Journal of the Institute of Circuit Technology

Vol.9 No.3 Summer 2016

Contents	

2016 Events

1st March	ICT Evening Seminar and AGM At the Hilton Puckrup Hall Hotel, Tewkesbury
11th - 14th April	ICT Annual Foundation Course At Loughborough University
1st June	ICT Annual Symposium At the National Motor Cycle Museum
20th September	ICT Autumn Evening Seminar At the Newtown House Hotel at Hayling Island
1st December	ICT Winter Evening Seminar At the Majestic Hotel, Harrogate

Editorial

Bruce Routledge, who founded and has edited this journal for the last nine years, is unwell and has been unable to complete this winter edition.

In the 21st century, we spend more time deleting history than making it, but the council are united in their determination to continue with our quarterly journal and although this edition is somewhat curtailed, we hope the next edition will continue to provide the technical content supplied by our Journal Editor.

Dissemination of information has always been a key principal of the Institute and the council are committed to maintaining this important tradition.

Council Members

Council Members 2016 : Andy Cobley (Chairman), Steve Payne (Deputy Chairman), Chris Wall (Treasurer), William Wilkie (Membership Secretary & Events), Bruce Routledge (the Journal) Richard Wood-Roe (Web Site),Martin Goosey, Lynn Houghton, Maurice Hubert, Lawson Lightfoot, Peter Starkey, Francesca Stern, Bob Willis.

Foundation Course

Our **Annual Foundation Course** has been running in much the same trusted format since 1980 and at Loughborough University since 2005. Next year, however we will be making major changes to the event and starting afresh at Chester University.

The format will be the same as previous years, with the same lecturers and we will be continuing the get-together-dinner on the Monday evening at a private dining room on the University Campus.

The first day will be spent at Merlin Circuits, Deeside, where we will be able to make use of the company's Training Room. Merlin will also be organising a Facility Tour and we would like to take this opportunity to thank Merlin and Neil Martin for supporting the Institute at our Annual Foundation Course

Membership: New members notified by the Membership Secretary

No.	NAME		COMPANY	GRADING
10378	Jon	Morgado	HSSMI	Associate
10379	Lloyd	Graham	HMGCC	Associate
10380	Simon	Ogden	Exception pcb Solutions	Associate
10381	Diana	Meneses	Exception pcb Solutions	Associate
10382	Paul	Rowsell	Eurotech Group	Associate
10383	Matt	Snushall	Eurotech Group	Associate
10384	Dell	May	Eurotech Group	Associate
10385	Colin	Ford	Sun Chemicals	Associate
10386	Jordan	Reilly	Zot Engineering	Associate
10387	Keiran	Yule	Zot Engineering	Associate
10389	Grant	Shiells	Zot Engineering	Associate
10390	Steven	Clark	Zot Engineering	Associate
10391	Robert	Dawe	Schloetter	Associate
10392	Josh	Lucas	Merlin Circuit Technology	Associate
10393	Ben	Lennox	Merlin Circuit Technology	Associate
10394	Matthew	King	CCI Eurolam	Associate
10395	Adrian	Croft	CCE Europe	Associate
10396	Megan	Connolly	CCE Europe	Associate
10397	Edward	Wright	Delta Impact	Associate
10398	Mark	Vernon	Amphenol-Invotec	Associate
10399	Fadzrul	Ramli	Amphenol-Invotec	Associate
10400	Tracy	Hodges	Anglia	Member
10401	Gavin	Brown	Anglia	Member
10402	Philip	King	Newbury Electronics Ltd	Member
10403	Paul	Goodfellow	Minnitron Ltd	Member

Event Revue: 7th Electronic Materials and Processes for Space Workshop (EMPS-7)

by

Barrie Dunn, EMPS co-founder and Professor, School of Engineering, University of Portsmouth

[Introduction and Welcome]

The EMPS-7 Workshop was held at the University of Portsmouth (UoP), UK on 13th and 14th April 2016. This Workshop followed on from an IPC/UoP Lead-free Risk Management (PERM) meeting at the same venue – convenient for participants attending both events and arriving from continental Europe and the US. The Organizing Committee of EMPS-7 consisted of Jussi Hokka, European Space Agency (ESA) and Misha Filip, UoP. The Programme Committee consisted of Barrie Dunn; Jussi Hokka; Bill Strachan, ASTA Technology; and Martin Wickham, National Physics Laboratory.

