Journal of the

Institute of Circuit Technology

Vol.10 No.1 Winter 2017Issue

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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

20 September — ***ICT Hayling Island Seminar***

1 December — ***ICT Harrogate Seminar at the Majestic Hotel, Harrogate*** *bill.wilkie@InstCT.org*

2017Events

14 March Tuesday — **ICT Evening Seminar and AGM** *at the Best Western Plus Manor Hotel, Meriden* *bill.wilkie@InstCT.o*

24-27 April — **ICT Annual Foundation Course** *at Chester University* *bill.wilkie@InstCT.o*

2017 - The year of **Productivity**

Random situations -

A one man business working 8hrs/day earning a basic living, is offered a larger market for his product.

What might he do?

Work overtime - Earn more money - Pay more Tax, which is possibly used by Government to support an unemployed person.

OR

A 10/15 employee business working 40hrs/week is offered a larger market for their product.

What might it do?

Invest in more expensive/productive plant, and to justify the new expense run the business on a shift basis, shorten the individual working week, pay a higher hourly wage and higher weekly wage, and increase employment.

(Shift working is very common, and embraces entertainment, transport, and most service industries.)

The result is “Higher Productivity” (more product/man hour). Thus more people are employed earning a higher weekly wage, and a larger amount of the product can be produced. The situation is now running into Political ground, not for discussion in a Technical Journal.

Hence - **Productivity**

Bruce Routledge

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Membership

New members notified by the Membership Secretary

Corrections & Clarifications

it is the policy of the Journal to correct errors in the next issue. Please send corrections to : -

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Review of :-

Institute of Circuit Technology Northern Seminar 2016, Harrogate

by **Pete Starkey**

Bill Wilkie
ICT Technical Director

A new location for the Institute of Circuit Technology Northern Seminar: Harrogate, the elegant and historic spa town in North Yorkshire, England. And an impressive venue: the chandeliered drawing room of the palatial and stately Majestic Hotel, dating from the Victorian era.

ICT Technical Director **Bill Wilkie** introduced a programme of four presentations, the first of which came from **Martyn Gibson**, Operations Director at GSPK Circuits in nearby Boroughbridge, who had sponsored the event. Speaking from forty years' experience in the industry Gibson, a Lean Champion who had introduced Lean to GSPK and also led a number of customer and supplier initiatives, gave a down-to-earth view of the benefits of lean manufacturing principles in a fast-turn batch manufacturing environment.

Lean Champion

Martyn Gibson
Operations Director at GSPK Circuits

Having reiterated the definition of lean manufacturing as an approach for providing products that a customer requires on-time, of the right quality, at the right price, in the right amount, whilst achieving profitability and continually reducing costs, he reviewed the business pressures that justified a lean approach: meeting customer service and quality requirements and extending the company's reach to global markets, lowering costs, improving operational efficiencies, tracking and controlling material costs, creating a flexible production environment and keeping products aligned to constantly changing market requirements.

He debunked some of the mythology regarding Lean just being about Japanese culture and only applying to the shop floor in automotive manufacture with the objective of cutting costs, and emphasised the focus of Lean thinking - reducing time spent on non-value-adding activities by concentrating on value-adding activities, eliminating waste in all its forms from the whole value stream and continuously striving towards the concept of zero stocks, zero rejects and zero downtime. His rhetorical question was "If your customers could see all the things that go on in your business, would they be prepared to pay for them?" adding "Because they do!"

GSPK recognised five principal elements of Lean: "value" was what customers were willing to pay for, the "value stream" was the series of steps that delivered value, "flow" was the process of organising the value stream to be continuous, "pull" was the act of responding to downstream customer demands, and "perfection" was the result of relentless removal of waste.

PCB and chip level heat dissipation methodologies

Dennis Price
Merlin Circuit Technology

A guru has been defined as "an influential teacher, guide, popular expert, or master of certain knowledge", and although industry stalwart Dennis Price pretended to be officially retired, it was clear to all present that "enjoying his retirement" necessitated maintaining his links with the ICT network and acting as informal guru to Merlin Circuit Technology.

In his presentation on PCB and chip level heat dissipation methodologies, he began by expressing some concern that a recent designer survey had indicated that heat dissipation was considered a low design priority by many engineers and that the majority of designers did not consider thermal management early enough in the design. More than one in four only considered thermal issues after the design had been completed and more than half only tested thermal design on the first prototype, if at all. And it was the view of many designers that thermal simulation techniques were too complex and time consuming.

Against this background, he explained the basic terminology and principles of thermal modelling, and reviewed the three ways in which heat could be dissipated from a component: by conduction into the PCB, to be spread by the traces or into a heat-sink, by convection into the local environment, either natural or forced and maybe via a heat-sink, or by radiation to any other surface. Conduction and convection were the only realistic methods of heat transfer "except in space where radiation is pretty much all you've got!"

Handing round samples from his extensive collection of real examples, Price catalogued the history of development of heat dissipation systems in PCB fabrication technology, from bonded external heat sinks, through copper-invar-copper constructions that served the additional purpose of CTE control, heavy copper single or multiple internal heat planes, to the insulated metal substrates that had become increasingly adopted in recent years. He listed available IMS materials, their suppliers and their data sheet properties, and went on to discuss how they could be utilised in simple single layer designs, and in two layer and four layer constructions incorporating thermal vias and thermally conductive pre-pregs. He also showed examples of double-sided designs with insulated electrical vias through the thickness of the aluminium and areas where the aluminium base had been exposed to enable the attachment of external heatsinks.

To conduct heat away from individual power devices, solid copper "coins" could be bonded into recesses milled into the PCB, and heat could be dissipated from QFN components by mounting them on thermal pads connected to copper planes by thermal via holes, although precautions had to be taken to avoid problems of solder voiding through wicking into them. Price explained how thermal vias could be plugged with thermally conductive resin and plated-over, or completely filled with plated copper. CTE control was still an issue in certain designs and proprietary carbon-core laminates were now being used to replace non-woven aramid composites, which had originally been offered as an alternative to copper-invar-copper but had suffered problems as a consequence of moisture absorption.

Price concluded his presentation with a discussion of developments in the design of heat pipes - capillary two-phase heat transfer devices which effectively worked as closed-loop evaporator-condenser structures transporting heat from a heat source to a heat sink via a volatile liquid, with the waste heat providing the driving force.

SYMETA project (SYnthesizing 3D METAmaterials)

Dr Darren Cadman
Loughborough University

Dr Darren Cadman from Loughborough University is project engineer with the SYMETA project (SYnthesizing 3D METAmaterials), funded by the Engineering and Physical Sciences Research Council. He explained that Loughborough were leading a consortium of five universities and twelve industrial partners, with expertise in engineering, physics and materials science, to develop a range of multifunctional 3D metamaterials with tailored electromagnetic properties for applications in RF, microwave and terahertz electronics.

