Journal of the

Institute of Circuit Technology

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2015 Events

22nd September Tuesday — *ICT Evening Seminar* at Newtown House Hotel, Hayling Island
The REINDUSTRIALISATION of EUROPE
bill.wilkie@InstCT.org

24th November Tuesday — *ICT Northern Evening Seminar* at St. Georges Hotel, Darlington
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2016 Events

1st March Tuesday — *ICT Evening Seminar & AGM* at the Hilton Puckrup Hall Hotel, Tewkesbury.
bill.wilkie@InstCT.org

11th-14th April Monday - Thursday — ICT Annual Foundation Course at Loughborough University
bill.wilkie@InstCT.org

13/14th April Wednesday-Thursday — EMPS-7th Electronic Materials and Processes for Space Workshop at Portsmouth University
http://emps.port.ac.uk/documents.html

1stJune Wednesday — ICT Annual Symposium at M Shed, Bristol
bill.wilkie@InstCT.org

Editorial

Collaborative Research – A good time to engage?

When times get tough in manufacturing an easy way to apparently reduce costs is to cut R&D spending. The logic behind this is difficult to argue with. Why spend money on an area of the business that doesn't actually produce anything that you can sell, certainly not in the short term anyway. But there is of course a counter argument that for industries such as electronics, which have to respond to fast changing technologies, carrying out research which means your production processes are leaner, more cost effective and ready for the next upturn in demand is critical for survival.

For this reason it's good to see that a number of companies in the PCB supply chain are actively engaging in cutting edge research. Those of you who have attended the ICTs symposia and evening seminars over the last few years will be aware of a number of research projects which involve companies in the PCB supply chain. Merlin Circuit Technology Ltd currently have a EngD student from Heriot-Watt University, Thomas Jones, working with them on the use of ultrasonic agitation in PCB production processes and indeed Tom won the ICT award for the best article by a research student. At the ICT Darlington seminar last year Anjali Krishnanunni of Coventry University gave a talk about her work with Stevenage Circuits Ltd as a KTP Associate investigating methods to enable miniaturisation in PCB manufacture. The STOWURC project, funded by Innovate UK, investigated the use of crab shells and other chitosan containing waste for recovery of metals from PCB effluent and included in its consortium Invotech Circuits Tamworth Ltd and Chestech Ltd (now A-GAS Electronic Materials). Other Universities such as Leicester, Loughborough and Brunel, to name a few, have also regularly partnered with companies in the PCB sector. At the start of this article I mentioned the cost of R&D but most of the projects mentioned above have been part funded by research bodies such as Innovate UK and the European Union. This means that depending on the research funder, funding scheme and the size of the company anything from 40-100% funding can be obtained for research projects. In addition Universities are now very keen to demonstrate the 'impact' of their research and a good way of doing this is to work with industrial partners. For this reason many Universities have excellent (and generous) schemes for co-funding research students.

There are currently dark rumours that the UK research councils and funding bodies will undergo some sort of reorganisation in the near future and this may result in cuts to research funding. In addition the UK's possible departure from the EU would also severely restrict access to EU research funding. For these reasons if your company wants to engage in collaborative research - such as 'productivity' - it might be better to do it sooner rather than later.

Andy Cobley
ICT Chairman

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Review of :-

ICT Tewkesbury Seminar

1st March 2016

by **Pete Starkey**

Bill Wilkie

The Annual General Meeting of the Institute of Circuit Technology was held at Puckrup Hall, near Tewkesbury in Gloucestershire, England, on 1st March 2016, and was followed by a well-attended evening seminar with presentations on a novel laser-induced deposition process, an analysis of the market for PCBs, and a review of three development projects in which the Institute had participated. The programme was introduced and moderated by ICT Technical Director **Bill Wilkie**.

Laser-induced forward transfer

Dr James Shaw-Stewart

Could laser-induced forward transfer (LIFT) offer a novel deposition process for PCBs?

