Journal of the
Institute of Circuit Technology

Vol.8 No.1 Winter 2015 Issue

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2014 Events

5th June **ICT Annual Symposium**
Thursday at Great Western Railway
STEAM Museum, Swindon
bill.wilkie@InstCT.org

23th September **ICT Evening Seminar**
Tuesday at Newton House Hotel, Hayling Island
bill.wilkie@InstCT.org

18th November **ICT Darlington Evening Seminar**
Tuesday at St George Hotel, Durham Tees Valley Airport,
DL2 1RH 01325 332631
bill.wilkie@InstCT.org

2015 Events

3rd March **ICT Northern Seminar and AGM**
Tuesday at Chimney House Hotel, Sandbach
www.instct.org
bill.wilkie@InstCT.org

13th -16th April **ICT Annual Foundation Course**
Tuesday - Friday at Loughborough University
bill.wilkie@InstCT.org

3rd June **ICT Annual Symposium**
Wednesday at Black Country Museum
bill.wilkie@InstCT.org

Editorial

At the start of 2015 – what are your New Year resolutions? Joining a gym, going on a diet, taking more exercise; will you be trying to change the habits of a lifetime?

What does 2015 hold for the PCB industry and for electronics in general? What will be our business and technical challenges in the coming year?

I've seen reports that in 2015 mobile connected devices will exceed the population of the world and maybe by the time you read this we've already reached this milestone! Mobile connectivity, the internet of things and the resource of the Cloud affect and influence our daily lives in business and in pleasure.

Within the electronics industry, miniaturisation has continued to be a driving force. It remains to be seen if the rate of semiconductor miniaturisation will continue at the recent rapid rate. However, the future burden of miniaturisation is now extending to the next levels of interconnect; to semiconductor packaging and the PCB. This potentially requires the integration of technologies such as photonics and microfluidics in addition to ultra-fine line and build up technologies to achieve the requirements of higher connectivity, higher bandwidth, lower latency, lower power and effective thermal management. Innovation will be needed at the PCB level of interconnection together with an environmentally sustainable and, of course, profitable approach.

Looking to the future in a positive way, these technology drivers can create business opportunities. Having a profitable and sustainable business designing, manufacturing and assembling PCBs increasingly requires differentiation in product offering beyond the ubiquitous Unique Selling Propositions. One of the areas where this can be achieved is to have an advanced technical capability striving to be at the forefront of new technology, thereby developing differentiators within your product offerings.

Looking back during my time in the industry, PCB fabrication primarily emanated from large electronic corporations who had considerable R&D resources. These could be directed towards advancing technical capability, fabricating innovative structures and developing new approaches to electronic interconnection and packaging. PCB fabrication and assembly has now almost all been outsourced, so that PCBs are now predominantly manufactured by SME companies. Resources for internal research programmes are hence more limited and technical advances in capability are primarily driven through developments from material suppliers and capital investment in new manufacturing plant and equipment.

So how can an SME company achieve meaningful differentiation that is more than using the latest materials or investing in the latest equipment - which are also available to their competitors? How can one undertake R&D projects that can result in relatively short term exploitable benefits with small or modest budgets?

One such solution is in collaborative research. Collaborative research programmes leverage the collective resources of the consortium partners being focussed on the project objectives. The research consortium can include key stakeholders in the supply chain including OEM's and ODM's to provide effective exploitation of results and enable a short route to market, as well as Universities to provide world class innovation and support. For some projects competitors can work together on issues such as industry standards or environmental and sustainability topics.

Collaborative research is not new and many SME's have taken part in research initiatives ; SME's have an enormous amount to offer and much to gain. Some research may always need to be undertaken in-house if IP is a key issue, but for many challenges collaboration can be highly successful. Our industry has an impressive array of world class individuals with unique expertise and experience. However, these experts can be spread thinly across many companies and organisations. Collaborative research enables one to call on and leverage this collective expertise for a common goal.

I'd like to suggest that one New Years' resolution would be to embrace the future challenges of technology and sustainability and explore all potential opportunities for collaborative research involving your supply chain, academia and maybe even your competitors. By way of example, the ICT is continuing to engage in collaborative R&D on behalf of its members and will be a partner in a new two year solderable finish project, which starts on the 1st January 2015. This project is called MacFest and we will report on progress in future issues of this journal and via our evening seminar programme.

In 2015 the Institute plans more highly informative and topical events centred on our collective technical challenges so make sure you add these dates into your new diary!

A happy and prosperous New Year to you all!

Steve Payne
Director of Cirflex Technology Ltd.

Membership

New members notified by the Membership Secretary

10341 Bradley Taylor M.Inst.C.T.
10342 Andy Critcher M.Inst.C.T.
10343 Tom Jones A..Inst.C.T.
10344 Emma Goosey A..Inst.C.T
10345 Amy May M..Inst.C.T

Corrections and Clarifications

It is the policy of the Journal to correct errors in the next issue.
Please send corrections to : -
brucer@john-lewis.com

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Smaller, Lighter and Faster PCB's

A New Development Programme devised by the Technology Strategy Board of UK known as the Knowledge Transfer Partnership (KTP)

A collaboration between Coventry University (Knowledge base) and Stevenage Circuits Limited (Industry)

The partnership will allow flow of information from the University to the Company where it can be directed towards innovative projects. Coventry University brings in the expertise of Dr.Andrew Cobley and his Functional Materials team, represented by Narinder Bains whilst the project at Stevenage Circuits is led by Tim Gee, Technical Director and Phil Firth, Technical Manager.

The aim of the project is to improve the manufacturing capability to meet the future requirements of the electronics industry particularly for high reliability for military grade HDI PCBs. As technology advances, in particular the component packaging device technology, the need for miniaturisation in the field of High Density Interconnect (HDI) Printed Circuit Board (PCBs) is increasing .

As the inexorably increase in packaging densities continues the device footprints reduce to a point where the current PCB fabrication technology will no longer be capable of meeting the requirement, this is also true for the component assembly - as the device pitch reduces so does the yield. Consequently resolving a design and cost effective solution for a high reliability HDI PCB that meet IPC class three compliance for design fabrication and assembly is getting more difficult.

The modern PCB's will have to be smaller, lighter and faster. Some of the ways this can be achieved is by reducing feature sizes, increasing stack layers and embedding electronic components within the PCBs and generally building better specification of surface mount devices whilst having minimum tolerance for errors. The advance in technology will be advantageous to the designers, fabricators and the assemblers of the electronics industry.

Stevenage Circuits, a reputed company known for its PCB manufacturing technology and its varied customer base, will be focusing on surface modification techniques, materials adhesion and electroplating processes. The university will help carry out some of the research at their facility. The success of the project relies on the integration of these three areas on a prototype to a large scale production level.

Anjali Krishnanunni, the KTP associate, who will act as a bridge between Coventry University and Stevenage Circuits and is based at Stevenage Circuits to implement the project that will last for two years. During this time she will also work to identify commercial links and undertake business development and disseminate the technology/project via articles and/or conferences.

The Stevenage Circuits – Coventry University KTP Team

From left to right

Narinder Bains (Coventry University, Knowledge base Supervisor)

Phil Firth (Stevenage Circuits Ltd, Technical Manager, Company Supervisor)

Anjali Krishnanunni (Coventry University, KTP Associate)

Tim Gee (Stevenage Circuits Ltd, Technical Director, Company Lead)

Andrew Cobley(Coventry University, Academic Lead)

A Celebration of the life of PAUL EISLER

5 May 1907 – 26 October 1992

Compiled by Maurice Hubert F.Inst.C.T.

Paul Eisler was born in Vienna, the son of Wilhelm Eisler (from Szered, now Sered, Slovakia) and Caecilie (née Fehl, from Nikolsburg, now Mikulov, Czech Republic). He qualified at Vienna Technical University (Dipl. Eng.), and worked in Vienna as the technical editor of Rundfunk, a weekly radio magazine (until February 1934). He registered patents on graphical sound recording and on stereoscopic television, and left Austria for Britain in 1936, where he applied for a patent for his printed circuit which he invented that year.