The project set out to compile a palette of meta-atoms as building blocks for metamaterials, which are synthetic composites with structures that exhibit properties not usually found in natural materials, and to use additive manufacturing techniques to achieve bulk dielectric, metallic and magnetic properties that would open up new innovative opportunities for designers. The aim was to create complex multi-component systems, incorporating elements such as inductors, capacitors, resistors, transmission lines and filters. The ultimate objective was to establish the capability to fabricate all-inclusive PCBs by additive manufacturing, although design for microwave applications, together with materials and processes, clearly presented many challenges.

The established materials for additive manufacturing by fused deposition modelling techniques were acrylonitrile-butadiene-styrene and polylactic acid. New proprietary low-loss polyphenylene ether composites were now available that had been specially designed for RF applications. Dr Cadman illustrated the types of complex three-dimensional cellular structure that could be created, and gave examples of how dielectric and magnetic properties could be modified by the inclusion of metallic elements in the form of disconnected and connected meta-atoms to offer additional degrees of freedom for material choice. A Voxel8 3D printer specifically designed to create electronic devices was being used for initial development work, with multi-material processing as a future objective.

Surface finishes for PCBs
The next-generation
Macfest

Professor Karl Ryder
University of Leicester

Professor Karl Ryder from the University of Leicester gave the final presentation, on next-generation surface finishes for PCBs. It was 150 years since Michael Faraday's statement of the laws of electrolysis and his first experiments in metal finishing. But all of his work related to aqueous solutions. Since the late 1990s, a research group at the University of Leicester had been exploring an alternative approach to metal finishing using non-aqueous chemistry based on a series of ionic liquids consisting of eutectic mixtures of quaternary ammonium salts with either metal salts or hydrogen bond donors. These ionic liquids were effectively room-temperature molten salts which had unusual solvent properties, low vapour pressure and good thermal stability, and many had wide electrochemical windows which enabled results that could not be achieved with aqueous systems. However, they were very expensive, and the team at Leicester had sought to develop liquids that had similar properties but were practicable and cost effective. Mixing ethylene glycol and choline chloride, both readily available in industrial quantities, in 2:1 molar ratio produced a type of ionic liquid classified as a deep eutectic solvent, which had been named Ethaline 200, and this had been used as the basis of a series of metal finishing formulations. Because of its ability to dissolve metal oxides, it had also been demonstrated to have great potential as a soldering flux.

Professor Ryder described applications in electroplating, electropolishing, metal recycling and energy storage before focusing on immersion coatings, in particular metals such as silver, palladium and gold used as solderable finishes on PCBs. Immersion deposition chemistries based on deep eutectic solvents were more environmentally friendly, less toxic and more energy efficient than traditional aqueous processes. The Ionmet project had demonstrated benefits with immersion silver and the Aspis project had shown that the corrosive effects of aqueous immersion gold on electroless nickel could be avoided using deep eutectic solvent chemistry. Moreover, the use of cyanide salts as the gold source was not necessary.

The current multi-partner project, with the acronym **Macfest**, was nearing completion and the outcome was a nickel-palladium-gold universal soldering and wire bonding finish for PCBs. The base layer was a commercial electroless nickel-phosphorus 3 to 6 microns thick, onto which was deposited a layer of palladium 50 to 150 nanometres thick by a novel immersion process based on palladium chloride in Ethaline. The final layer was 25 nanometres of immersion gold, deposited from an acid-free and cyanide-free formulation where the source of gold could be either gold chloride or sodium gold thiosulphate, again using Ethaline 200 as the solvent. This finish, named ENIPIG had been independently tested for solderability and had shown results as good as or better than standard ENIG, without any evidence of the grain boundary attack which had been shown to cause "black pad" failures with the latter.

Bill Wilkie wrapped up the proceedings, acknowledged the generous support of GSPK Circuits and thanked presenters for sharing their experience and delegates, some of whom had travelled from afar, for their attention and their participation in the question and answer sessions. The formal business over, the informal networking session characteristic of ICT events carried on well into the evening.

Pete Starkey
I-Connect007
December 2016

Review of :-

EIPC Workshop on PCB Bio MEMs, London Heathrow, 8 December 2016

by **Alun Morgan**

The Premier Inn conference centre at Heathrow Airport was the venue for the EIPC workshop on PCB Bio MEMs. What, I hear you ask, is a PCB Bio MEM? This is an abbreviation for biomedical (or biological) microelectromechanical systems, otherwise known as Lab-on-Chip.

Given the strong market "pull" for more BioMEM devices (USD 2.5 billion in 2014 and anticipated to grow at CAGR of over 25% from 2016 to 2023), the commercialization of Lab-on-Chip devices is currently the "holy grail" of the research community.

The Lab-on-PCB approach (aka PCB BioMEMs) is being followed in various research groups all over Europe, owing to its inherent upscaling potential: the PCB industry is well-established all around the world, with standardized fabrication facilities and processes, however is commercially exploited currently only for electronics.

Dr Despina Moschou, *50th Anniversary Prize Fellow/Lecturer at the Centre for Advanced Sensor Technologies at the University of Bath.*

The workshop began with an introduction from Dr Despina Moschou, 50th Anniversary Prize Fellow/Lecturer at the Centre for Advanced Sensor Technologies at the University of Bath. It was Despina who first introduced the concept of PCB BioMEMs to the EIPC at its Summer Conference in Edinburgh, June 2016 which ignited interest. She asked why Lab-on-Chip is not already more established using PCB technologies to provide the needed integration between the microfluidics, the biological elements and the electronics required to form an analytical system highlighting the long-standing industrial infrastructure, microfabrication capabilities and intuitive integration of electronics.

Microfluidics technology

Dr Yuksel Temiz *of IBM's Zurich Research Laboratory*

The first speaker was **Dr Yuksel Temiz** of IBM's Zurich Research Laboratory. Dr Temiz explained that although there are over 1400+ infectious species and 347 significant diseases less than 5% of their prevalence has been accurately mapped.

He postulated that the use of IoT (Internet of Things) based devices linked to Smartphones or a handheld reader could revolutionise infectious disease mapping. He contrasted conventional lateral flow technology, such as that used in pregnancy detectors noting that microfluidics technology would require a much smaller sample size and optimised flow control to give much better quantitative results when used in a portable immunodiagnostic microfluidic platform.

Dr Temiz then showed a fascinating video of a microfluidic system incorporating valve, reagent mixing, flow splitters and capillary pumps but on a microscopic scale. Being based in Switzerland Dr Temiz couldn't resist explaining "Chip-olate" which is a high-throughput fabrication and efficient chip singulation technology having closed microfluidic structures taking advantage of dry-film resists (DFRs) for efficient sealing of capillary systems.

The outlook was shown as including microfluidic chips with autonomous capillary driven flow, integrated receptors with controlled release of detection antibodies, assay validation and compact readers including Smartphone integration. Dr Temiz closed with an explanation of microflow monitoring with the use of integrated electrodes.