Dr James Shaw-Stewart, senior lecturer and researcher at Coventry University, gave an insight into the concept and applications of LIFT in transposing images from a donor substrate onto a receiver substrate. The transferred material could be a solid metallic or non-metallic film, or a liquid nano-ink, coated onto a sacrificial photosensitive layer on a transparent substrate. Ablation of the photosensitive layer by a laser caused transfer material to be propelled forward as "flyers", and deposited on the receiver, placed a short distance away. A video illustration of an early example showed an 80 nanometre aluminium layer on a 350 nanometre photosensitive layer being successfully transferred across a 1 millimetre gap at a laser intensity of 270 milliJoules per cm^2 and the efficiency of transfer increased as pressure was reduced from atmospheric. A further example demonstrated how a pulsed laser could be combined with a video image source to transfer a donor nano-ink to a substrate on an X-Y platform. The laser energy required to drive the transfer was significantly dependent on the viscosity of the ink.

LIFT techniques had been successfully used to build several different types of organic semiconductors, sensors and capacitors, and as a means of creating micro-bumps on flip-chip packages. The US Naval Research Laboratories had demonstrated the capability to laser-print metals to form microbridges and microcantilevers. More recently, extreme-aspect-ratio copper structures had been deposited from a solid copper donor. Dr Shaw-Stewart's description prompted a question from the floor about the possibility of applying LIFT techniques to the repair of open circuits on PCBs and it was acknowledged that this was a topic worthy of investigation.

Dr Shaw-Stewart concluded his presentation with "something a bit different" - a discussion of what could be accomplished by a technique known as scanned mask imaging (SMI), a development in which he was collaborating, which achieved excimer-style beam uniformity with cost-effective solid-state lasers. The system used a scanning 355 nanometre laser, with optics to shape the beam and project it onto a static substrate through a static photomask, to structure interconnects as fine as 3 micron lines and spaces with 10 micron vias. Scanned mask imaging had the potential to bridge the 1 micron to 10 micron "technology gap" between silicon wafer and PCB design rules in advanced packaging applications.

Francesca Stern
Independent consultant providing market research analysis and forecaststo the electronics industry

From imaging technology the attention turned to business forecasting. Market analyst and ICT council member Francesca Stern presented an outlook on the global PCB and electronics industry, beginning with an overview of trends in world electronics equipment production.

Overall value in 2015 was about $1.5 trillion, almost unchanged from 2014, and distributed geographically: Asia 53%, North America 19%, Europe 15%, Japan 3%, Rest of World 10%. The forecast for 2016 was for a slight overall increase to $1.6 trillion.

Looking specifically at PCBs, world production in 2014 had been $60 billion, and this had declined about 3% in 2105 to an estimated $57.8 billion with slight growth in Europe and North America, no growth in Japan and a slight decline in South Korea and Taiwan. There had been a huge variation in the fortunes of the top twenty-five PCB fabricators in 2015, for example Fujikura showing as much as 46% growth whereas Daeduck's figure was -22%, the overall average being 1.6% growth. Exchange rates could distort figures such that apparently positive growth measured in Asian domestic currencies could in fact be negative when converted to US dollars.

In terms of geographical distribution, of the $57.8 billion world PCB production total for 2015 China accounted for 46%, Europe 4%, and North America 5%. And the end market for PCBs was 45% in China, 10% in Europe and 8% in North America. The corresponding figures for 2016 were forecast to be $59 billion total, with production from China 46%, Europe 4% and North America 5%, supplying a market of which 46% in China, 10% in Europe and 8% in North America.

The outlook for the UK PCB industry was that the current downward trend would bottom-out mid-2016, and move into positive growth by the end of the year, peaking mid-2017 then cycle down again. European PCB production would follow a similar cycle, but with smaller peaks and troughs.

ICT Research & Development

Prof. Martin Goosey

Back to technology developments, as Professor **Martin Goosey** took the floor with an update on ICT's research and development projects, specifically the two current Innovate-UK funded programmes in which the Institute was the dissemination partner, STOWURC and MACFEST. (The acronyms stand for Sustainable Treatment Of Waste Using Recycled Chitosans, and Manufacturing Advanced Coatings for Future Electronic Systems)