Soon engaged by Oscar Deutsch (Odeon Theatres), he invented a continuous film projector and a differential mirror drum.

In WW2, several family members perished in the Holocaust, although his parents managed to reach London. Paul was interned on the Isle of Man as an 'enemy alien'. Anxious for his inventions to contribute to the war effort, he convinced a music printing company to support his projects, inadvertently surrendering the patent titles to them.

He incorporated his Printed Circuit (Foil Technique) in a radio set, which he demonstrated to the UK Government, which declined to accept it, but the Americans used it (without due acknowledgement) in proximity-fused anti-aircraft shells.

Applications of the Printed Circuit multiplied: guided missiles, miniaturised walkie-talkies, instrumentation, telephone exchanges, radios, TVs and computers.

Having first worked on the upper floor of a building in Shaftesbury Avenue, he transferred to Camberwell as director and manager of Technograph Printed Circuit Ltd (resigning in 1957), making it the first Printed Circuit factory.

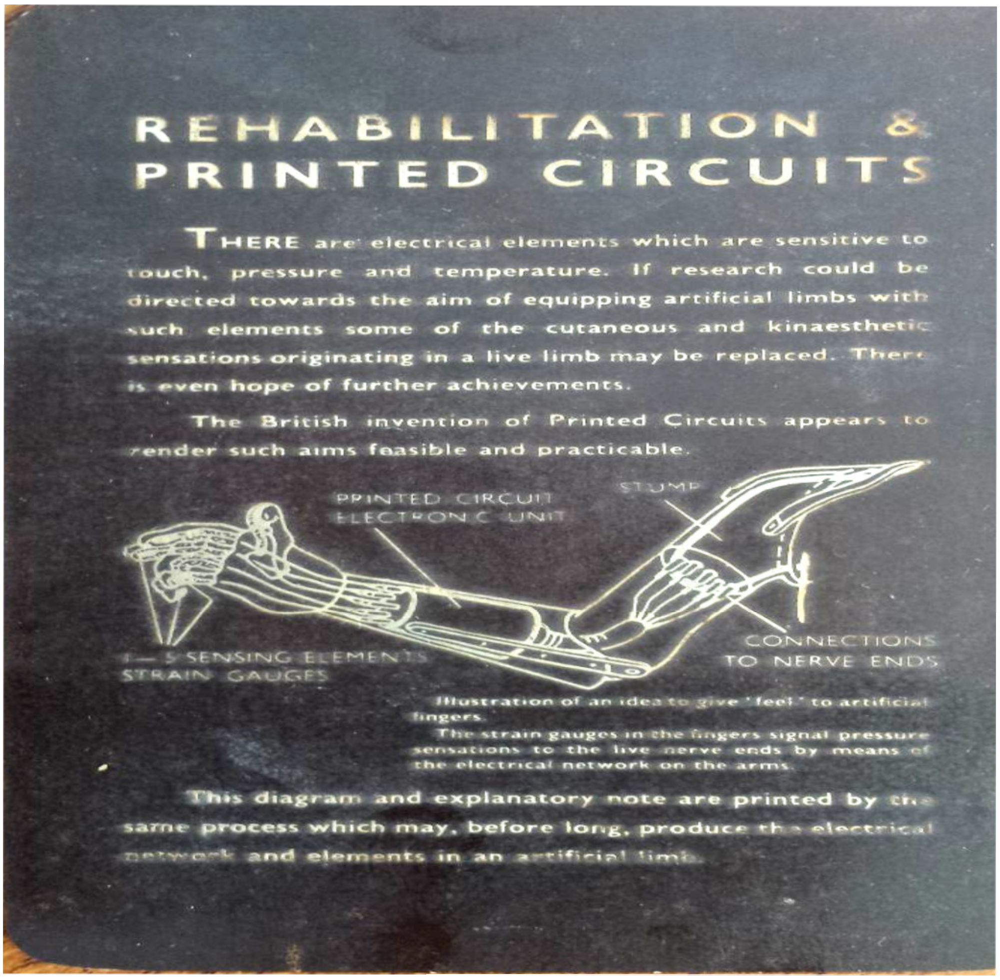
The first Printed Circuit radio was made in 1942 (now in the Science Museum), and the Foil technique patent was applied for in February 1943.

Eisler invented Hotfoil, and Foil Heating Film used for electric surface heating. In the early 1950s, his de-icing mats were used by Rolls-Royce and other companies.

Disregarded by the British establishment, he was acknowledged abroad; he was appointed Officier de l'Ordre du Merité pour la Recherche et l'Invention, and a corresponding member of the Accademia Tiberina, Rome. He was elected FIEE and awarded the Nuffield Silver Medal for Industry. He married Frieda Goldman-Eisler, a kindred Jewish refugee from Vienna and a noted pioneer of psycho-linguistics in 1952

Paul Eisler with the 1st Printed Circuit radio in it's touch proof transparent exhibition case. (Now in the Science Museum)

Early examples of Printed Circuit Boards produced by *Technograph Printed Circuits*



REHABILITATION &
PRINTED CIRCUITS

THERE are electrical elements which are sensitive to touch, pressure and temperature. If research could be directed towards the aim of equipping artificial limbs with such elements some of the cutaneous and kinaesthetic sensations originating in a live limb may be replaced. There is even hope of further achievements.

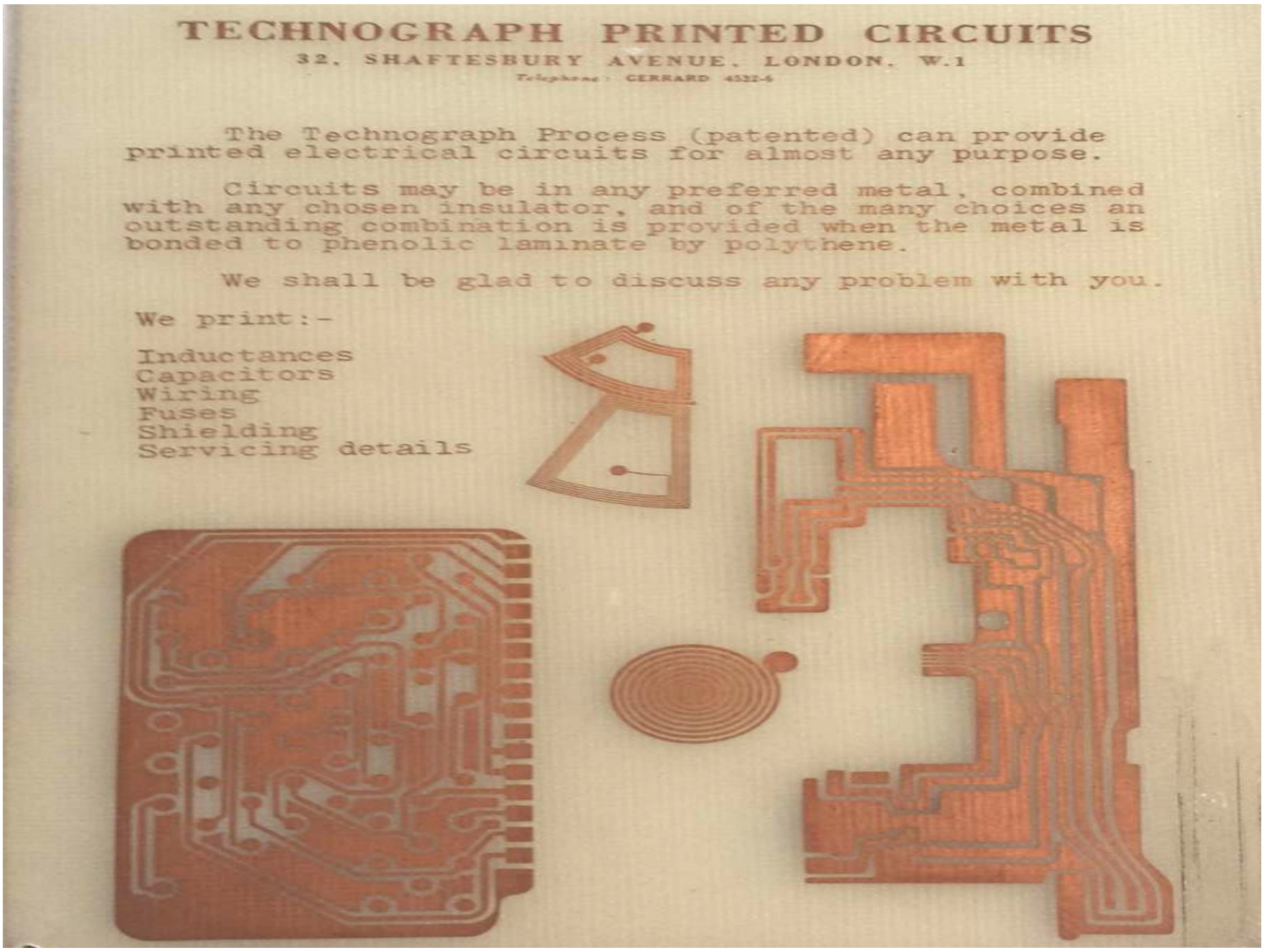
The British invention of Printed Circuits appears to render such aims feasible and practicable.