Microfluidics

Dr Peter Hewkin, *CEO of the Centre for Business Innovation*

Dr Moschou then introduced **Dr Peter Hewkin**, the CEO of the Centre for Business Innovation (CfBI) whose organisation creates international collaborative communities and runs a consortium, MF-8, which brings together stakeholders in Microfluidics from across Europe and the USA. http://www.cfbi.com/microfluidics.htm

MF-8 members were invited to the workshop with the purpose of bringing together European academics working on PCB-based LoC devices, providing the PCB industry with information on Lab-on-Chip technology/potential/challenges and to promote synergies between academics, PCB and the microfluidics industry amongst all interested stakeholders.

Peter explained that microfluidics is about doing chemistry on a tiny scale and trying to emulate nature, in our bodies microfluidics is manifest in capillaries with their large surface area. It was noted that microfluidics is a term covering feature sizes in the range of 10^{-9} to 10^{10} and a key feature is to use as little reagent as possible.

Applications were identified as medical devices, drug delivery, point of care diagnostics, genomic diagnostics, high throughput screening, environmental sensing and chemical synthesis.

Hewkin went on to describe how applications could be lead to personalised medication whereby drugs could be tested on a cell, tissue or even organ on a chip simulating an individuals personalised response before applying the drug to the patient. The potential for such personalised medication would lead to a drastic reduction of unnecessary or ineffective drug use and much quicker diagnostic and treatment regimes. For now the main focus is on medical uses, however the technology could also be beneficial in testing water, air, food and crops in a future connected world.

The traditional model of table top or large chamber reactors in laboratories employing large numbers of skilled analytical staff could be effectively replaced with single use microfluidics devices employed at the point of care. It was noted that workload of traditional testing laboratories is reducing by around 5% per year as diagnostics functions are becoming more distributed and less centralised.

Hewkin asked "is there a market"? This was answered with a resounding "Yes" supported by a series of charts showing growth in medical markets with the USA leading the way. Current mass market applications were identified as pregnancy and blood glucose testing. There are obstacles to gaining approval from regulatory authorities for new devices, but once approval had been granted this gives a commercial advantage as a barrier to competition.

Hewkin explained that the microfluidics market is highly fragmented and showed many examples of real product examples including a sweat sensor and an electrochemical immunoassay system.

In concluding Hewkin highlighted the opportunity to embed microfluidic functionality into electronic devices and vice-versa and left us with the knowledge that 40% of all microfluidic disposable systems already integrate some electronics content.

Differences between using Silicon and PCB technologies for MEMs

Prof Lienhard Pagel
University of Rostock

Next we heard from **Prof Lienhard Pagel**, Professor for Microsystems at the Faculty of Computer Science and Electrical Engineering at the University of Rostock, Germany. Prof Pagel contrasted the differences between using Silicon and PCB technologies for MEMs.

He noted the advantage of rapid prototyping with PCB MEMs, but identified the disadvantages of minimum feature size in the 20 to 100 micron range and the relatively high tolerances. But he asked "Who needs nano structures"? Pagel went on to explain that systems could be categorizes into two basic structures, microstructures in the range of 10 to 300 microns and macrostructures in the range of 0.3 to 10 millimetres. He explained that microstructures are characterised by low flow and features produced by chemical processes whereas macrostructures are characterised by high flow and features produced by mechanical milling processes.

Some systems integrate both micro and macro channels in a single package and Pagel considered the key to success was the integration of microfluidics and electronics in a stacked system.

He described a project whereby apertures to be used as microfluidic channels were formed in a PCB structure using multilayer lamination techniques. Pagel explained that the project faced some challenges, especially of delamination in the low pressure areas but these were eventually overcome by the use of a two stage production technique and the application of no flow prepregs.

The next example was that of a CO_2 insufflator which is a device used to inflate body cavities during laparoscopic surgery and other minimally-invasive surgical procedures. These devices use flow rates of between 1 and 45 litres of gas per minute and achieve an intraabdominal pressure in the range of 9 to 15 mmHg.

Pavel showed the PCB design using embedded channels instead of discrete piping and integrated flow and pressure sensors. The PCB version of the insufflator achieved a significant size reduction from its predecessor and a cost reduction of 75%.

Pavel concluded by showing an example of a micro PCR (polymerase chain reaction) device for in vitro amplification of specific DNA or RNA sequences, allowing small quantities of short sequences to be analysed without cloning. PCR is a technique used in the diagnosis and monitoring of genetic diseases and studying the function of a targeted segment of DNA. The microfluidics version uses 4 integrated heating zones and 8 CV (coefficient of variation) sensors in a single unit. The advantages of using PCB technology for this device were explained as short prototyping timeframe, low cost production and miniaturisation.

DNA amplification principles using PCR & isothermal amplification

Dr Angeliki Tserepi
The Institute of Nanoscience & Nanotech at the National Centre for Scientific Research "Demokritos" Greece

Dr Angeliki Tserepi of The Institute of Nanoscience & Nanotech at the National Centre for Scientific Research "Demokritos", Greece took the podium next.

Tserepi expanded on the theme of DNA amplification principles using PCR & isothermal amplification explaining that traditional techniques required 2 – 3 days for diagnosis, however using a PCB solution could reduce that time to 3 hours.

A microPCR design was shown fabricated on a thin flexible polyimide substrate with copper heaters defining each of the three thermal zones and a plasma etched microfluidic channel. A flow rate of 8 µl per minute was established as the maximum flow rate for good linearity of the DNA amplification.

Simulations performed allowed optimisation of parameters to achieve temperature uniformity and linearity of the temperature/resistance curve. The device demonstrated integration in Lab-on-Chip for a DNA-based pathogen detection system with sufficient amplification comparable to conventional thermocyclers. The system was capable of using different thermal and flow templates to enable detection of a wide range of pathogens including salmonella for food safety and mycoplasma for pneumonia.

The benefits of using PCB technology for the system were explained as being quick, cheap, low power, reproducible and amenable to mass production in addressing point of care/point of need diagnostics, food safety and in-the-field environmental analysis. Dr Tserepi ended with showing a video animation of a prototype portable MicroNanoBioSystem and Instrument for ultra-fast analysis of pathogens in food.

PCB technologies in lab-on-chip applications.

Prof Jose Manuel Quero
of the SOLAR MEMS Technologies unit at the University of Seville, Spain

After lunch **Prof Jose Manuel Quero** of the SOLAR MEMS Technologies unit at the University of Seville, Spain explained that now was the right time for deployment of PCB technologies in lab-on-chip applications.

He considered mature PCB technologies to be a natural partner to Lab-on-Chip development. Examples of devices including a pressure sensor using capacitance changes in adjacent copper layers, a fluid impulsion device, a flow meter and nebuliser were explained.

The flow meter utilised a tiny wheel produced in copper with an opto coupler to detect and measure air or fluid flow. Flow focussing was the key feature of the nebuliser using PCB technology to produce the flow focussing elements which were capable of producing a very consistent bubble size for drug delivery.