The two-year STOWURC project, which had developed new effluent treatment processes using materials derived from crab shells had just reached a satisfactory conclusion, and demonstrated how a natural waste product from one industry could be utilised to treat waste from another industry by removing and recovering trace metals from PCB and metal finishing process effluents. Background to the project was that the seafood industry produced large quantities of shellfish waste, which was becoming increasingly expensive to dispose of. The potential value of crab shells was that they contained a compound called chitin, which was capable of absorbing metals, and one gram of shell could potentially absorb up to 250 milligrams of copper. A typical PCB factory effluent could still contain several parts per million of copper after normal effluent treatment, which required to be reduced to lower levels to satisfy discharge regulations, generally by the use of ion-exchange resins. Crab shells offered a readily-available natural alternative, and the project partners had comprehensively investigated and optimised the physical, chemical and economic parameters required to achieve a practicable and cost-effective effluent treatment process, which was currently running successfully at 100 kg pilot-plant scale in a large PCB factory. An additional application of crab shell materials was as the active component in spill kits and static drag-out

bags, to treat spills and localised effluent issues, and this had also been successfully demonstrated. Full details of the project and further information could be found on the website www.stowurc.co.uk .

The two-year MACFEST project had set out to utilise the properties of ionic liquids to produce solderable finishes with improved joint reliability, and had just passed its half-way point. New ionic-liquid-based nickel-palladium-gold systems were being investigated and a process for the deposition of good quality palladium and gold coatings onto 'aqueous' electroless nickel has been developed. PCB test coupons were currently being prepared for evaluation, and would also be tested as part of a major SMART Group programme taking place over the coming few months. Potential benefits of coatings resulting from the MACFEST project would be a reduction of environmental impacts through the elimination of cyanide-based aqueous chemistries and a reduction in the amount of palladium consumed. The principal technical benefit would be the elimination of known reliability issues with nickel-palladium-gold finishes deposited from aqueous chemistry, particularly black pad effects, brittle joints and void formation. And the new coatings would meet the requirements of the industry and current IPC standards. Further information can be found on the website www.macfest-project.co.uk .

MESMOPROC project,

Narinder Bains

Project Manager and Research Fellow at Coventry University, **Narinder Bains** gave the final presentation, on the optimisation of process conditions for the maskless electrochemical patterning of materials, with particular reference the university's collaboration in the MESMOPROC project, co-funded by the EU Eco-Innovation initiative.

The concept of electrochemical 'maskless' selective metallisation of materials had been established and demonstrated in the Enface process, where instead of a plating resist image being applied photolithographically to each workpiece then stripped off after a single operation, the image was applied to the anode and effectively re-used many times. With the selectively masked anode placed close to the workpiece, and using a low-acid, low-metal electrolyte and good agitation, the pattern on the anode could be replicated in metal deposited on the workpiece, enabling selective metallisation of microscale devices, components and printed circuit boards. A limitation of the process had been the difficulty in maintaining the intensity and uniformity of solution agitation when scaling up the electrochemical reactor.

In the MESMOPROC project, low frequency ultrasound was introduced to the system to enable high efficiency, focused agitation. The team at Coventry, with many years' experience of ultrasonics applications, had modified the reactor to incorporate ultrasonic transducers and had studied the general effects of ultrasound on the electrochemical deposition process. The team had then studied the effects of ultrasound on deposit quality in low metal, low acid copper electrolytes with commercial electroplating additives. It had been demonstrated that low or no acid electrolyte formulations, together with very narrow anode-cathode spacing gave the best image reproduction and good deposit quality, although low frequency ultrasound tended to increase additive consumption. The overall conclusion was that ultrasound increased the limiting current density and opened up the process window.

The MESMOPROC process had been demonstrated and validated at pilot scale in a PCB shop and a specialist plating shop, and offered enhanced efficiency through a shorter and simpler process using fewer materials and less energy, with reduced waste generation and CO^2

emissions. Further information can be found on the website www.mesmoproc.eu.

In his closing comments, Bill Wilkie acknowledged the generosity of Exception PCB Solutions in supporting the event, and reported that the membership of the Institute continued to increase, presently standing at over 350, with members drawn from over 100 companies. The seminar had once again brought together an enthusiastic group of industry professionals to further their technical knowledge and their awareness of business trends, and, equally importantly, to network with their peers.

I am grateful to Alun Morgan for allowing me to use his photographs

Pete Starkey
I-Connect007
March 2016

Review of :-

REPRIME: The application of advanced ultrasonics to replace explosive precursors and poisons used in industrial metal plating processes

by Stuart Dalrymple of C-Tech Innovation.