Illustration of an idea to give 'feel' to artificial fingers.

The strain gauges in the fingers signal pressure sensations to the live nerve ends by means of the electrical network on the arms.

This diagram and explanatory note are printed by the same process which may, before long, produce the electrical network and elements in an artificial limb.

Proposal for prosthetic applications of Printed Foil Circuits, in the format of Printed Foil on Bakelite



TECHNOGRAPH PRINTED CIRCUITS

32, SHAFTESBURY AVENUE, LONDON, W.1

Telephone: GERRARD 4532-6

The Technograph Process (patented) can provide printed electrical circuits for almost any purpose.

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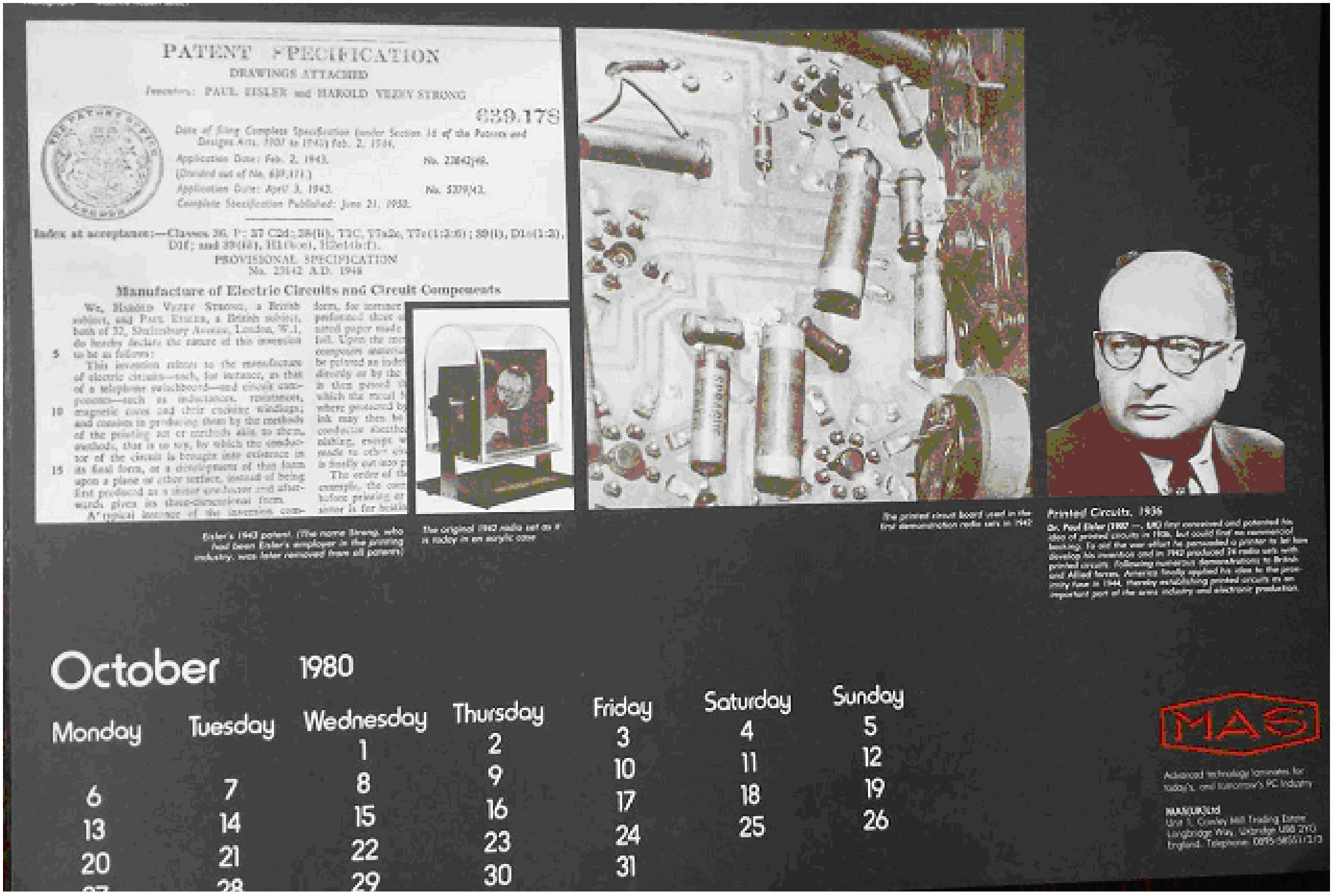
We shall be glad to discuss any problem with you.

We print:-

Inductances
Capacitors
Wiring
Fuses
Shielding
Servicing details

Promotional card of *Technograph Printed Circuits* (at 32, Shaftsbury Ave., London W1) made by the Printed Foil Technique.



PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventors: PAUL EISLER and HAROLD VEZEY STRONG

639.178

Index at acceptance:—

PROVISIONAL SPECIFICATION

Manufacture of Electric Circuits and Circuit Components

Eisler's 1943 patent. (The name Strong, who had been Eisler's employer in the printing industry, was later removed from all patents)

The original 1942 radio set as it is today in an acrylic case

The printed circuit board used in the first demonstration radio sets in 1942

Printed Circuits, 1936

Dr. Paul Eisler (1907 —, UK) first conceived and patented his idea of printed circuits in 1936, but could find no commercial backing. To aid the war effort he persuaded a printer to let him develop his invention and in 1942 produced 24 radio sets with printed circuits. Following numerous demonstrations to British and Allied forces, America finally applied his idea to the proximity fuse in 1944, thereby establishing printed circuits as an important part of the arms industry and electronic production.

October 1980

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
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6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

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Paul Eisler with a copy of his 1943 patent and radio of 1942 with its Printed Circuits on a calendar of 1980, entitled *Spark of Genius*

Surface heating for foot warming

L'ACCADEMIA TIBERINA

ISTITUTO DI CULTURA UNIVERSITARIA E DI STUDI SUPERIORI

CHE HA PER SCOPO L'ESALTAZIONE E L'INCREMENTO DELLE ARTI, DELLE LETTERE E DELLE SCIENZE.