The fluid impulsion device was novel in that it used a fusible element formed in copper as a single-use microfluidic valve. This device demonstrated that a fully integrated microfluidic circuits can be implemented within a PCB substrate without the need of complex interfaces to external impulsion actuation. Quero explained that this technology also brings outstanding advantages of the possibility of integration with sensing and auxiliary electronics and a significant reduction in fabrication cost. A series of microvalves has been characterized varying their parameters of fabrication, leading to a device that requires 0.35 J of electrical energy and supports a range of differential pressures from 50 to 400 kPa.

Quero summed up by stating that PCB technology is a good candidate as a Lab-on-Chip substrate as its flexibility allows for a large diversity of devices and manufacturing techniques and was competitive as a mature technology for mass production of devices. In closing he emphasised the importance of technology transfer from academia to industry to take advantage of the synergies.

Fluidic PCB MEMS devices

Prof. Stefan Gassmann,
Jade University of Applied Sciences, Wilhelmshaven, Germany

Next we learnt about the requirements for fluidic PCB MEMS devices from **Prof. Stefan Gassmann**, of Jade University of Applied Sciences, Wilhelmshaven, Germany.

Gassmann explained the route from the laboratory to full scale production and chose the examples of bubble detectors, active valves, analytical systems, micropumps, static mixers, pressure sensors and a water sample treatment system with which to whet our appetite.

He considered the use of PCB technologies as a low cost route to fabricating MEMs, often utilising non-standard properties. Gassmann explained that to achieve success in novel application of PCB technology it was essential to find the right PCB fabricator who was innovative enough to find solutions.

A 5cm x 5 cm monolithic chip system for a miniaturised flow injected analysis system for ferrite ion detection was the next example. The channel structures were formed from 4 PCBs with a polyimide film forming the pumps.

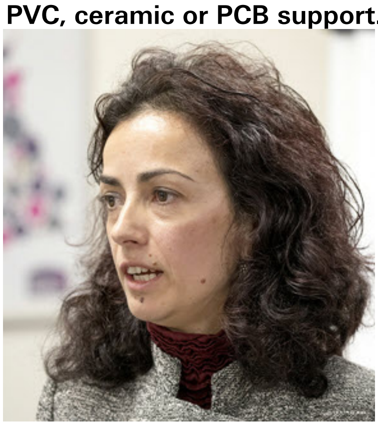
An example of the issues facing novel design was next expounded on a disposable device for genetic testing utilising 32 sensors for DNA detection on a 20µl sample. The device uses PCR for DNA amplification and it was very important that wetted parts should not inhibit the PCR process. It is known that many metals used in PCB fabrication can act as biocides and it was therefore decided to use gold plated sensors which were known to be inert to the PCR process. However, after initial prototypes were built it was discovered that the standard gold plating was not pure enough with nickel and copper being detected at the sensor surface.

Gassmann explained that the solution eventually required a redesign of the sensor with a secondary solder mask defined gold plated layer.

The PCB fabricators in the audience were not at all surprised at this and an interesting discussion on precious metal plating technology ensued.

Grossman closed by emphasising the need for innovative PCB fabricators to partner with technically minded researchers and commented that from "lab to fab" a special effort is needed.

Fabrication process for screen printed electrodes (SPE) on conductive paper using a PVC, ceramic or PCB support.



Dr Felismina Moreira,
post-doctoral researcher at BioMark Sensor Research in the School of Engineering of the Instituto Superior de Engenharia do Porto, Portugal

Dr Felismina Moreira, post-doctoral researcher at BioMark Sensor Research in the School of Engineering of the Instituto Superior de Engenharia do Porto, Portugal was next to address the audience. Moreira described a fabrication process for screen printed electrodes (SPE) on conductive paper using a PVC, ceramic or PCB support.

The biorecognition elements of the sensor used biomimetic techniques of molecular imprinting to make "plastic antibodies", the plastic being later extracted to form artificial antibodies. The technology was demonstrated with the example of a carcinogenic embryonic antigen detector using a silver electrode on a PCB support. Carcinoembryonic antigens are harmful substances (usually proteins) that are produced by some types of cancer, the test is used to check how well treatment is working in certain types of cancer.

The electrochemical behaviour of the electrodes and the analytical response and selectivity of the detector were shown, this demonstrated the sensing materials stability and suitability for the task.

Moreira closed by stating that PCB technology with silver tracks offers great advantages in terms of cost with real cost of each SPE in the range of a few Euro cents.

Bioanalysis integration

Prof Frank Bier
Department of Biosystems Integration and Automation at the Fraunhofer Institute for Cell Therapy and Immunology, Germany

The workshop then moved on to the subject of bioanalysis integration which was presented by **Prof Frank Bier** of the Department of Biosystems Integration and Automation at the Fraunhofer Institute for Cell Therapy and Immunology, Germany.

Bier explained that diagnostics are moving to where they are needed – the point of care. He stated that with an ageing society and better known biomarkers that diagnostics will be the pharma market of the future.

He used an image of a "Star Trek" tricorder and went on to say that the best solution would be based on less infrastructure and miniaturisation but that diagnostic quality must equal that of a traditional laboratory.

An integrated approach with new interfaces, perhaps expert systems and sensor ruled implants would form the necessary diagnostics as part of an early warning health system. Bier stated that it was critical to make the correct decision on technology early in the development cycle as this defines the ultimate cost of production and avoids falling into "Death Valley" on the product life cycle curve.

Bier ended his presentation with an introduction to the "Fraunhofer ivD-platform" which consists of a credit-card sized cartridge and a small read-out unit. By taking a small volume of sample and insertion into the Fraunhofer ivD-platform, assays based on a microarray are performed automatically. Within 10 to 15 minutes, a multitude of different parameters can simultaneously be measured and displayed. Bier explained that the platform minimises interfaces between the test cartridge and the measurement device and is an open platform for different sensor types including optical and electronic.

Developments of the ivD platform are continuing and will cover new assay formats including nucleic acid based detection for antibody resistance, epigenetic patterns for transfusions and transplants, non-coding and circular RNA and liquid biopsy.

Steve Driver,
CEO of SCL PCB Solutions Group

Prior to the open panel discussion **Steve Driver**, the CEO of SCL PCB Solutions Group, addressed the delegates and thanked the speakers and participants in an enthusiastic address highlighting his passion for this technology and motivation to make products for an industry with a bright future. He echoed the sentiment around the room from those connected with the PCB industry in wanting to be a part of this exciting future. Steve concluded by telling us that his Grandmother thought of a PCB as "that green thing in the back of a TV set", he explained that he now knew that actually it was a manifold for liquids!

The day ended with an open panel discussion led by Dr Moschou where the interconnectivity between the technical and commercial aspects were further explored by an enlightened audience.