Most surface modification chemical treatments by their very nature contain hazardous and oxidising chemicals; there is a major concern that these chemicals are used maliciously with the intent to manufacture explosives or formulate poisons to harm the public. Cyanide based plating solutions and high concentrations of hydrogen peroxide used in current techniques are a significant use of these materials in industry.

The use of cyanide and hydrogen peroxide is concentrated in a few industries: large polymer manufacturers, chemical manufacturers, and surface finishing companies. Surface finishing / PCB manufacturing is a particular risk as in general the sites where these processes are run are small distributed and significantly less secure than large chemical plants. Consequently, amounts of these dangerous substances are found across the UK with varying and sometimes limited control over their use, representing a significant risk.

Barriers to implementation of cyanide free plating solutions are related to quality of product and operational requirements. Introduction of the novel ultrasound technology can overcome these barriers, but must be validated on full scale processes and over a range of plating systems.

The introduction of ultrasound to current industrial protocols has been demonstrated in the first phase of this REPRIME project to allow the removal of cyanide from metal plating processes, and significantly reduce the amount of hydrogen peroxide use. This work has now been extended to larger scale to prove industrial relevance. A plating line designed to match small production scale (around 300litres of plating chemistry) was set up at C-Tech Innovation to perform the work.

Fig.1: *Plating line at C-Tech incorporating ultrasound equipment.*

Results from zinc plating trials on fixings, showed that cyanide free solutions could be improved in terms of the weight addition (up to 20%) and the coverage consistency with appropriate application of ultrasound. The technique particularly aids coverage when used on

unusual shapes and through holes which are typically problematic with cyanide free solutions. Limited throwing power can be compensated by improved mass transfer created by ultrasound addition.

Fig.2: *Improved zinc plating on cast items and fixings using ultrasound.*

Plating of copper has also demonstrated improved finishes when ultrasound is applied to items plated with cyanide free chemistry. Results shown below use large flat plates on which are typically difficult to achieve a consistent coating finish because the current density naturally varies across the surface. The normal system has a dull colour and various imperfections in the coating quality over the item. When ultrasound is applied, the colour is much brighter and the imperfections are reduced. However, when continuous ultrasound is applied to items plated on jigs it is not always the optimum solution because standing waves can be formed, focusing the ultrasound in certain areas. By applying a bespoke power sweep function to the ultrasound, the power can be applied across the whole vat evenly. Thus, the best resulting finish on these difficult items was achieved using the sweep function.

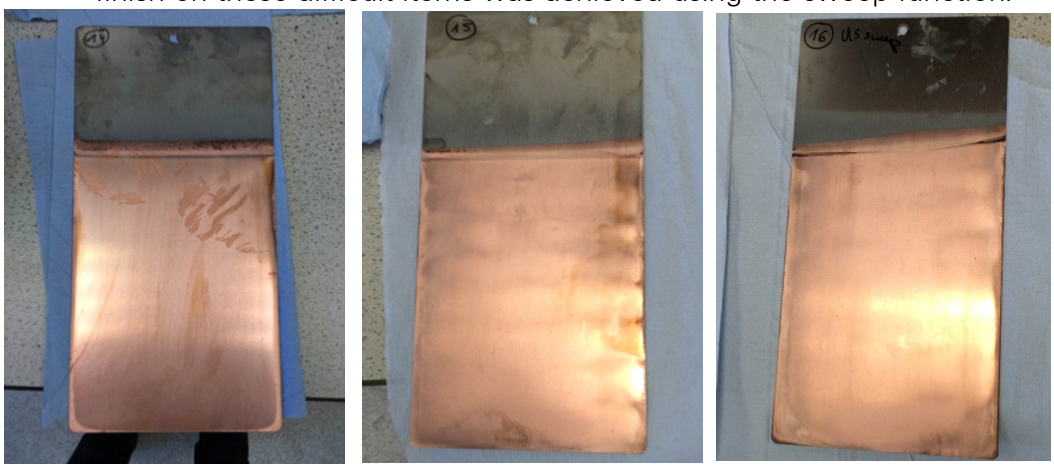

Fig. 3: *Improved copper plating on mild steel sheets.*

Left; Standard cyanide free chemistry finish,

Centre; addition of continuous ultrasound,

Right; with ultrasound power sweep function.