EMPS workshops are publicized on a University of Portsmouth website from which all past presentations (2010 – 2016) can be freely downloaded: http://emps.port.ac.uk/documents.html

A brief welcome and introduction to the EMPS-7 Workshop was given by **Jussi Hokka** and **Barrie Dunn**. This was followed by the opening address provided by **Professor Graham Galbraith**, **Vice Chancellor of the UoP**. 95 delegates from industry, space agencies and academia attended this two-day workshop which was held in the magnificent Portland Building auditorium.

The participants this year represented 16 countries and included engineers from the USA and China. Prof. Galbraith was proud to note that this workshop had been founded by the University in 2010 and has continued each year at a different European venue.

Fig. 1 The EMPS-7 Social Dinner was held in the Still and West public house in this area of Old Portsmouth, also known as Spice Island, which is where all the spices used to enter the city. The area features part of the fortifications for the harbour entrance built in 1415.

Portsmouth is a dynamic and vibrant waterfront city and is unique being the UK's only island city and is noted for its links to the British navy, shipbuilding and in recent years it has become a hub to Space industries such as Astrium-Airbus, Spur Electron and BAeSystems. These companies rely on advanced materials for high strength/low weight spacecraft structures - many are based on carbon fibre technology. Coincidentally, these CFRP materials are also selected by the Ben Ainslie Racing team for the fabrication, in Portsmouth, of world class racing yachts. Summer 2016 will see these yachts take part in the Americas Cup which is being hosted by the City of Portsmouth - here the Land Rover BAR team is on a mission to bring the America's Cup back to British waters!

Maartin Cauwe

Centre for Microsystems Technology

[Passive Component Embedding in Printed Circuit Boards for Space Applications]

The first Workshop session concerned *Printed Circuit Boards and Circuit Technologies*. **Maartin Cauwe** from the **Centre for Microsystems Technology**, Belgium presented the results of an extensive study into the embedding of passive components into printed circuit boards (PCBs) for space applications. The reliability of such embedded passive components has been evaluated and a functional demonstrator manufactured. It was found the embedded technology samples performed almost as well as surface mount technology (SMT) counterparts environmentally tested in parallel. It was only the embedded 0201 resistors that had a minor impact on component reliability. At present standarised testing of such technology is challenging as there are no design rules for space products and, as required by spacecraft contracts, there is no possibility for component replacement or repair with this new technology. Dr Cauwe considered further embedding activities should include MOSFETs, power components and more complex modules.

Karl Ryder

University of Leicester

[PCB Surface Finishes and Electronics Assembly Using Deep Eutectic Solvents]

The next presentation concerned the development of new PCB surface finishes using "deep eutectic solvents" (DESs) based on environmentally benign liquids with remarkably high salt content. This work was described by **Karl Ryder** from the **University of Leicester**. DESs have found many applications related to electroplating, electro-polishing, immersion coatings, metal recycling and energy storage. DES technology has enabled the plating of PCB copper tracks with silver, nickel, tin and gold. A so-called "universal surface finish" has been developed by the Leicester team. Its plating chemistry and main successes were detailed by Dr Ryder. The main PCB finishes comprise of electro-less nickel, immersion palladium and immersion gold (ENIPIG) – these potential space PCB finishes have uniform coverage combined with excellent planarity. The DES processes are free from acids and cyanides, have little effect (dissolution) on the substrate copper and were stated to result in highly solderable surfaces.

Hans-Peter Klein

Dyconix

[Flex PCB Reliability: An Objective Evidence Based Approach]

The reliability of flexible PCBs for aerospace applications was discussed by **Hans-Peter Klein** of **Dyconex AG**, Switzerland. Interconnect mechanical stress testing and exposure to extensive temperature cycling was performed on micro-vias having a diameter of less than 100 microns. It was found that flex materials having a low Tg could be subject to early in-service damage and their failure mechanisms were described in detail. Materials with a high Tg were recommended as they are not subject to either the assembly stresses caused by solder-assembly or the conventional spacecraft in-service life stresses. Flexible circuits with a high Tg can undergo rapid acceptance testing and provide meaningful predictions of service life.