Alun Morgan

The event was attended by 25 delegates covering a wide spectrum of expertise from academia to industry. The organisers, EIPC, were very grateful to Dr Despina Moschou of Bath University and Dr Peter Hewkin of CfBI for bringing together such a knowledgeable and interesting group of delegates and speakers. PCB technology and medical advances rarely fail to surprise, this was especially true at this workshop where those from the PCB industry left excited about the role they could play in the advancement of technology that would transform medical diagnosis and much more besides!

Alun Morgan

MACFEST: Benchmarking a new solder-able finish for the PCB industry

by ***Thomas Jones***

New, innovative manufacturing procedures have been developed by the recently completed project, **M**anufacturing **A**dvanced **C**oating for **F**uture **E**lectronics **S**ys**T**ems (MACFEST, www.macfest-project.co.uk), which has been funded by several partners and the government's Innovate UK. The objective of the project was to harness the potential of Ionic Liquid technology, to be used as a substitute for dangerous and costly processing chemistries applied in Printed Circuit Board (PCB) manufacture.

The specific process under consideration for Ionic Liquids was the **E**lectroless **N**ickel **I**mmersion **P**alladium **I**mmersion **G**old (ENIPIG), plating finish. ENIPIG is recognised as a 'universal finish' [1], as it allows a circuit designer to cater for the competing needs of wire bonding and surface mount soldering, which are often both required for high density circuit designs. The chemistries currently applied within the ENIPIG process employ the use of complex multistage processes with high material costs and with dangerous chemical formulations. These costly processing factors can be overcome by the substitution of novel Ionic Liquids, developed by the University of Leicester (UoL), within the ENIPIG process. [2, 3]

Merlin Circuit Technology has worked closely with UoL and Bob Willis, a recognised global expert in microelectronics testing and training, to benchmark the performance of the Ionic Liquid-ENIPIG coatings developed in the project. Tests were performed on the finish, where an evaluation of the solderability was made. Solderability provides a measure of the ease with which a solder joint can be made between materials and includes a review of the wetting of the solder to the board surface. Solderability is a vital parameter defining the success of component assembly onto a PCB, where poor quality could result in a manufacturing or an in service failure.

A PCB test board was provided by Bob Willis to evaluate the quality of the new Ionic Liquid-ENIPIG finish for the 2016, Swedish Electronics Exhibition (SEE) in Stockholm. As part of the testing, Bob offered to benchmark the performance of the Ionic Liquid-ENIPIG finish against existing finishes applied in industry.

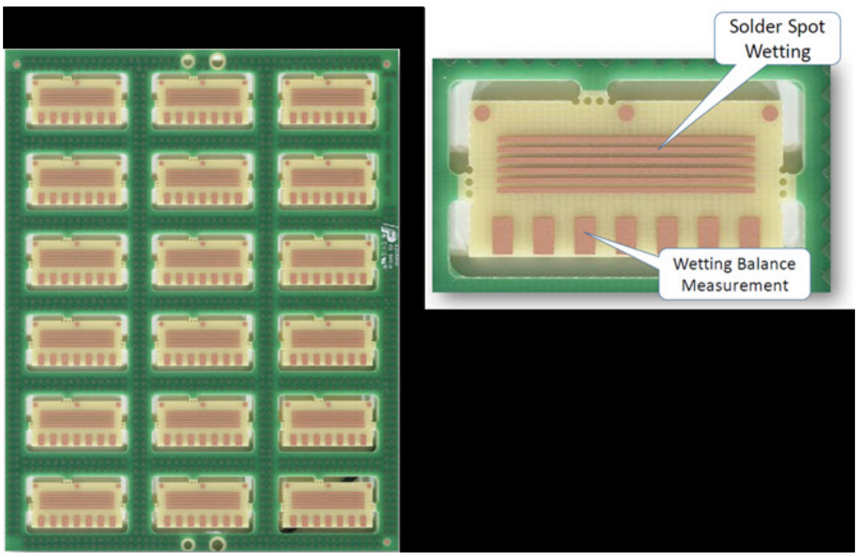


Figure 1 – Test board for solderability evaluation. 18 test coupons for solder spot and wetting balance measurements. 6 rows of tracks for spot patterning of 22 paste dots and 7 pads for wetting balance measurement

The test boards are highlighted in Figure 1, showing a 15.3 cm by 10.2 cm panel with a copper finish which includes smaller pop-out coupons. A single board contained 18 test coupons for solder spot wetting and wetting balance measurements.

The test boards were plated at the UoL with an Ionic Liquid-ENIPIG finish. The thickness of the finish was measured using an X-ray Fluorescence (XRF) device at Merlin Circuit Technology, Deeside. The plating outcome is displayed in Figure 2, showing a plot of the metal thickness measured tangential to the surface of the board for the different metals applied in the Ionic Liquid-ENIPIG and on different pad sizes. Two pads were measured. One was a 10.5 mm^2 rectangular pad and the other was a 1.8 mm^2 circular pad. The plating behaviour typically varied for the immersion palladium and gold plating processes, depending on the area and shape of the pad plated. The general trend showed that pads of a larger surface area produced thinner deposits. The Ionic Liquid-ENIPIG was no different, showing a variation in plated thickness dependent on the pad feature size.

When processing the panels, the amount of metal plated was deposited down to within the standard set by the IPC, and as outlined for ENEPIG plating, which stipulates Ni, 3 - 6 μ m, Pd, 50 – 150 nm and Au, 25 nm or larger [4]. The measured thicknesses were within the guidelines, showing that the Ionic Liquid chemistry could be made to perform comparably to the existing processes. The Pd thickness failed to measure on the large pad due to the detection limit of the XRF device, although independent measurements, not shown, confirmed that Pd had deposited to within minimum specification.

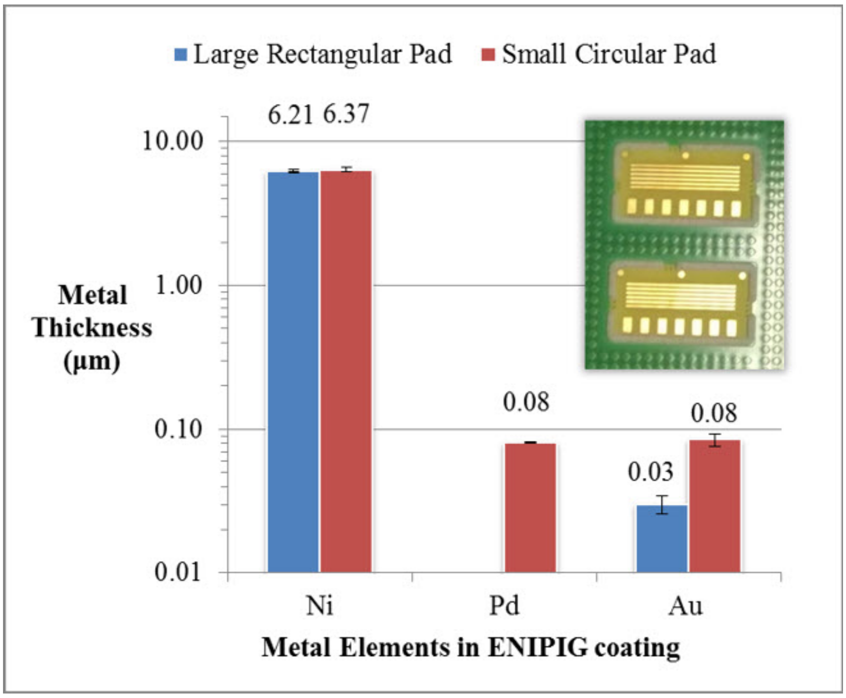


Figure 2 - X-ray fluorescence measurements obtained at Merlin Circuit Technology, of the Ionic Liquid-ENIPIG finish plated at the University of Leicester. Results show average thickness for different metals on rectangular and circular pads of sizes 10.5 mm^2 and 1.8 mm^2, respectively. Insert of plated board included.