Further tests were carried out to prove industrial application of the technology. It is important that this solution can be easily and cheaply retrofitted into existing equipment. The ultrasonic equipment has been designed to enable the transducers to be submersed in the solution. This was used at a surface finishing company “Poeton Limited” in one of their existing plating lines on a Zinc / Nickel alloy process. This non-cyanide based chemistry is being used as a replacement for cadmium cyanide.

Fig.3 *Experimental set-up at Industrial plating facility.*

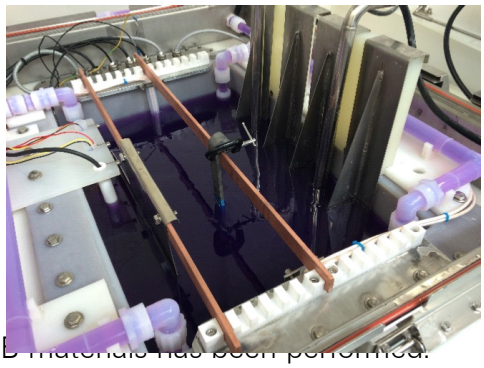

Fig.4 *Samples being treated both with and without Ultrasound.*

Ultrasound was shown to reduce the levels of hydrogen peroxide required in etchant solutions used in PCB manufacturing. However, the biggest improvements were seen when considering bath life. Peroxide based etchants deteriorate with time and with copper concentration. Baths treated with a particular configuration of ultrasound could perform for significantly longer timescales without performance degradation. Therefore, bath chemistry can be replenished at a less frequent rate, reducing chemical use and handling requirements. Deterioration in etch rates both with and without ultrasound are shown in the graph below. Energy consumption is increased when using ultrasound, however it was also found that ultrasound can enable operation at lower temperature, thus offsetting the additional power requirements. The graph below shows that when temperature of the etching bath was reduced from 60C to 40C the etching performance drops from the nominal level of around 8% weight loss. However, when ultrasound is applied, the required weight loss can be achieved at lower temperature.

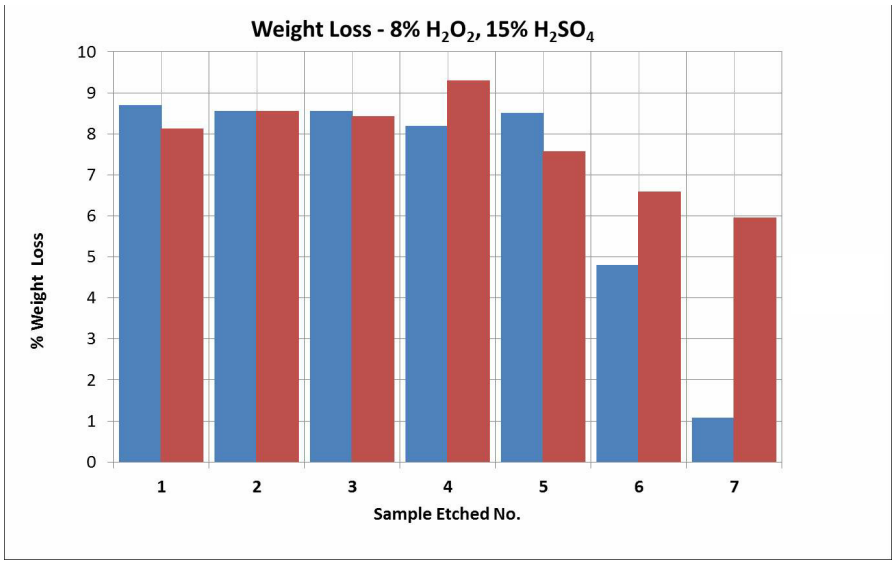

Fig 5*; Weight loss due to etching copper from PCB materials at low temperature.*

Blue without ultrasound and *Red with ultrasound.*

To go beyond the current process development in PCB etching and achieve impact in industry, the scope of work must be increased to test at an industrially relevant scale. This work will continue at C-Tech innovation using standard 24" x 18" circuit boards.