Per-Erik Tegehall

Swera IVF

Impact of Cracks in the PCB Laminate during Thermal Cycling on the Fatigue Lives of Solder Joints

Other research performed at **Swera IVF**, Sweden focused on the cracks that may form in PCB laminate during the thermal cycling of assembled electronic components. It was noted by **Per-Erik Tegehall** that tin-silver-copper (SAC) alloys are far stiffer than the tin-lead solders they are replacing. One effect, during large delta T thermal cycling of area grid array (AGA) packages mounted to PCBs, is that the SAC solders stress the solder pads far more than the "compliant" SnPb solders and this can cause cracks to develop beneath the copper pad terminations. Many reliability tests have been performed at Swera, particularly related to Ball Grid Arrays assembled onto daisy chained monitoring circuits within PCBs. In general the reliability of the SnPb solders was found to be "lower" than that of the SAC alloys, but it is only when detailed metallography is performed that defects are observed in both configurations. It is essential that any micro-sectioning of solder joints assemblies, after completion of environmental testing, includes the removal of all flux residues followed by mounting the samples in a room temperature hardening epoxy (under low vacuum). When a fluorescent agent is added to the molding resin fine cracks can be observed during optical inspection under UV light. SnPb solders degrade by thermal fatigue within the solder alloy, however it was surprising to find that the SAC soldered assemblies can also degrade in two distinct failure modes. Some SAC joints become completely recrystallized, and comprise of single grains. These are very strong in the Z direction and cause extensive pad lifting and fracture in the resin below the pad. Beneath the same AGA some SAC joints are seen to be multi-grained and these were noted to fail at the solder to pad interface. Figure 3 shows images of SAC solder joints taken with Electron Back Scatter Diffraction (EBSD) after thermal cycling – the left-hand image shows a single grain of random orientation (other single-grained balls had different orientations) and there is no crack within this grain, only a lifted pad. The right hand ball is multi-grained and here the failure is within the solder.

Dr Tegehall concluded that cracks forming in the PCB laminate might "improve" the fatigue life of SAC joints – but they can lead to an overestimation of the fatigue life of such joints by at least a factor of three.

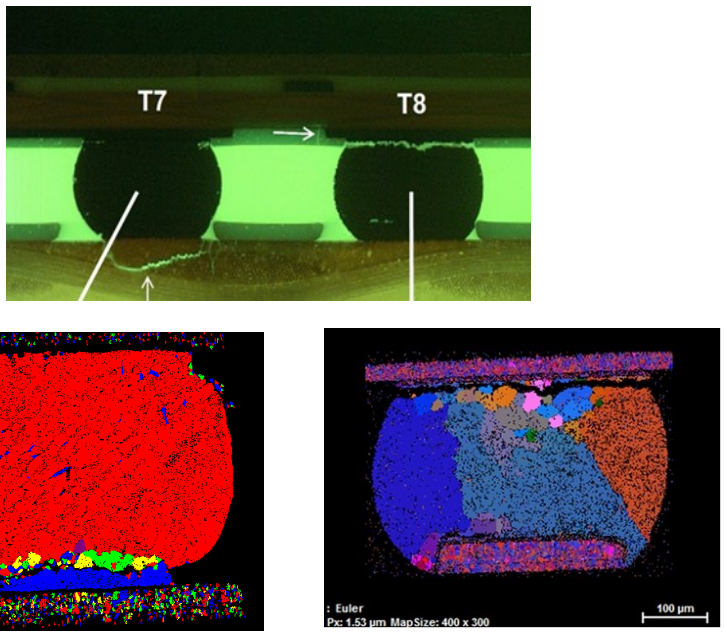

Fig.2 AGA ball joints made from SAC alloy but having various grain sizes, orientation and two distinct thermal-fatigue failure

PCB and Assembly Technologies Roadmap for Space Applications

Jussi Hokka outlined the roadmap identified by **ESA-Estec**, the Netherlands for advancing technologies related to PCBs and several assembly technologies until 2020. He detailed the activities of several ESA-Industry working groups actively engaged with SMT and PCBs and emphasised the importance of miniaturizing circuitry with high density interconnect technology. The roadmap also addresses spin-in opportunities and legislation threats posed by REACH and RoHS.

Asensio Zapata of Airbus-Toulouse

Space Hardware and REACH Regulation

The REACH regulations and their impact on space hardware were also covered by **Asensio Zapata** of **Airbus-Toulouse**, their surface treatment and M&P expert. Of particular importance to the space industries will be the exclusion of hexavalent chromium whose sunset date is expected to be September 2017. This is of significant concern due to such chemicals being used extensively for the corrosion protection of spacecraft electronics and structures. The workhorse, Alodine 1200, employed throughout spacecraft hardware for surface corrosion protection, or as a primer for paints, also has a low contact resistance which is ideal for the grounding of spacecraft electronics constructed from aluminium based alloys. Mr Zapata's laboratory research covered many coatings and indicated that alternative Cr+6 -free conversion coatings, such as SurTec R 650 may have suitable properties for passivating aluminium along with low contact resistance - this coating has a faintly visible blue coloration.