RICONOSCENDO I MERITI DEL SIGNOR

Dott. Paul Eisler - Ingegnere

HA DECRETATO DI ANNOVERARLO TRA I SUOI MEMBRI IN QUALITA' DI

Accademico Corrispondente

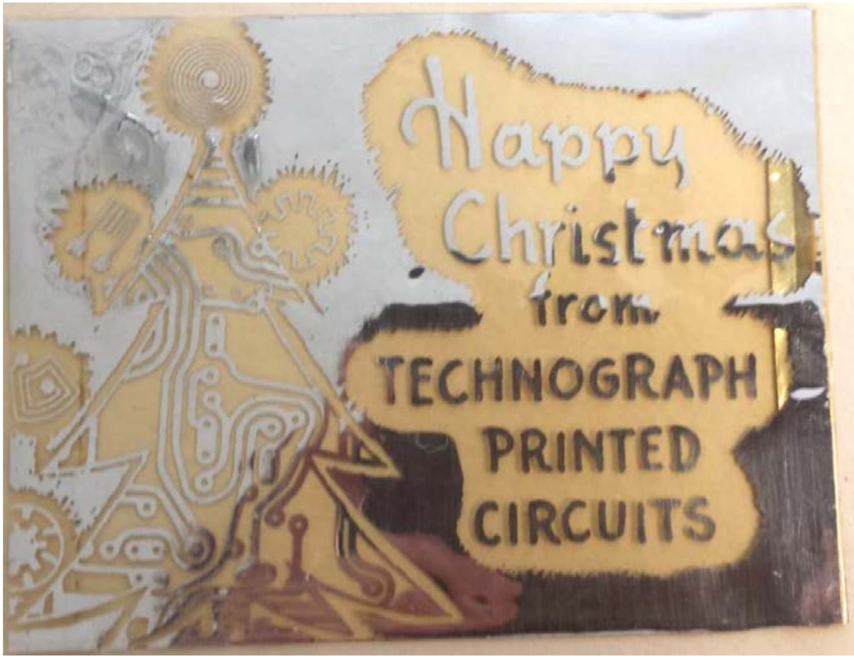
DATO IN ROMA 25 Ottobre 1966 , ANNO 154° DALLA FONDAZIONE DELL'ACCADEMIA, ANNO DI ROMA MMDCCXX

IL PRESIDE DEL COLLEGIO DEI CENSORI

IL PRESIDENTE GENERALE

REG. N. 5541 S.N.

Certificate of Corresponding Membership of the Accademia Tiberina awarded to Paul Eisler



Christmas card of *Technograph Printed Circuits*
made by the Printed Foil technique on clear paper

The illustrations on the preceding pages show in a limited way how during Paul Eisler's career he was able to conceive, develop and in some cases produce a vast number of what our now every day articles, outstanding of course being our own precious Printed Circuit.

Maurice Hubert a Council Member of the Institute writes :-

" I was very proud to be asked by the Science Museum and The Anglo Austrian Society along with Dr Eisler's executors to the unveiling of this Blue Plaque. It has taken them a long while to get this sorted and I even have a copy of a letter from an American Journalist that at least acknowledges that Dr Eisler was the father of our industry ... including this statement....." ***Dr Paul Eisler is perhaps the worlds most unsung inventor of the 20th Century"***

Dr Eisler's original radio is now on display in the Science Museum in London as a commemoration of the development of the printed circuit."

photo by maurice hubert

Blue Plaque marking the residence of Paul Eisler
in north London for nearly 40 years.

Implementing new surface pre-treatment processes in the PCB industry through the application of acoustic agitation

by Thomas Jones


Thomas Jones

1. Introduction

Printed circuit boards are ubiquitous in our modern lives, from the PC we use to our phones and mobile devices, even in the cars that we drive. From the United States, wider applications include smart cookers to pre-cook our dinners when we get home from work, and programmable home heating and sound systems. To develop a new manufacturing technique for Printed Circuit Boards (PCBs) or modify an existing method is, to say the least, exceptionally difficult, due to the complexity of the different processes and their interlacing with one another. Any change made on one stage of the process will drastically impact on others further down the manufacturing line, so that negative artefacts can form on the PCB, reducing its quality and effectively turning it into scrap.

To change a manufacturing process first requires a Design of Experiments (DoE) investigation, which implements changes to its operational conditions, followed by an analysis and comparison of the output made by PCBs following this change. The true benefits gained from modifications can only be evaluated after determining the impact on the quality and production yield of the resulting PCBs.

This article briefly outlines some key parameters that have to be considered when making a change to a working procedure in the hope of improving it, in the area of wet-chemical surface treatment. The article also highlights an innovative and ground-breaking manufacturing aid, in the form of acoustic agitation into wet chemical procedures.

2. Pre-treatment wet-etches

The morphological topography of a substrate is an extremely important property, which has to be controlled, if a conductive material is to be adhered to a PCB, be it by an electrochemical process or by direct deposition. To achieve the desired topographical properties, a chemical etch pre-treatment is applied to a circuit board. The etchant may typically be a wet solution or a dry plasma gas. A wet etch is more common than the plasma counterpart in PCB fabrication due its lower maintenance and equipment costs although, plasma is typically still employed for fabrication involving point contact, positive etchback. The etch chemistry used is chosen so as to match the PCB material's chemical response and the desired outcome of the procedure. To selectively manipulate topography, the following process parameters are considered; etch duration, chemical activity of the etch, as determined by chemical concentration and species; and, if additional actions are applied to the etch-process to improve its efficiency, panel movement or air bubble agitation.

When introducing a PCB into a wet chemical etch, the surface of the board undergoes a characteristic change where the molecular bonds are broken down. The change induced causes either a large or small removal of the top surface material, which is controlled by the previously mentioned process parameters. The amount of material removed is predetermined before processing and is chosen to fit the desired outcome of the process it is involved in. The structural properties of the material must be known before etching; this includes its chemical response to the etch chemistry. Once known, a working procedure can be developed to either remove the set thickness of material or pattern its surface.

The chemical concentration and/or process duration can be increased to enhance the chemical aggressiveness of a pre-treatment process. These solutions are not the most cost effective, as increasing the concentration increases the amount of chemicals required and increasing the process time hastens the depletion of the bath chemistry, which will also increase in the long term the amount of chemicals required. An alternative to these options is to add an external device to the wet-etch solution. This is currently employed in PCB fabrication in the form of bubble agitation and panel movement. These both act to improve the access of the solution onto the board surface and improve on the uniformity of the etch process across a surface. Both actions are important when sub-micron accuracy is desired for the removal of material.

3. Investigating improvements to PCB manufacturing procedures

To improve on the manufacturing capability in the PCB industry major changes to manufacturing procedures would be required. The changes could take the form of modifying the settings of a pre-existing procedure, or implementing a new device into an existing process to enhance its efficiency.

An example of a new device aiding an existing process is the addition of an acoustic transducer into a wet-etch chemical process. In silicon wafer manufacture, a 'sister' industry to PCB fabrication, acoustic energy has been introduced over the last 17 years as an assist to wet chemical cleaning processes [**1**.]. Some of its other various applications include the removal of photoactivated dry-film resists, which are employed in track definition on wafer surfaces [**2**.], and enhancing plating reactions on a surface [**3**].

Recently, studies have been performed which investigate the implementation of acoustic-agitation in similar, equivalent processes, in the Printed Circuit Board (PCB) industry, so as to harness its potential benefits. Some of the work to date includes; the application of ultrasound-assisted (~40 kHz) agitation to assist in a desmear process, which ensures the removal of unwanted drilling debris and micro-roughening [**4**.] ; the development of dry-film resists using megasonic (~1 MHz) agitation; and the enhancement of copper electroplating reactions in high finesse features [**5**.]. Before these processes can be discussed, the rationale behind the beneficial impact of acoustic assisted agitation will be mentioned.

4. Acoustic Enhancement

When acoustic agitation is incident upon a PCB surface in a bath, the pressure variation caused by the travelling wave causes the localised growth and implosion of gas bubbles in solution. The implosion of the gas bubbles results in a micro-jetting effect which increases the pressure drastically, leading to thermal increases comparable to the surface of the sun ~5000^0 C [6.]. The formation of bubbles, bubble collapse and the energy released, collectively describe the effect of cavitation. Indicated in fig 3 A & B, (*on next page*) are pictures of cavitation where the high pressure micro-jetting is indicated on the inside of the bubble.

When acoustic agitation is sonicated upon a surface, cavitation is the most significant factor influencing the surface topography due to the extremely large thermal increases. Harnessing this effect would be useful in fabrication especially for surface pre-treatment procedures and for dry-film removal.