This work is possible due to funding received from The Home Office.

Update Article:-

MACFEST: Manufacturing Advanced Coatings for Future Electronic Systems

Dr Andrew Ballantyne and Prof Karl Ryder

Materials Centre,
Chemistry Department,
University of Leicester

Now in its second year, **MACFEST** is a collaborative research project involving partners :-

A-Gas Electronic Materials,
C-Tech Innovation,
MTG Research,
The Institute of Circuit Technology,
The University of Leicester and
Merlin Circuit Technology.

Part funded by **Innovate UK (formerly the Technology Strategy Board)**,

The aim of the project is the development of new "universal" PCB surface finishes which are suitable for both solder reflow and gold wire bonding. This will help PCB manufacturers meet the performance demands for high value electronic systems, ensuring long term reliability, even in harsh environmental conditions. In addition, the use of deep eutectic solvents (DESs), a patented technology of the University of Leicester, offers the ability to significantly reduce the environmental impact of a number of PCB plating technologies, reducing the requirements for use of cyanide and toxic/corrosive acids in plating baths.

DESs are a novel class of solvents similar to ionic liquids (ILs). Whereas ILs are composed exclusively of ions, DESs are liquids composed of a salt and complexing agent, commonly a tetraalkylammonium salt, such as choline chloride, and a hydrogen bond donor (HBD), such as 1,2-ethanediol or urea.[1] When mixed together the HBD binds to the anion, resulting in a large depression of the melting point. At Leicester we have used DESs in the development of immersion silver,[2,3] electroless nickel-immersion gold (ENIG)[4] and hot air solder levelled electroless nickel (HASLEN) processes, each of which offer its own benefits over existing processes[5] from the reduced safety and environmental concerns mentioned above as well as, in some cases, the removal of existing failure mechanisms such as "black pad".

The MACFEST project is building on this previous work in the development of a new, state of the art PCB surface finish for use in both reflow and wire bonding applications. Taking inspiration from the electroless nickel - electroless palladium - immersion gold (ENEPIG) surface finish, we have developed a novel nickel/palladium/gold coating where both the palladium and gold have been deposited though an immersion process from DESs. This coating is termed electroless nickel - immersion palladium - immersion gold (ENIPIG). Because of their inherent thermodynamic properties, electroless processes are fundamentally unstable. This can lead to spontaneous bath breakdown or extraneous plating which requires either bath replacement or scrapping of the Pd plated PCB, both of which can be very costly. However, immersion plating baths are fundamentally stable and not prone to either of these issues. Nevertheless, it is still essential that a uniform adherent coating is produced to prevent the underlying nickel substrate from oxidation. Using the DES Ethaline 200, a uniform Pd coating of c.a. 100 nm thick can be achieved in 20 minutes using

palladium chloride as the Pd source. An example SEM image is shown in Figure 1 where the characteristic nodular structure of the electroless nickel can be observed. Few other features are apparent, despite the presence of c.a. 100 nm palladium on the surface, because of the uniformity of the coating.