Iñaki Hernanz, from SENER

Effects of Gluing on a 3D-Plus EEPROM at SMT Certification

Engineers **Ángel Bustos** and **Iñaki Hernanz,** from **SENER**, Spain described an extensive verification program where a space-approved adhesive staking compound was used to provide more robustness to 3D-Plus EEPROMs solder-mounted onto printed circuit boards (Figure 3). Without special component-lead bending design such adhesives can over-stress solder joints due to their high thermal expansion coefficients (during both assembly/curing and subjection to thermal cycling during verification tests). Of particular importance is the application point of the glue – by trial and error this location was optimized in order to satisfy both the vibration and the thermal cycling test environments stipulated by ECSS-Q-ST-70-38 (the European space standard: "High-reliability soldering for surface-mount and mixed Technology").

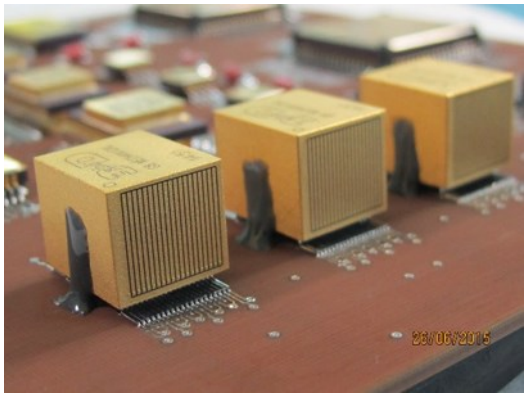

Fig.3 Populated PCB that included 3D-Plus EEPROMs for SMT Verification testing. SENER

Luis Pina
INEGI,
University of Porto

[Development of a Thermally Conductive Carbon Fibre Reinforced Polymer (CFRP) Electronic Box for Space Applications]

The development of a thermally conductive carbon fibre reinforced polymer (CFRP) manufactured electronic box for space applications was described by **Luis Pina** on behalf of teams from Portugal and Germany (led by **INEGI, University of Porto**), a study financed by ESA. The CFRP test structure represented a mass saving of 23% when compared to a similarly shaped aluminium housing. The electrical conductivity (Figure 4) and thermal conduction of the CFRP material was enhanced by adding carbon nano-tubes to a special epoxy resin system developed by Huntsman for "low outgassing under vacuum" space systems. Although the mass reduction was deemed a significant success, the lower than expected thermal performance (92°C compared with a predicted 85°C) during thermal balance testing was thought to be due to the difficulty in mixing the nano-particles into the components of the Huntsman resin. Materials and molding/manufacturing times were costed. It was calculated that if more than 7 housings were to be procured, CRFP housings would become cheaper than if manufactured from aluminium alloy.