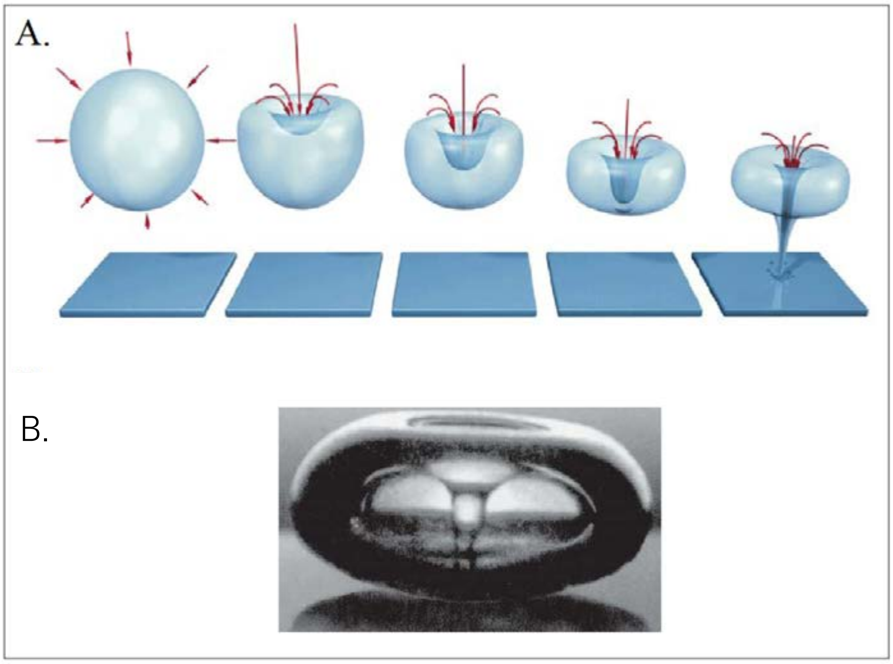


Fig.3 - 'A' shows the steps prior to and including bubble collapse, indicating the jet streaming effect. 'B' shows the implosion of an air bubble under 25 kHz ultrasonic agitation, where the internal jet stream is shown [**6.7.**]

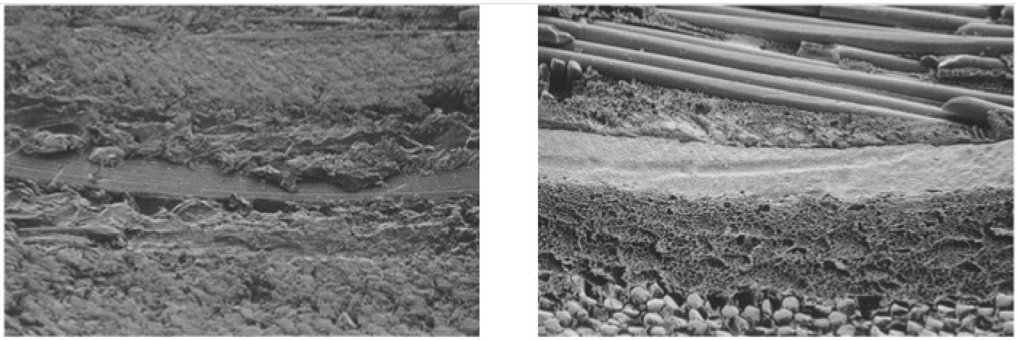
Acoustic assisted agitation additionally causes acoustic streaming. Acoustic streaming is fluid motion induced by the travelling acoustic wave. When directed at a PCB, it locally increases the pressure in the vicinity of the bath solution / PCB interface. At the interface of the PCB/solution, a diffusion layer exists over which Cu cations are transported. For increases in acoustic power and frequency, the diffusion layer width reduces in size. This increases the limited current density at which current can pass, which in turn enables a larger, more efficient plating reaction. [**8.**]

Finally, acoustic streaming also provides forced convection. This forced convection may replenish the access of depleted cations onto the PCB surface. This is important as, without efficient replenishment, the plating reaction slows down, regardless of the size of the diffusion layer, or the magnitude of the current density. Harnessing the two effects could enable increased efficiency in plating, especially in high finesse features such as micro-vias [**9**.]. Outlined next is some of the recent research performed on the different potentially beneficial applications of the acoustic technologies.

5. Ultrasonic-assisted wet-chemical Desmear

Using acoustic cavitation energy, researchers at Coventry University, Heriot-Watt University and Merlin Circuit Technology, have investigated the implementation of ultrasonic energy into a pre-treatment process. The pre-treatment process concerned is applied to remove smeared laminate resin form the inside of Through-Hole Via (THV) interconnects on a PCB. THVs are electrically conductive cylindrical tubes, which connect one side of a PCB to the opposite one as well as to the inner layers. The removal of resin smear is to ensure that the subsequent conductive palladium deposition process can occur successfully and that good deposited metal adhesion is achieved.

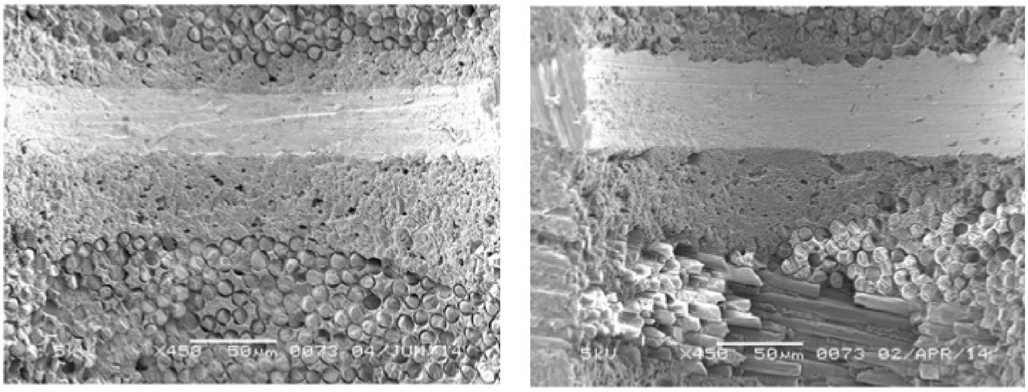
A THV is fabricated generally by the mechanical drilling of a PCB. In the drilling procedure, heat is generated which can extend beyond the Tg of a resin. For this reason, when the drill retracts it may pull out resin particles, smearing them across the inner wall of the THV where they cool and set. This material is undesired in the deposition of the the subsequent palladium seed layer and will impact on the further electrodeposition processes. To remove the resin – to desmear - the PCB is processed in a wet immersion bath. As indicated in fig 4, before the desmear the surface is coated in unwanted particulates and after the desmear, the particulates are removed leaving behind a clean, patterned surface for palladium adhesion.



Before After

Fig. 4 - High resolution images of the surface of a THV. Indicated in the middle is a copper layer and surrounding is an epoxy resin impregnated with a fibrous glass weave. The two images indicate the condition of the resin-smeared surface before and after the desmear process.

Using a bath modified with ultrasound transducer plates on either walls of the container, a high frequency (40 kHz) acoustic wave was incident upon a phenolic-cured FR4, PCB in a permanganate desmear solution. Some results from the trials indicated in fig 5 provide a comparison of the surfaces processed under standard and acoustic-assisted conditions. The two results both produce a surface free of resin smear and successfully micro-roughened for palladium adhesion. From a simple observation the two results show an indiscernible difference between them. The results were obtained from a reduced processing temperature and concentration applied in the synthesis of each although, it was uncertain whether this improvement was due to the acoustic effect or whether it was a consequence of the bath chemical makeup.



Standard Desmear Ultrasound-assisted Desmear

Fig. 5 - Scanning Electron Microscope images of the inner surface wall of the THVs desmear process with and without acoustic-agitation (Images obtained at Coventry University).

From the trials, the results showed that, with acoustic agitation, the bath performed equally well in comparison with standard processing. The most likely cause behind the lack of variation could have been due to the setup of the PCB in the ultrasonic tank. If a PCB is placed in the tank at a distance further than the natural focus of the ultrasound wave (3-7 cm), then the pressure induced on the PCB will be weak. The PCB was setup in the ultrasound tank at a distance of 8 cm from the acoustic transducer faces and so attenuation may have been detrimentally reducing the influence of the ultrasonic wave.