After plating, the first quality test was a solder wetting balance measurement. The solder wetting balance test evaluated the ability of solder to adhere to the test panel, as it was vertically submerged with flux on its surface into a bath of molten solder. Once submerged, the solder climbed up the panel and the quality of the soldering was evaluated from the total increase in weight of solder adhered onto the board and its wetting speed. [5]

Solder wetting was performed on the test coupon, as highlighted in Figure 1, where the sample was lowered into a bath and the rectangular pads took up solder. The process is outlined in Figure 3, showing a plot of the weight of solder, measured as force against time, which is officially known as a wetting curve.

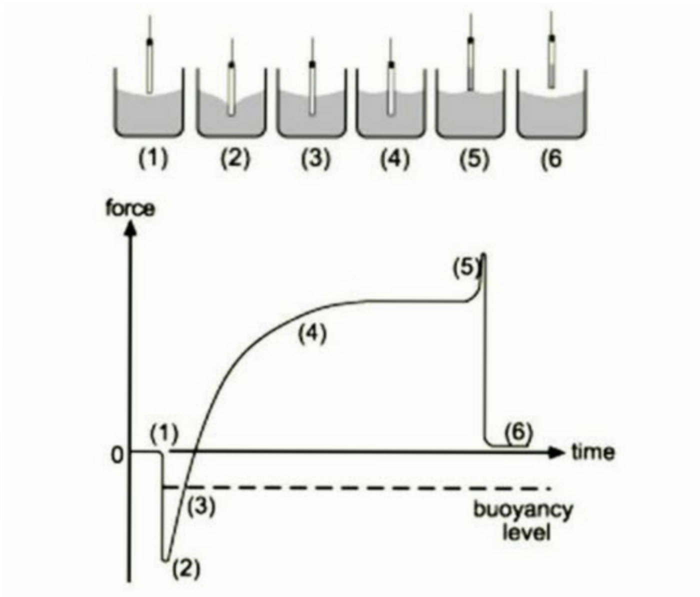


Figure 3 - Solder wetting balance test with plot of adhered solder weight force against time on a wetting curve.

The tests were benchmarked against a variety of other widely used surface finishes including Organic Solderability Preservative (OSP), Electroless Nickel Immersion Gold (ENIG), Immersion tin and Hot-Air Solder Levelled (HASL). The different finishes are applied in PCB manufacture due to the differing costs of materials and the conditions they will be expected to perform under, for example,use in the defence, aerospace, or space industries etc.

Two test boards were pre-treated before soldering. This was to mimic the conditions which the boards would undergo if they were processed in component assembly. A board may require several solder cycles dependent on the complexity of the component assembly, such as when components are added to both sides of the PCB. This will occur in two separate process heating operations. One such process could involve: the pre-treatment of the surface by a flux solution, the application of solder paste to the conductive pads, the application of the components to the paste covered pads and, finally, heating of the board to a temperature beyond the melting point of the solder, to enable the solder paste to reflow onto the pads, whilst aligning the components into the correct positions on the pads. If the board requires further component assembly then the pads on the unprocessed side of the board will have degraded in surface quality, due to thermal expansions caused by the first heating operation. Therefore, it was useful to test the condition of the test boards after a heating operation to evaluate changes in quality.

Different commonly applied heating methods are convection reflow, which in these trials applied 200 mg, Sn-Ag-Cu (SAC) lead free solder alloy at peak temperatures of 260 °C and vapour phase reflow, which applied Galden® (an inert high boiling inert heat transfer fluid) at peak temperatures of 240 °C. Vapour phase soldering typically induces a more uniform distribution of heat to the board by the process of latent heat of condensation, enabling a more uniform solder quality of the different components. It also provides a reduced operational costs and risk from fires, due to the more safe heating method and so for these reasons is often used manufacture [6].

Highlighted in Figure 4 is a plot of the average force of the wetted solder weight after two seconds immersion for the different finishes and pre-treatments. The Ionic Liquid-ENIPIG results showed that the amount of solder wetted varied little between the different processing conditions and that the temperature ageing of the board induced only small performance changes. The finish performed on par with existing industry finishes such as ENIG.

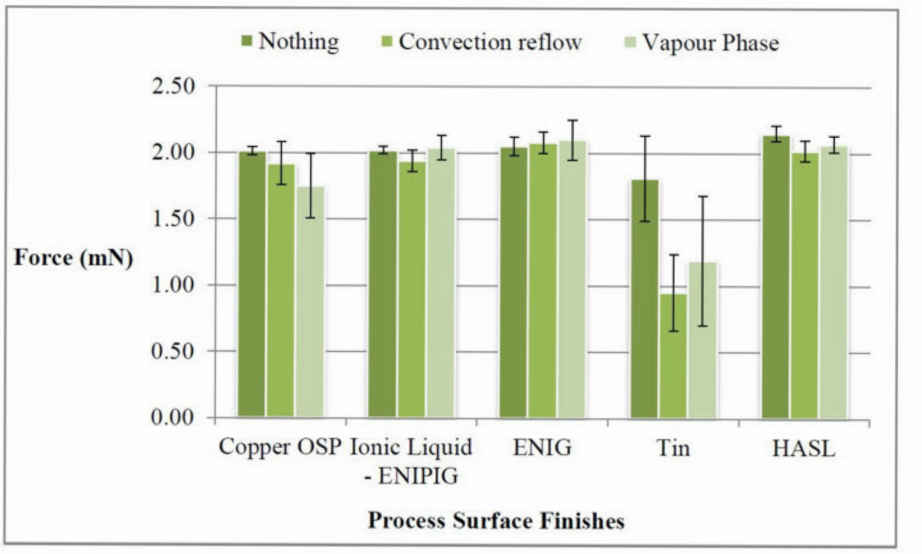


Fig. 4 - Average solder wetted weight after two seconds immersion. Test performed on five different finishes with each pre-processed under three different conditions.