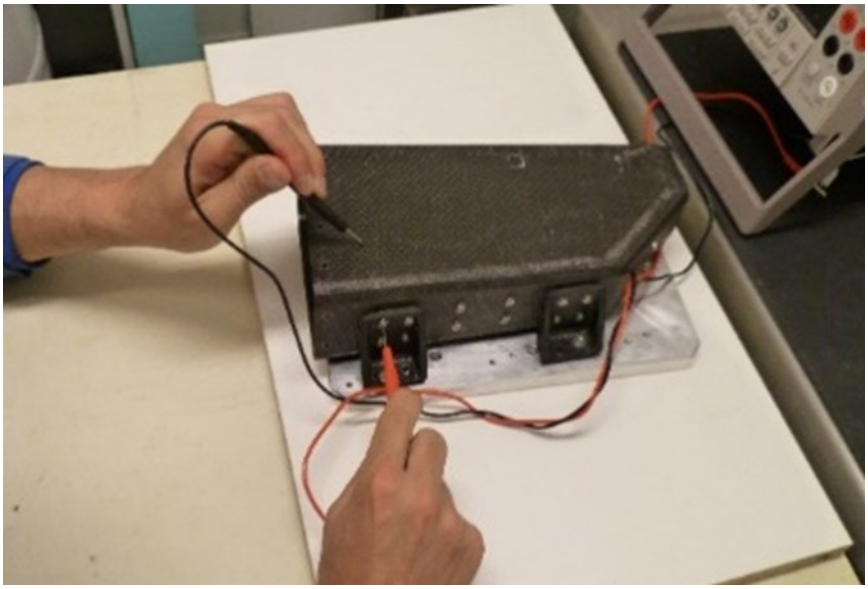

Fig.4 Electrical resistivity measurements being performed on a prototype CFRP electronic housing:
Resistance between metallic base-plate and bonding studs < 0.1Ω. Resistance between housing surface and bonding stud (shown above) < 1 Ω. Maximum resistance between two arbitrary points on this housing <10 Ω. (INEGI).

David Pinsky
Raytheon

Mitigation of Pure Tin Risk by Tin-Lead SMT Reflow- Results of an Industry Round-Robin

David Pinsky described the results of an industry round-robin (including **Raytheon**-Boeing-Rockwell Collins and Raytheon Space) that investigated the risk of tin whisker growths on surface-mount components solder-assembled to PCBs. These components had been electroplated (leads and terminations) with pure tin containing less than 3% lead. Various well-defined soldering processes were selected by the participating companies in order to assemble a large variety of component types onto PCBs. Some soldering processes could achieve full dissolution of the pure tin into the resulting solder joints. These are termed "self-mitigation" processes as they prevent the risk of whisker growths and electrical shorting. The study included various PCB finishes and a very wide range of component package styles. The assembled sample boards were then inspected by XRF in several lead locations. It was found that the PCB finish and the PCB pad size had minor effects on whisker mitigation, but the actual soldering process applied was extremely significant. Pinsky's presentation highlights the component types nearly certain to self-mitigate under all process conditions (e.g. the smaller chip components). Usually it was the process which caused some components to self-mitigate, but one component (0612 chip) stood out as exhibiting a very low probability to self-mitigate. This round-robin study is continuing and will incorporate many new families of components/packages.

Mark Ashworth
Loughborough University

Atomic Layer Deposition (ALD) for Tin Whisker Mitigation on Pb-free Surfaces

Tin whisker mitigation for lead-free surfaces was also described by **Marko Pudas** (**Picosun Oy**, Finland). Here, atomic layer deposition (ALD) conformal coatings were applied to finishes having a propensity to whisker. Scanning electron microscopy revealed that ALD coatings markedly reduce the occurrence and length of tin whiskers on so-treated PCBs. **Mark Ashworth** (**Loughborough University**) also characterised whisker mitigation processes that utilised the electrochemical oxidation of electroplated tin and tin-copper samples. The oxidation of parallel sets of samples was achieved either naturally in air, or by using both borate buffer solutions, and potassium carbonate/bicarbonate solutions. After almost 4 years of ambient storage the tin whisker density on samples naturally oxidised in air remained high (~6000 whiskers cm^{-2}), whereas the artificially oxidised coatings demonstrated far lower whisker densities (about two orders of magnitude below the untreated samples). Another coating was finally described; it was based on a molybdate conversion coating. Although this produced the thickest of all measured oxides on tin, remarkably, it was less able to mitigate whisker growth.

The Development of Post-Electroplating Surface Modification Treatments to Mitigate Tin Whisker Growth

Fig. 5 Some participants to EMPS-7 (photo: Leo Schöberle).

Johan Leijtens

LENS R&D

[Novel Materials and Solutions to Build High Reliability Sunsensors]

The session covering *Space Design and Components* commenced with **Johan Leijtens**, (**LENS R&D**, Netherlands), and an overview of his designed and built BiSon series of sun sensors (Figure 6). These sun sensors have been used in commercial applications, in particular for the management of continually rotating/moving of solar arrays in the Sahara desert in order to achieve optimal orientation to the Sun's rays. His latest design of sun sensor incorporates an integrated connector and PEEK inserts to a ceramic molded part. All build materials are selected so have low-outgassing-under-vacuum and matched coefficients of expansion; this provides for a simple design resulting in a high reliability with ultimately lower costs. The recent designs are very suitable for use onboard the many hundreds of solar powered small/cube satellites being built by universities and institutes.