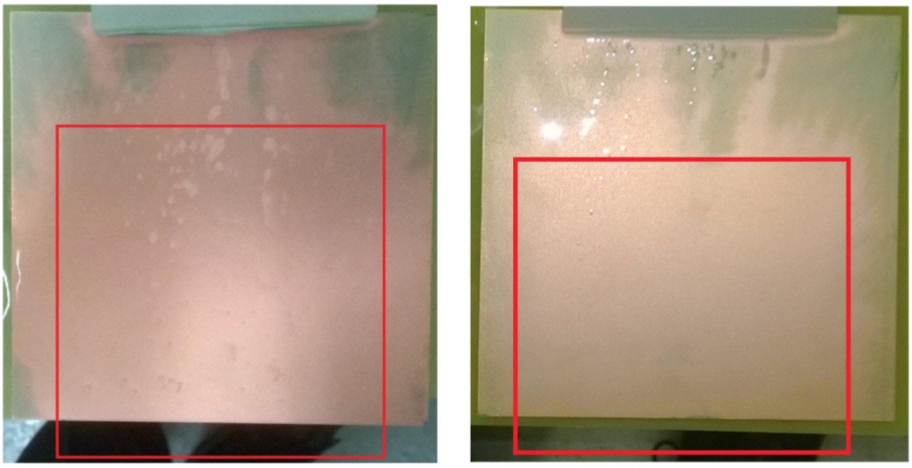
From this point onwards, to completely evaluate the performance of acoustic-assistance, further trials are required to assess the performance of changes to the PCB placement and different PCB laminates such as polyimide, which display more resistance to chemical processing. This would be of use to fully take advantage of the potential benefits offered by the acoustic technology as seen in silicon wafer processing [**5**.].

6. Megasonic-assisted dry-film development

Photo-activated dry-film resists are an important manufacturing material, which are both applied to and removed from PCBs during fabrication. Resists are employed to define where the copper tracks are formed on the different layers of the PCB. Different dry-film resists are employed due to the different plating finishes and the variable fabrication techniques employed for inner-layer and outer-layer PCB fabrication. An example of a standard used in outer-layer manufacture is the Ordyl 950NDI, although some resists are required to be more durable, specifically the Ordyl 350 Alpha, which has to survive aggressive hydrogen bubble generation in the gold plating process. Due to its chemical resistance, it is more difficult to remove efficiently from the PCB, leaving it to remain behind on the PCB and so longer developing durations (dwell) are required for 100% removal.

Highlighted in fig 6 are results indicating the removal of two different dry-films, the Ordyl 950NDI and 350 Alpha, using megasonic (1 MHz) acoustic agitation. The red square is the area directly sonicated by the transducer. Within this area the dry-film was efficiently removed for both resists and for the same dwell time durations. This is an important result as the 350 Alpha typically requires 2.5× longer dwell times than the 950NDI. The results highlight that the megasonic-agitation provides resist removal independent of the type applied.

Further investigations shall be made into this effect to determine the exact mechanism behind the resist removal and to determine its performance on track-feature definition.


Ordyl 950NDI
(standard outer resist)

Ordyl 350Alpha
(difficult to remove resist)

Fig.6 - Photographs of PCB surfaces with dry-film developed away. The red squares highlight the area sonicated and the remaining dry-film can be observed outside of the active area. Shown on the left is the dry-film Ordyl 950 NDI , and on the right is a more difficult to remove dry-film, Ordyl 350 Alpha.

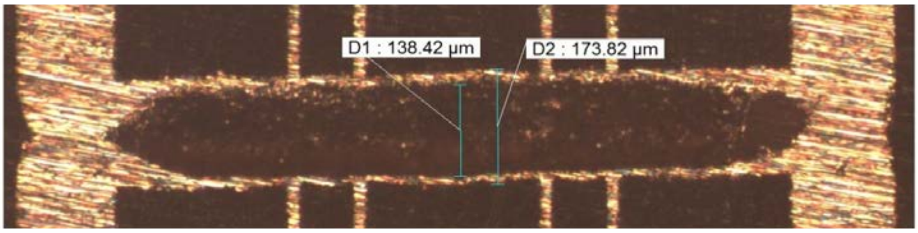
7. Megasonic-assisted copper electroplating

To improve the component density on a PCB, reductions in the copper interconnection size and an increase in aspect ratios is desired. To effectively fill THV interconnects with copper would be desirable for the structural stability in the PCB, where it could assist in the reduction of copper cracking during thermal expansion and, also, for its heat dissipation properties, which are an ever growing issue in PCB design.

Highlighted in Fig 7 are results indicating the plating behaviour obtained for a 1 mm thick PCB, electroplated with 0.17 mm diameter THVs and with megasonic (1 MHz) assistance. The results show that, without acoustic agitation, a small amount of copper is deposited down the THV. This is due to the poor circulation of electrolyte solution failing to replenish the recently depleted copper cations, lowering the plating rate. With the acoustic agitation, significantly more copper is deposited down the via, which is attributed to the forced convection as caused by the megasonic acoustic streaming[10.].

The results do not show the desired 100% filling which has been highlighted by previous research [9.], although megasonic-enhanced plating is highlighted. The largest issue preventing conformal filling appears to be the pinching occurring at the neck of the THV. This pinching has been dealt with in other THV filling techniques through the introduction of chemical etches and reverse-pulse copper stripping, during the plating cycle [11.]
. In future, further investigations shall be performed investigating the implementation of such techniques, so as to potentially reduce the unwanted via pinching and possibly attain higher % of THV filling.

Without megasonic - assistance when plating



With megasonic - assistance when plating

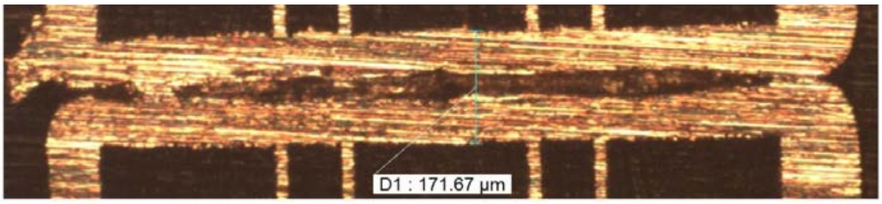


Fig. 7 - Microsections of 0.17 mm diameter through-hole vias plated in an attempt to copper fill, for with and without megasonic assisted agitation.

8. Overall Conclusions

This article presented three different applications of acoustic technology being introduced into PCB fabrication. The first highlighted the use of ultrasound (40 kHz) into a surface desmear process. The results highlighted a fabrication quality similar to standard fabrication. The most likely cause behind this was possibly due to the large distance apart of the PCB / transducer surface causing attenuation of the acoustic wave. This result highlights that further investigations would be required making sure that the PCBs are directly in the path of the ultrasonic wave and that they are being agitated. This could be evaluated through the use of an aluminium foil test [12.] .

Two different applications were provided introducing megasound (1 MHz) into dry-film development processes and copper electroplating. Megasonic agitation is more directional than ultrasound and so the agitation can be focused with greater ease. As a result, increases to manufacturing efficiencies were observed in the form of a reduction in dry-film process variability and an increase of copper replenishment within a THV. The research performed on both processes is still within the early implementation stage, and a significant amount work is required before evaluating its end application.

It must be noted that making a change in the PCB industry requires an extensive and detailed knowledge of the processes, which are going to be changed. It also requires a precise and effective comparative design of experiments, which investigates the quality and yield variation on a PCB in response to the specific changes made. Without detailed prescriptive studies like those performed, what is certain is that the future effective development and growth of the PCB industry simply will not occur and the potential cost saving and benefits on processes will never be realised.

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Acknowledgements

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Biography

Thomas Jones received an MSc in Nanoelectronics from the University of Sheffield in 2012, and a BSc in Nanoscience from Heriot-Watt University in 2011. He is currently a doctorate student studying on an Engineering Doctorate Programme, under the supervision of Prof. Marc Desmulliez, in a joint collaboration between Heriot-Watt University and Merlin Circuit Technology, Ltd. As a complement to his duties on the full time degree, he also helps manage other active research and development projects at Merlin. His recent research interests are in nano-photonics; electrochemistry; acoustics; and high-tech Printed Circuit Board fabrication. He has recently won the award for best young person’s article from the Institute of Circuit Technology.

