating rate, stabiliser type, and a scaled-up pilot line had been built to enable the production of larger sample quantities.

The modification strategy had been to reduce the tendency for the immersion gold process to produce concentrated attack, to adjust the chemical properties of the nickel deposit to decrease the risk of concentrated corrosive attack, to increase the intercellular boundary volume to disperse the attack, and to eliminate intercellular boundaries to prevent attack. The most obvious method was to increase phosphorous content. Although other elements or compounds might also have beneficial effect, most had been reported to be detrimental for other ENIG functionality. It was well known that increasing phosphorus content would improve corrosion resistance, although this might reduce solderability and increase the risk of brittle joints.

It had been found that the phosphorus content of coatings produced by a range of temperatures and pH's resulted in coatings with minimal differences in phosphorus content, and that addition of lactic or acetic acid increased deposition rate but did not change phosphorus content.

The morphology and characteristics of the coatings were dependent on nucleation events and subsequent growth, and it was hypothesised that if nucleation or growth could be altered then a more resilient microstructure could be developed. Electrolytic nickel growth was initiated by catalytic treatments, and the coating characteristics were partially determined by the condition of the underlying substrate. It was suggested that reducing the size of the nickel deposit cells could have beneficial effects, and that reducing the ratio between intracellular and intercellular region would reduce the driving force for differential attack. A larger area would distribute the necessary corrosive attack required for the immersion gold process, avoiding maximum level of attack being experienced in any one location.

Studies of copper pre-treatments and activation methods had shown that increasing the nucleation rate of nickel deposition was difficult, and might prevent sufficient size reduction in deposit cells to produce positive effects. Inhibiting nickel nucleation was possible and boundary-free nickel deposits could be produced, but a low-energy nucleation additive inhibitor was needed, and investigations were now proceeding in this direction.

Members at the ICT Arundel Seminar - 6th February 2013

ICT Technical Director Bill Wilkie brought proceedings to a close, thanked presenters for their contribution and delegates for their attention, and the ASPIS project for supporting the event.

www.aspis-pcb.org www.instcp.org

Pete Starkey
I-Connect007

Future Events

The Attraction of Tin Whiskers
6 March 2013
This webinar will focus on electrostatic attraction of tin whiskers, increased shorting due to contact pressure, voltage breakdown of whisker contacts and electrical resistance of whiskers. More

Piezo 2013
17 March 2013
Piezo 2013 will continue the well established traditions of presenting the latest piezoelectric and multifunctional materials, technologies and devices research and development, and of bringing together the international community. More

12th Millimetre-wave Users Group
19 March 2013
This technical meeting will review latest developments in the area of millimetre-wave science, engineering and technology, and will comprise presentations from both industry and academia. More

Metrology for Solid State Lighting
23 April 2013
European Metrology Research Programme (EMRP) End of Project Results Conference for partners, those who wish to use the project output, and UK and international stakeholders interested in project outputs. More

NPL Training
NPL and partners run a series of courses at a variety of locations throughout the UK, find out more

Portable Co-ordinate Measurement Systems
26 February 2013
Coventry University

Instrumentation and Sensors
27 February 2013
NPL, Teddington

Dimensional Measurement: Level 1 - Measurement User
18 March 2013
Coventry University

Geometrical Tolerancing to BS 8888 and ISO standards
25 March 2013
NPL, Teddington

Laser Safety Workshop
2 May 2013
NPL, Teddington

Understanding & Evaluating Measurement Uncertainty
14 May 2013
NPL, Teddington

Corporate Members of The Institute of Circuit Technology February 2013

Organisation	Address	Communication
Anglia Circuits Ltd.	Burrel Road, St.Ives, Huntingdon PE27 3LB	01480 467 770 www.angliacircuits.com
Atotech UK Ltd.	William Street, West Bromwich. B70 OBE	01210 067 777 www.atotech.de
CCE Europe	Wharton Ind. Est., Nat Lane, Winsford CW7 3BS	01606 861 155 www.ccee.co.uk
ECS Circuits	Centrepoint Business Park Oak Road, Dublin 12, Ireland	++353-(01)1-4564855 sales@ecscircuits.com
Electra Polymers Ltd.	Roughway Mill, Dunks Green, Tonbridge TN11 9SG	01732 811 118 www.electrapolymers.com
The Eurotech Group	Salterton Industrial Estate, Salterton Road Exmouth EX8 4RZ	01395 280100 www.eurotech-group.co.uk
Falcon Group	Riverside Ind. Est. ,Littlehampton BN17 5DF	01903 725 365 www.falconpcbgroup.com
Faraday Printed Circuits Ltd	15-19 Faraday Close, Pattinson North Ind. Est., Washington. NE38 8QJ	01914 153 350 www.faraday-circuits.co.uk
Graphic plc	Down End, Lords Meadow Ind. Est., Crediton EX17 1HN	01363 774 874 www.graphic.plc.uk
GSPK (TCL Group)	Knaresborough Technology Park, Manse Lane Knaresborough HG5 8LF	01423 798 740www.gspkcircuits.ltd.uk
Invotec Group Ltd	Hedging Lane, Dosthill , Tamworth B77 5HH	01827 263 000 www.invotecgroup.com
Metrohm UK Ltd.	Evanwood Close, Daresbury Court Runcorn, Cheshire, WA7 1LZ	01928 579 600 sales@metrohm.co.uk
PMD (UK) Ltd.	Broad Lane, Coventry CV5 7AY	02476 466 691 sales@pmdgroup.co.uk
Rainbow Technology Systems	40 Kelvin Avenue, Hillington Park Glasgow G52 4LT	01418 923 320 www.rainbow-technology.com
Spirit Circuits	22-24 Aston Road, Waterlooville, Hampshire PO7 7XJ	02392 243 000 info@spiritcircuits.com
Stevenage Circuits Ltd	Caxton Way, Stevenage. SG1 2DF	01438 751 800 www.stevenagecircuits.co.uk
Teknoflex Ltd	Quarry Lane, Chichester PO19 8PE	01243 832 80 www.teknoflex.com
Ventec Europe	1 Trojan Business Centre, Tachbrook Park Estate Leamington Spa CV34 6RH	01926 889 822
Zot Engineering Ltd	Inveresk Industrial Park Musselburgh, B19 EH21 7UQ	0131-653-6834 www.data@zot.co.uk

The Membership Secretary's notes - February 2013

The highlight of this quarter has undoubtedly been the application and grading of our 300th Member. Although we were a larger Institute in the Eighties, in the heyday of the Electronics and PCB Industry, this is a modern day record and highlights the strength of the ICT as a forum for the PCB and related Industry in the 21st century.

Our 300th Member is David Wyllie of Stevenage Circuits and we will be presenting an inscribed tankard and framed certificate to commemorate the event at our Arundel Seminar and AGM in February 2013.

We hold six events each year at various venues and delegate numbers have been increasing steadily to the point that it was sometimes difficult to hear the presenter at the back of the hall. The council were in agreement that we needed to address this matter and this quarter we invested in a state of the art, but fairly discrete, PA system. We were able to trial the system at our Northern Seminar in November and I can report that it has made a considerable difference to the enjoyment of the large group of delegates, who supported this event. We will be using it at all our events and I hope that we never again hear the cry "Can you speak up, please!"