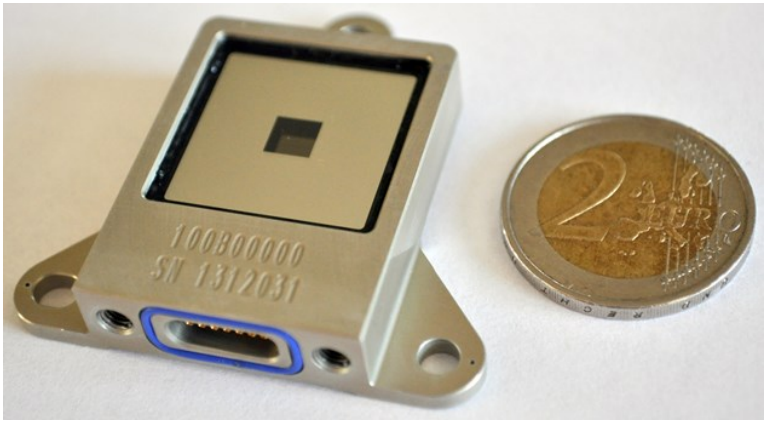

Fig.6 BiSon 64 type miniature sun sensor from LENS R&D.

Sinarova Simandjuntak

University of Portsmouth

[Review of the Performance of Sensors used for Corrosion/ Damage Detection System for Cables and Components located in Marine Environments]

Sinarova Simandjuntak, (**University of Portsmouth**), then reviewed the performance of sensors that have the potential to be used for the detection of corrosion or damage within electronic cables and connections. Spacecraft launch sites are frequently located in marine environments (e.g. the Kennedy Spaceflight Centre in Florida and the Kourou Spaceport in French Guiana). The proposed sensor designs are expected to detect degradation of both power cables and communication cables between launch complexes and on-site command centers. This technology is certainly of value to the wind power industry where turbines are located off-shore and where such saline environments have caused costly failures to power lines.

Area Grid Arrays are usually terminated with solder balls or solder columns; **Wilfried Akalmavo** from **HCM- Systel**, France, described how such terminations can be removed and then replaced by far more robust columns of solder that are reinforced with very fine copper tape. Advanced electronic packages supporting the reinforced copper-SnPb columns have been evaluated to an "ESA-ECSS capability and verification test plan". The extensive programme described in detail by Akalmavo, demonstrated that the refurbished AGAs have passed environmental testing (comprised of thermal shocks, 1,500 thermal cycles and vibration) with flying colours.

Rajan Bedi (Spacechips Ltd.)

[Signal Integrity for Rocket Scientists]

Rajan Bedi (**Spacechips Ltd.**) ended this session with a talk that described selected technical requirements for the next generation for spacecraft electronics.

The final Workshop session, entitled *Interconnection Materials*, was kicked off by **Dong Junking** of the **Chinese Academy of Space Technology** (CAST). She presented an overview of spacecraft assembly capabilities in China and described their visual inspection and x-ray requirements for column grid array packages. Typical defects were illustrated and an account given as to how they could be minimized during processing. Her second presentation was a review of the development and challenges associated with RF-MEMS packages for integration into spacecraft. Known good die (KGD) testing for best electrical properties is seen in Figure 7. RF-MEMS packages are considered more critical than IC packages, especially for space applications. This is due to effects of both radiation and RF loss - caused by miniaturised designs and exposure to thermal-mechanical stresses during operation.

Dong Junking

Chinese Academy of Space Technology

[The Development and Challenges of RF-MEMS Packages in Space and CCGA Solder Joint Defects]

Fig.7 KGD testing during MEMS assembly for a satellite light phased array antenna (Courtesy of CAST).

Michael Sheerer

Aerospace & Advanced Composites GmbH

[Electrical Resistance, Microstructure and Mechanical Performance of Solder Alloys]

An extensive overview of the work performed under ESA contract by **Aerospace & Advanced Composites GmbH** (Austria), was presented by **Michael Scheerer**. He discussed the results of testing the electrical resistance, microstructure and mechanical performance of a wide range of solder alloys. These included the SnPb, SAC and InPb solders prescribed by ECSS Q-ST-70-08 for specific applications. Properties were assessed from cryogenic, to room- and elevated-temperature environments. Microstructure features were equated to creep resistance, mechanical properties and modes of failure. The influence of grain boundaries on electrical resistance could be verified (smaller grains lead to higher electrical resistance).