Review of papers presented at the
Institute of Circuit Technology
Darlington Seminar, November 18th 2014

by Pete Starkey

A long drive up to the North East of England on November 18th for the Institute of Circuit Technology annual Darlington Seminar, held on the site of the former World War II Royal Air Force Bomber Command Station, Middleton St. George, now Durham Tees Valley Airport

ICT Technical Director **Bill Wilkie** introduced and moderated a diverse and thought-provoking programme, acknowledging the generous support of **Faraday Circuits**.

Megasonic agitation

Tom Jones

First to speak was **Tom Jones** from Merlin Circuit Technology, winner of the ICT “Best Young Person’s Technical Paper” award, with an extremely professional presentation on acoustic-assisted manufacturing techniques in the PCB industry.

Megasonic agitation, an acoustic technique working at much higher frequencies than ultrasonic agitation with less-damaging cavitation effects, had been successfully employed to enhance the filling of high-aspect-ratio blind micro-vias with electrodeposited copper. Jones described current work on the effects of megasonic agitation on the filling of high-aspect-ratio through vias.

Some anomalies in copper thickness had been observed, with thin areas at certain positions along the length of the hole, and it was suspected that these were consequences of overtones and harmonics causing an acoustic standing wave within the hole. Hydrophone measurements of acoustic pressure corroborated the observed behaviour, positions of maximum pressure appearing to correlate with regions of reduced copper thickness. Modelling and simulation techniques were being used to investigate the impact on wave formation in response to changes to via size, acoustic impedance of PCB material and transducer position.

Current-thieving by the transducer had caused variations in copper distribution on the PCB surface, including low current frosting and high current burning. The effects had been minimised by modifying the cell geometry, particularly moving the megasonic transducer further away from PCB, although this was a trade-off against the efficiency of agitation. In other process areas, indirect acoustic agitation with megasonics had been demonstrated to have the potential to improve pattern definition in developing and etching.

Multilayer layup of thin copper foils

Tom Brown

If only making circuits was easier! **Tom Brown**, Technical Manager of Holders Technology, whimsically suggested that every PCB manufacturer aspired to an easier life – all he really wanted were higher manufacturing yield, lower cost of production and better product quality. But where to find them within the mix of materials, equipment, chemical processes, mechanical processes and people? Some solutions were high-tech, some were highly automated, but not all depended on a high level of investment and need not be complex – indeed in certain cases a solution could lie in making things simpler.

Brown took the multilayer layup process as his example to review and considered issues associated with the use of thin copper foils, speculating upon the possibilities of making thin copper foils easier to handle and less vulnerable to damage, and protecting them against particulate contamination. Was this too much to expect? In Brown’s view it was not a dream but a practical reality and the answer was to laminate the copper foil with a proprietary protective film at the roll stage, prior to panelising. The protective film supported and protected copper during foil handling and throughout the lamination process, and was simply peeled off at the breakdown stage.

Benefits included the elimination of epoxy spots and a reduction in pits and dents due to airborne particulates or damaged separator plates. In his experience this protective film significantly improved handling of thinnest copper foils, speeded-up the lay-up process, allowed user the choice of steel or aluminium separator plates and was suitable for automated handling systems.

As a potential further economy, traditionally-generous oversizes on foil could be reduced.

Conductive Fabrics to Enable Wearable Electronics

Dr Andrew Cobley

Dr Andrew Cobley, Director of the Functional Materials Research Group at Coventry University gave a presentation entitled "Conductive Fabrics to Enable Wearable Electronics" describing a new Knowledge Transfer Partnership project, in which Coventry University were collaborating with the National Physical Laboratory.

There was an increasing demand for wearable technology from industry sectors such as medical and healthcare, sport and fitness, consumer electronics and defence. The world market for wearable e-textiles was projected to grow from approximately $300 million to $1.5 billion by 2020, and healthcare would remain the dominant sector.

Various methods were available to introduce electrical conductivity into a fabric: woven metal threads, metal-coated fibres, carbon fibres, printed or deposited conductive polymers and inks, or plasma deposition of metal. Disadvantages of current methods were the poor conductivity of non-metallic fibres, the limited bendability and stretchability of metallic fibres and difficulties in achieving selective conductivity.

Washability of conductive fabrics was an essential requirement. The approach being taken in this KTN project was to fully encapsulate fibres within the fabric with a coating of nano-silver particles, formed in-situ on a chemically functionalised textile material. This resulted in 100% encapsulation of fibres in a 20 nanometre silver coating with excellent adhesion, flexibility and wash-resistance, although conductivity was limited but could be improved by electroless copper plating and applying immersion silver as a final finish. The process had been successfully demonstrated on a wide range of natural and synthetic textiles. The principles established presented opportunities for selective functionalisation by ink-jet or screen printing, such that useable electrical circuits could be created within the fabric.

Design for a 36 layer backplane

Martin Cotton

Martin Cotton, Ventec's Director of OEM Technology, can always be relied upon to deliver a dynamic and inspirational presentation. His down-to-earth discussion of practical design considerations for high speed PCBs was dedicated to the memory of the late Fred George Pochodnia, who had been a great motivator in the early days of his design career.

With the emphasis on "practical", Cotton set out to build the basis of a design for a 36 layer backplane example, working at 10 Gigabits per Second data rate and 100 ohm impedance.

Initial questions to be answered were whether the data rate was for a single-channel differential pair or for a buss, buss speed being the total of all the channels in that buss. 100 ohm differential impedance used two tracks in harmony to keep losses to a minimum, and the geometry of those tracks and their positioning within the PCB build structure were critical to the realisation of a successful design, and the ability to manufacture it at a good yield. Setting-up the differential pairs in X, Y & Z axes began with material selection and consideration of dielectric constant and loss factor, then the creation of “cells” to define trace geometry, trace separation, pair separation, layer to layer separation, taking material properties into account – particularly dielectric constant – before carrying out impedance modelling. The completed “cell” was the essential foundation of the design. Once it was established, the designer could proceed to initial stack-up and trace mapping, and sample simulations on maximum trace lengths. Knowing the material and the build enabled cost estimates to be made. Only then would the actual layout proceed, with periodic checking simulations to ensure acceptable signal integrity.

In Cotton’s example, 36 layers were required to realise the design, but post-layout simulation revealed signal integrity issues with 90 differential pairs of the 2000 contained in the layout. The designer was then faced with a dilemma: to fix these by reviewing them individually, which would take time, or to move them from within the 36 layers and add four additional layers, plus two power planes for reference, making a total of 42, which would increase unit cost and could complicate the mechanical design. Another option might be upgrade to a more expensive material with better Dk and Df values, although Cotton stressed that in principle the material supplier should always be consulted in the first instance, rather than too late in the design process.

“Design once, make many times” was his message, “take the time to create what you set out to do”, adding that although CAD and simulation systems were very powerful tools the actual designing was done “up here” – pointing at his head!

A long drive for some, but well worth the journey – the Darlington Seminar was another very successful event in the ICT calendar, combining technical enlightenment with a great networking opportunity for the many members who attended.

Pete Starkey,
I-Connect007,
November 2014

A new project to develop novel PCB effluent treatment processes using materials from crab shells.