Fig. 5 shows a plot of the average solder wetting time taken to reach 2/3 of the final wetting force. This shows how fast the solder wetted to the surface, where a short time is desired. The Ionic Liquid-ENIPIG showed a range of behaviours which differed depending on the pre-treatment conditions. Its performance dropped – shown by the increase in time to wet - for the application of convection reflow. Convection reflow is processed at higher peak temperatures than vapour reflow and so the impact of thermal expansion on topography, and thus solder-ability, would have been greater. Regardless, the performance drop was not significant and the time to wet was less than the majority of the other surface finishes. This showed that the surface topography of the deposit was of a sufficient quality to enable wetting to the board and displayed a high surface energy like the other surface finishes, despite heating damaging its surface.

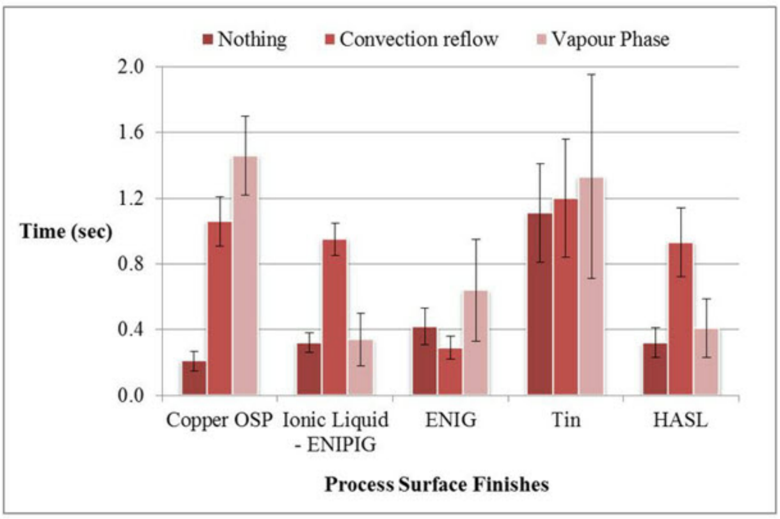


Figure 5 - Average Solder wetting time taken to reach 2/3 of the final wetting force. Test performed on five different finishes with each pre-processed under three different conditions.

The final evaluation of the solderability was the Wetting Dot Test This evaluated the ability for solder paste to flow across test pads plated with a surface finish [7]. The test was performed using the test coupon highlighted in Figure 1 again. 22 solder paste dots were stencil printed onto the 6 tracks above the rectangular tracks, with an example shown in Figure 6. The board was then subjected to reflow heating which melted the solder paste. Upon melting, the paste spread across the surface of the pad and coalesced when it came into contact with dots. After a heating cycle the number of spots remaining on the board surface was counted, two or more coalesced spots were counted as one

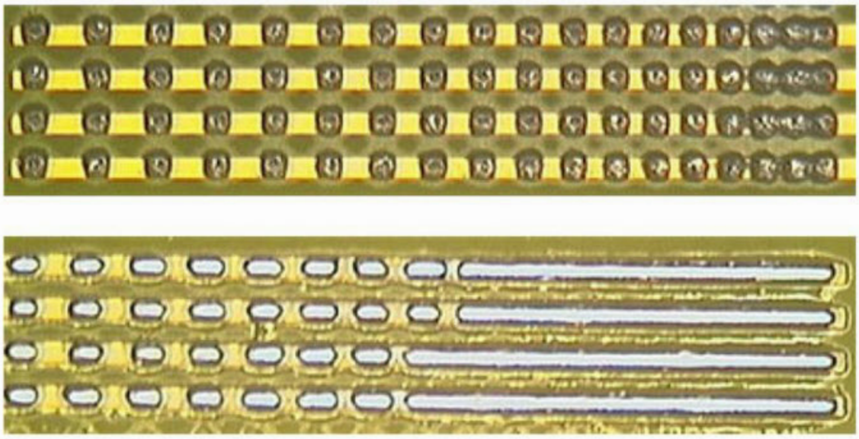


Fig. 6 - Example of solder spot test. Top shows solder spots added to tracks with reducing distance between features. Bottom shows coalesced spots after reflow heating of board.

A surface finish with high wettability allows for increased coalescence and a smaller number of counted solder spots on the surface after reflow heating. The results for the spot test are displayed in Figure 7, showing the number of spots counted for HASL, ENIG, Ionic Liquid-ENIPIG, Immersion tin and OSP. The test was performed with different pre-treatment conditions, which were convection, vapour phase, no pre-processing, and the application of nitrogen, which is used to aid soldering and to prevent surface modification [8].

When populating both sides of a PCB with components and applying two heating operations, an unintentional pause may be introduced in the manufacturing process between heating cycles, due to the work load of the assemblers. During this pause in processing oxidation occurs on the metal surface, negatively influencing the performance of the board for soldering [9]. For this reason, an additional test was performed whereby convection and vapour phase reflow operation were performed individually on test boards, and a hold period introduced - to simulate degradation which may occur when leaving the boards during component assembly - before spot wetting testing.

The results showed that the most effective finish for coalescence of spots was the HASL, and the least effective was the OSP, which were unsurprising results. The performance of the finishes dropped with the introduction of a hold cycle and for processing at higher temperatures - such as processing under convection reflow – which was also as expected. The Ionic Liquid – ENIPIG performed well relative to the other finishes, where coalescence was high on its surface regardless of the pre-treatment conditions. The finish specifically performed better than the ENIG, which had a similar material composition and topography.

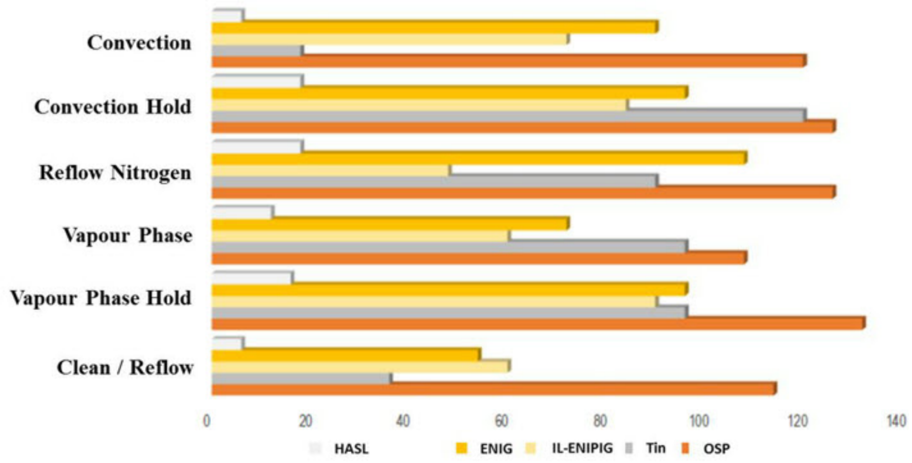


Fig. 7 - Solder spot wetting test results for different plated finishes and processing conditions.