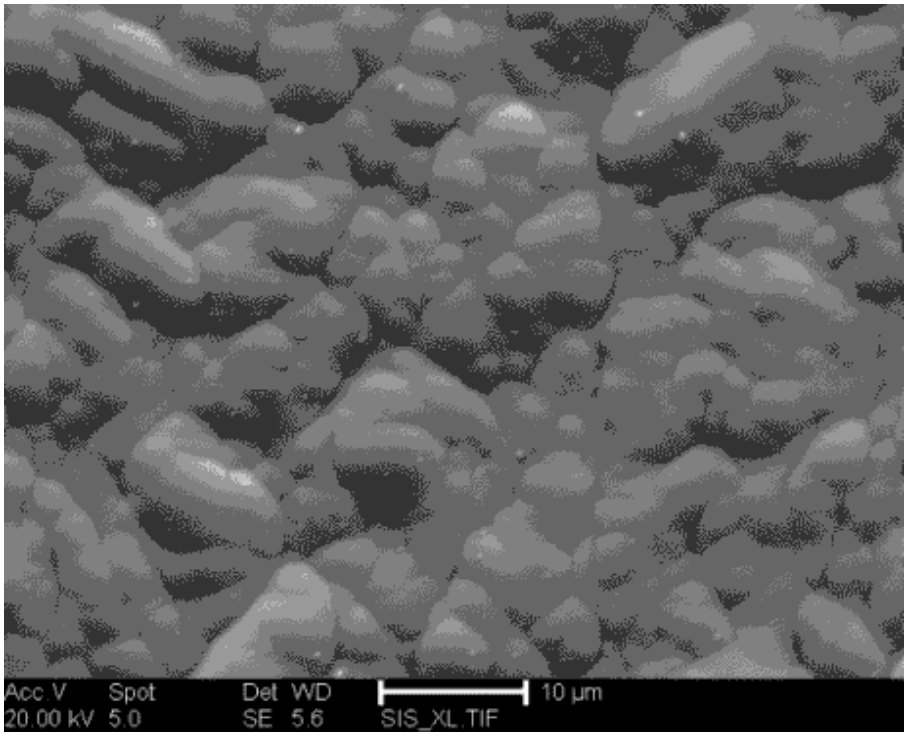

Fig. 1: SEM of an electroless nickel - immersion palladium coating

Currently, immersion gold plating processes from aqueous chemistries for ENIG and ENEPIG coatings utilise potassium gold cyanide as the Au source. However, by using DESs, gold (I) chloride can be used as the gold source. In addition, acid is required in aqueous media to help prevent passivation of the nickel surface; this is linked to the "black pad" phenomenon where hyper-corrosion occurs near the grain boundaries resulting in a poorly solderable coating. Because of the unique behaviour of metal salts in DESs, no acid is required in the plating formulation helping to minimise the risk of "black pad". A bright uniform gold coating, as shown in Figure 2, is possible in a short period of time (c.a. 5 minutes).

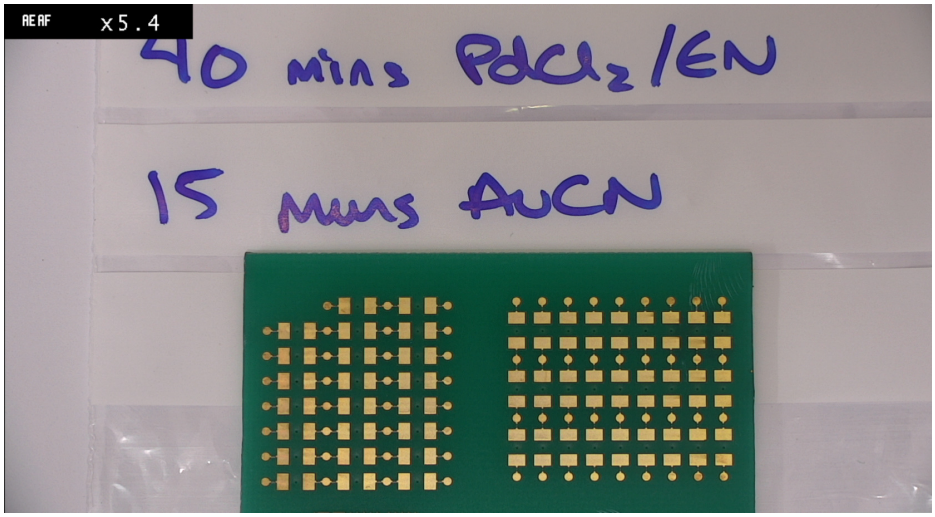

Figure 2: PCB with an ENIPIG surface finish, pad sizes are 2.0 x 1.5 mm

With nine months left, the project is proceeding according to the initial timeframe. Laboratory scale trials at the University of Leicester, while still

ongoing, have resulted in a number of interesting plating formulations for both immersion palladium and gold plating processes, some examples of which have been described above. We are now engaged in further validation of the coatings. Working with Bob Willis, of The Smart Group, our coatings will form part of a trial to evaluate the properties of a number of surface finishes in a variety of assembly and soldering conditions. This exciting opportunity will provide us with the chance to directly quantify the quality of our coatings against the current industry standards with testing being carried out by a well-known, impartial, industry expert. In addition, C-Tech and Merlin will further develop scale-up protocols for the process, developing an understanding of plating behaviour along with bath evolution and replenishment procedures.

This project is co-funded by Innovate UK.