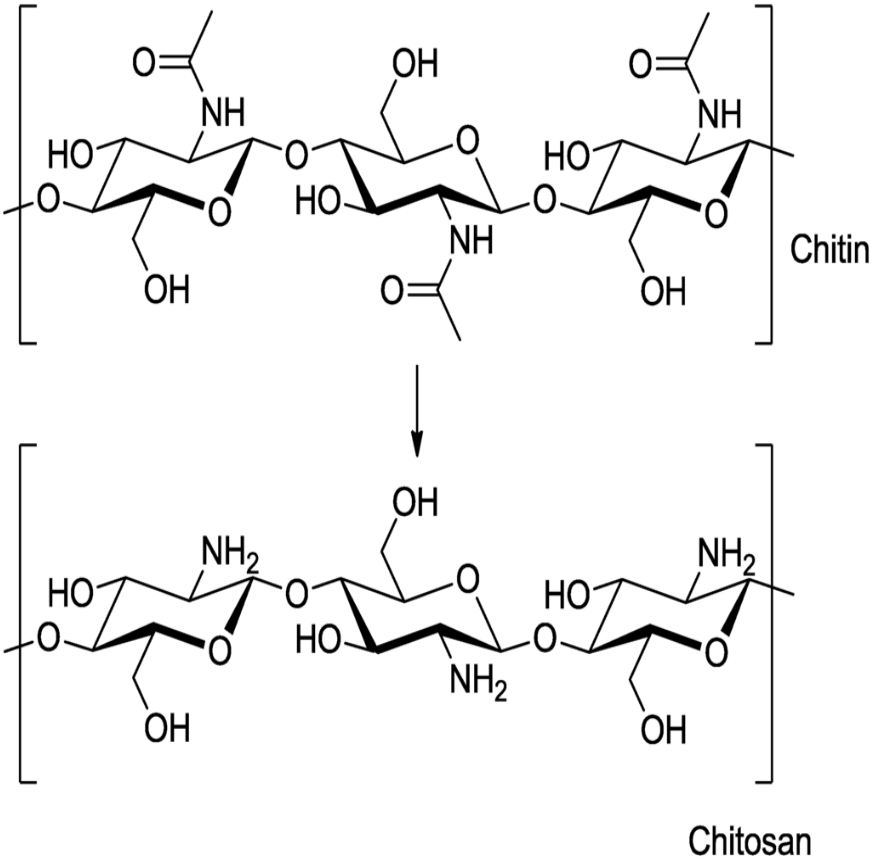
***Month 12 Update* - see also Vol.7No.1p13 & Vol.7No.3 p5&6**

Prof. Martin Goosey

Sustainable Treatment of Waste Using Recycled Chitosans (STOWURC)

Over the last twelve months the ICT has been participating, as a dissemination partner, in a two year collaborative research and development project that is investigating the use of materials derived from crab shells for treating the metal bearing effluent produced by the PCB and related industries. The project is now at the mid-point and there has been a large amount of novel and very interesting work undertaken during the first year. This short article provides an update on the project progress and also outlines the approach and work-plan that is proposed for the next twelve months.

Crab shells, and the shells of other crustaceans, contain the material chitin, which has long been known to have the ability to absorb a range of both metals and other materials. Chitin can also be converted into chitosan, which is even better at absorbing metals and the project is investigating the use of both of these materials for treating copper-bearing effluent, and related solutions, from the PCB industry,. The structure of chitin is shown below and it can be converted to chitosan, also shown below, via a deacetylation process.



During the first twelve months of the project, the focus has been on the conversion of crab shells into a useful form and the preparation of the crab-derived biosorbent materials. Ideally, it would simply be possible to use crab shells, or at least crab shells ground to an optimum particle size, in effluent treatment applications. However, crab shells are not just made of chitin, they also contain substantial amounts of other materials including various organic components and, perhaps most importantly, calcium carbonate. These can all have an impact on the performance of the crab shells when treating metal-bearing effluent. For example, the calcium carbonate will dissolve in acidic media with the generation of carbon dioxide. Depending on the particle size and other factors, this can be the cause of excessive foaming during the treatment process. Also, if sulphuric acid is used, there will be formation of insoluble calcium sulphate, which is again undesirable.

A key challenge in using crab shell derived material is the cost of producing it. Initially, the figures are positive as the disposal of crab shells is increasingly regulated and expensive. However, every subsequent treatment step to improve performance incurs additional costs. Even when just using untreated crab shells, there is likely to be the need to subject them to a comminution stage to increase the surface area in order to optimise the performance. Beyond this, subsequent processing can involve deproteination, deacetylation and demineralisation stages. Chitosan offers superior performance compared to chitin, but its production from crab shells also requires several costly treatment stages. A key action for the remainder of the project will therefore be to develop a better understanding of the performance versus cost relationships and to identify a range of applications where each of the specific materials produced can be aligned with their production costs.

Over the last few months, the STOWURC team has focussed its work on material optimisation for metal recovery. Completion of validation trials by C-Tech and Chestech has led to the development of defined pre-treatment procedures, and an assessment has been made of the various deacetylation procedures that can be used. C-Tech and Chestech have also been working to compare the crab shell derived biosorbent performance to that of commercially available ion exchange resins currently used by the PCB industry. Comparative performance results have been positive for the crab-derived biosorbent and have indicated a pathway towards a pilot design and subsequent application to meet industry needs, whilst utilizing a cheaper, environmentally benign material, and adding value to a waste material.

As most of the initial work was performed at the beaker scale, another recent activity has been to scale up the processing to a small pilot plant unit that is compatible with larger trials using real PCB effluent produced at Invotec in Tamworth. This unit has the capacity to hold 1 litre of the crab-shell derived biosorbent and a 30 litre effluent supply tank that typically represents the equivalent of about one day's throughput in a conventional ion exchange column. At this scale, it is possible to carry out large numbers of different absorption experiments without the need for large quantities of waste crab shells. (fig. 1)

fig. 1 **The small prototype pilot unit installed at Invotec,**

Although the initial aim of the project was to use crab-shell derived bioabsorbents for absorbing and recovering metals such as copper from effluent in a similar manner to ion-exchange resins, the results to date have indicated a potential wider applicability and the opportunity to develop specifically tailored treatment solutions for specific waste streams. This will be explored further in the second and final year of the project. The key determining factors will not just be about the actual performance of the specific material selected for the application but also the cost of producing it. These are important issues that will be evaluated via a more detailed cost benefit analysis in the coming months.

In summary, the STOWURC project has clearly demonstrated the ability of crab shells and crab shell derived materials to treat the type of effluent produced by the PCB and related industries. A key objective aim for the second part of the project is to match specific types of crab shell derived materials to individual effluent streams to provide individual cost effective tailored solutions.

Additional updates will be provided as the project progresses and further information about the project can be found at the STOWURC website, www.stowurc.co.uk, where there are various newsletters detailing progress on the project.

Martin Goosey
December 2014

Views of parts of the small prototype pilot unit installed at Invotec

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The Membership Secretary's notes - January 2015

We generally hold three to four evening seminars each year plus an annual symposium and an Annual Foundation Course, held each year at Loughborough University. The first evening seminar in 2015 will include our cheese and wine inspired AGM and is being held at the Chimney House hotel at Sandbach on the 3rd March and will be sponsored by Lamar Group UK. We held the same event here last year with four excellent papers and a buffet comprising the local delicacy of chips and bacon Barm Cakes – delicious!

The 2015 Annual Foundation Course is being held between the 13th and 16th April at Loughborough University and looks like being well subscribed already, with 12 pre-bookings. This course has been running in the same format since 1980, when it was established by the Northern UK Circuit Group in Galashiels and does an excellent job in training future engineers and managers for our PCB Industry

We held our 2014 annual symposium at the GWR Museum in Swindon and had seven interesting papers and an opportunity to visit a fascinating exhibition of past steam locomotives and this year we have booked the Black Country Living Museum at Dudley. We hope to have a day of good technical papers and will be able to look over the museum, including a 19th century street and a working brass foundry. Instead of the usual finger buffet for lunch, delegates will be able to sample fish and chips from a good old-fashioned chip shop – can't wait!

I would also like to take this opportunity to thank all those who have sponsored us for this year's events, the speakers, who gave their time freely to support us and all the delegates who attended.

Institute of Circuit Technology

ICT Northern Seminar and AGM

The ICT 2015 Northern Seminar and AGM will be held at the Chimney House Hotel, Sandbach

Event Info

Tuesday
March 3rd 2015
AGM begins at 16.30
Registration at 17.00
Seminar begins at 17.30
Chimney House Hotel, Sandbach

Full Agenda to Follow on our Web Site www.instct.org

Or from bill.wilkie@InstCT.org