Conclusions and Future Studies

The performance of the new Ionic Liquid – ENIPIG finish was benchmarked against widely applied surface finishes for the PCB industry, where its performance was exemplary in terms of the solder-ability.

One of the uses of the ENIPIG finish is for high density circuit builds with small feature sizes. To connect the PCB to the small pad features on the integrated circuit component, wire bonding is required. Trials are being developed for the remainder of the project, looking to test the ability to wire bond to the surface finish, defining its bond strength and performance on differing pad sizes.

To date, Ionic Liquids have performed well in their bespoke applications within PCB manufacture. The success to date of the MACFEST project and the potential for cost savings from the novel chemical formulation shows that their continued development and introduction into manufacturing is well worth pursuing.

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A brief history of the UK Captive PCB Fabricators

By **Bill Wilkie**

The following list contains many of the PCB fabricators, who were around in the 1980s and 90's and the first photograph shows the fine edifice of Ferranti Cairo Mill in Oldham.

Ferranti was one of *the* great captive shops in the history of the UK PCB Industry, although there were others including ICL, IBM, Hewlett Packard, Marconi, Burroughs, Plessey and Barr & Stroud.

They were all important because they were in-the-main large engineering and electronics companies with in-house PCB manufacturing facilities, some of whom supported research and development and in some cases pure research facilities. These captive facilities contributed to and raised the technology and profiles of our PCB industry before their demise.

Ferranti

The company had factories in Greater Manchester at Hollinwood, Moston, Chadderton (Gem Mill), Waterhead (Cairo Mill), Derker, Wythenshawe, Cheadle Heath, West Gorton, and Poynton. During WWII Ferranti set up a factory in Edinburgh at Crewe toll where Gyro-gunsights were built for the RAF. Other facilities were subsequently opened at Silverknowes, Robertson and South Gyle. Ferranti also had facilities in Dalkeith, Aberdeen, Dundee, Bracknell, Barrow in Furness and Cwmbran.

PCB's were produced in house at Robertson Avenue, Cairo Mill and Bracknell and one of our members, Jim Francey, started as a chemist in Crewe Toll before moving to the board shop in Robertson Avenue. John Haywood, Senior Vice President at Morton, came from Ferranti Bracknell as did David Kingsley, who delivered many papers at local and international seminars, with the Institute inherited his library of slides upon his death.

Plessey

The Allen Clark Research Centre at Caswell, near Towcester, became the location for Plessey's first dedicated research centre in 1940, and the total workforce of Plessey's Electronic Systems division grew to over 15,000 people by 1986. Plessey had other sites for electronics and semiconductors, including large facilities at Swindon and Plympton. Martin Goosey, now Professor Goosey worked at Caswell early in his career during the 1970's and 80's.

Plessey Ilford, at Vicarage Lane had a fairly large in-house board shop, where ICT Member Steve Snell began his career and where

Mike Fisher, well known in the Industry was Production Manager. Mike and Brian Saville eventually ran Trulon Circuits and Mike was also one of the founders of Express Circuits.

Plessey

Plessey invested heavily in Plessey South Shields on the site of the old Bush TV factory. ICT Member Erik Butchert was there at its inception and it grew rapidly until sold to ISL, who turned it into the largest PCB shop in Europe, outputting more than half the UK board production.

Hewlett Packard

HP had one of these rare items – a purpose built no-expense-spared manufacturing shop with the tank farm in the basement so as not to spoil the lines on the shop floor - and a state of the art effluent treatment plant. HP's corporate panel finish was gold plating over the entire board. The only other purpose built PCB facility using a similar design was Flexible Technology Limited (1980) at Rothesay on the Isle of Bute, which is still run by Peter Timms (ex IBM), one of the original founders.

IBM

IBM had two main plants, both state of the art at Greenock and Havant. The Greenock facility, built in the 70's had a 6-storey automated parts retrieval system, when most operations were run by a storeman. They produced mainly flexible circuits for hard drives and at that time were still a major computer company.

IBM used MBM's Filmwire division for volume production. MBM in Victoria Road, Portslade was owned by Morgan Crucible, and was a captive shop in a small way, using the test facilities in the engineering and metal working division. When Morgan split up the facility, the flexible side was bought by Neil Martin, who now runs the Merlin Group. Neil began his working life at MBM and I was the chemist there in the late seventies.

Marconi

Marconi manufactured boards at Hillend in Fife and at New Street, Chelmsford and had a research facility at Great Baddow.

ICL

International Computers Limited was formed in 1968 as a part of the Industrial Expansion Act of the Wilson Labour Government. ICL was an initiative of Tony Benn , the Minister of Technology, to create a British computer industry that could compete with major world manufacturers like IBM . ICL represented the last step in a series of mergers that had taken place in the industry since the late 1950s.

The Kidsgrove and West Gorton sites produced boards and a steady flow of trained people into the Industry. ICT Members such as Richard and Lynn Houghton, Tom Parker as well as Industry stalwarts Tim Tatton, Harry Buckroyd and David Kinnaird all came out of ICL.

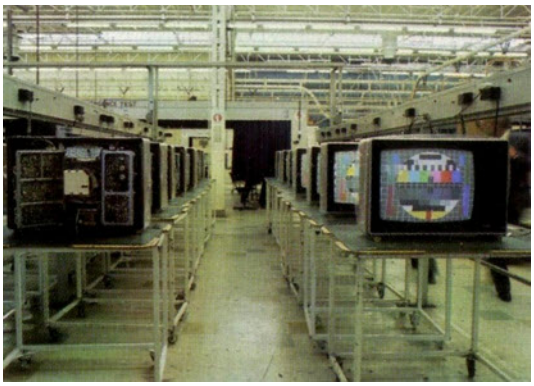
Barr & Stroud

Barr & Stroud were part of the Reed Group with a large facility in Anniesland, Glasgow, producing optics and optoelectronic devices. They operated a small board shop, which became Strathclyde Circuits with founder Bill Briscoe, who is still at European Circuits.

PHILIPS

Almost anyone involved in television servicing during the late sixties or the seventies will have encountered a Philips TV set on one occasion or another. The brand itself dates back to 1891 in Eindhoven in the Netherlands and began life making carbon-filament lamps

Many of the Philips TV sets were designed and produced at the firm's consumer electronics factory on Commerce Way in Croydon. The Company acquired the site in 1956 and by the eighties, was the largest producer of single-sided boards in the UK, and possibly Europe.



The list is by no means exhaustive and I'm sure that members will be able to add their thoughts and reminiscences!

Bill Wilkie

Corporate Members of The Institute of Circuit Technology January 2017

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Atotech UK Ltd.	William Street, West Bromwich. B70 0BE	0121 606 7777 www.atotech.com
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Exception PCB Solutions	Alexandra Way, Ashchurch Business Centre, T ewkesbury, Gloucestershire. GL20 8NB	01684 292 448 wwwinfo@exceptionpcbsolution com
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 798 740 www.gspkcircuits.ltd.uk
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