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1st March
John at the 2016 AGM

John Brian Walker, FInstCT, 1928 - 2016

The Institute of Circuit Technology has lost one of its longest-standing and hardest - working officers.

We are sad to record the passing of our Honorary Secretary John Walker at the age of 88 Only a couple of weeks before his death, John made the effort to attend the Council meeting of the Institute, contributing to the proceedings in his customary forthright manner, then took his place as Hon. Sec. at the Annual General Meeting, where with great authority he ensured that the business was enacted in proper accordance with the Constitution, gave his report and recorded and published the minutes.

John was an elder statesman of the printed circuit industry, his contribution extending over 50 years, joining the newly established Photo Printed Circuits Ltd, in Bisley as early as 1954, and later becoming general manager at printed circuit manufacturer Palmer Aero Products in Blackwater. In 1971, John joined Nevin Electric in Colnbrook as Sales Director, and remained there until the company was sold in 1987.

John became a Member of the Institute of Circuit Technology shortly after its foundation in 1974, with membership number 24. His contribution was recognised and he was soon elected a Fellow and eventually became an Honorary Fellow. John was appointed Chairman of the Institute in 1990 and served in that position for two years, after which he accepted the office of Honorary Secretary and worked tirelessly in that position for the rest of his life.

John was a proud member of the ICT team that was instrumental in organising the first Printed Circuit World Convention, held at the Café Royal in London in 1978 and attended by over 1000 delegates. That and subsequent PCWC events were fundamental in sharing and disseminating technical information throughout the world industry.

He remained dedicated and devoted to furthering the aims and objectives of the Institute, and was respected by fellow Council members as the uncompromising defender of the Institute's independence and financial security. We will miss John Walker. We did not always agree with his views, but always respected his commitment to his interpretation of our responsibilities and priorities. And his enormous contribution to our industry and our Institute will not be forgotten.

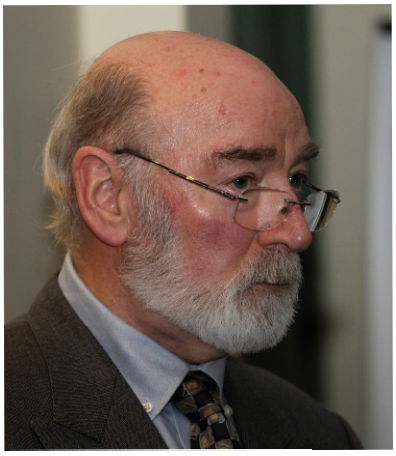
Pete Starkey
ICT Council

The Membership Secretary's notes - April 2016

The Institute website (InstCT.org) is looked after by Council Member Richard Wood-Roe and has grown steadily in importance over the last few years and amongst other attributes, the entire membership process now begins and ends with the website. Potential new members fill in the application page, which sends an email to the membership secretary's inbox, triggering the on-line grading process via the grading committee. After confirming the grading with the grading committee and posting a membership certificate, the members' details are posted on the members listing section of the website, triggering a welcome email to the new member.

Apart from enabling the joining process, there is information about the ICT, a who's who on council members, a list of future events and news items, a corporate members' page, job vacancies and job seekers, seminar and symposium reports as well as a contact page.

As you can see, the site is now far more than a list of members, and has become integral to the smooth functioning of the entire Institute. Well worth a look!



Bill Wilkie
April 2016

Corporate Members of The Institute of Circuit Technology April 2016

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Atotech UK Ltd.	William Street, West Bromwich. B70 0BE	0121 606 7777 www.atotech.com
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ICT Annual Symposium 2016

at the
M Shed on Bristol Harbour
Wednesday
1st JUNE

Registration 09:30
START - 10:00

Presentations from :

Alun Morgan will deliver the Keynote presentation on **Vehicle Electronics**

Steve Brewer of C-Tech Innovation will update on **REPRIME 2** - the use of advanced ultrasonics to improve process efficiencies

Francesca Stern of FSC will give her **Annual 'state of the nation' address**

Dr Andy Ballantyne of Leicester University will present the **MacFest project** - the use of ionic liquids as replacement technology

Andy Cobley of Coventry University will update us on **Research Projects** supported by the ICT

For further information, email :
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