Poul Juul

Hytec

Voids in Solder Joints for Space Applications

The presence of voids in solder joints have been a focal point for electronic manufacturing engineers since the start of the Space Age. Up until 1997 internal voids were not considered a real problem. However, today the same joints are considered a problem - but this might only be because we now have the ability to observe them under high resolution x-ray inspection! **Poul Juul** (manager of **Hytek**, Denmark) presented an interesting review relating various types of voids in solder joints to reliability concerns. He discussed the root causes of different kinds of voids and concluded that voids in solder fillets could be reduced by optimizing the quality of surface finishes on components and PCB pads. The selection of correct solder alloy and flux is also important, as is the optimization of soldering temperatures and profiles.

Luca Moliterni (IIS Progress, Italy)

The Impact of the Automated Paste in Hole Soldering Process and the Automated Selective Wave Soldering Process on High Reliability Electronic Assemblies

Luca Moliterni (**IIS Progress**, Italy) compared the impact of "automated paste in hole soldering" with "automated selective wave soldering" on the reliability of electronic assemblies. He described the characteristics of both soldering technologies. A chart compared "paste in hole" and "selective wave" against important parameters that included energy consumption, flux contamination, repeatability, defects (solder and short circuits), component availability and the prospect of successful industrialization of these processes.

Martin Wickham, National Physics Laboratory, UK

Recent Work to Assess Sintered Materials and Conductive Adhesives as Alternatives to Solders for High Temperature Electrical Interconnects

The final presentation was made by **Martin Wickham** (**National Physics Laboratory, UK**). Martin assessed various sintered materials and conductive adhesives as alternatives to high temperature solder alloys. Such high temperature attachment processes are required for electronics incorporated within high performance power equipment, electrical vehicles and spacecraft such as the current ESA BepiColombo mission (to the planet Mercury) where electrical systems are expected to endure temperatures in access of 350°C. High lead-containing alloys are no longer permitted by RoHS legislation. Electrical connections between various ceramic component terminations and PCB finishes have been evaluated by NPL using conductive adhesive such as Elcosint®. The properties of conductive adhesives were compared against samples made using conventional high melting point solder alloys. Preliminary test results, based on thermal ageing and thermal cycling, were presented and results demonstrated the Elcosint® materials (Figure 8) to have outperformed each solder alloy. Additional work is planned and will be supported by the sponsoring partners – persons interested in joining this partnership can contact Martin at NPL.

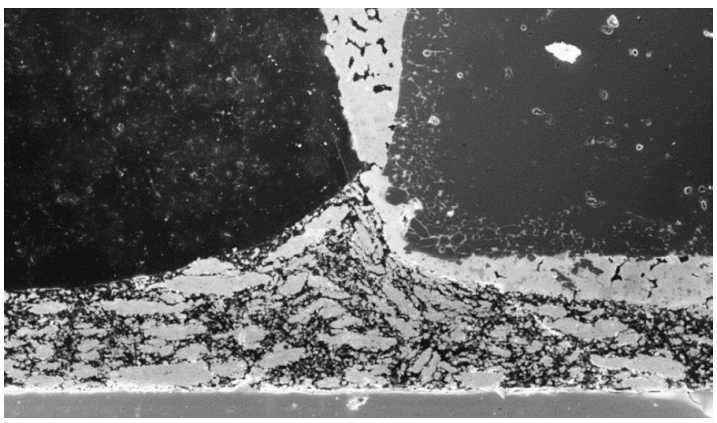

Fig.8 Micrograph of a high temperature adhesive under evaluation at the National Physics Laboratory, UK.

Review of:-

Institute of Circuit Technology
Annual Symposium

Birmingham, UK, 1st June 2016

By **Pete Starkey**

Bill Wilkie
ICT Technical Director

Alun Morgan
EIPC Chairman

Technical Director Bill Wilkie introduced the 42nd Annual Symposium of the Institute of Circuit Technology, at the Motorcycle Museum in Birmingham, UK, commenting upon the success of the recent Foundation Course and acknowledging the sterling efforts of his course tutors, although recognising that some of his longest-standing experts were now retiring. With Institute membership currently standing at 353, there existed a wealth of talent from which he hoped to strengthen his team.

Keynote presentation came from **EIPC chairman Alun Morgan**, with a highly informative and occasionally humorous insight into the evolution of automotive electronics, from 1986, when Karl Benz produced the first petrol-engined automobile, which at least had an electrical ignition system, to the present day where, in a world automotive market worth $600 billion, electronics represents 40% of the value. There had been rapid growth over the last decade, as a consequence of developments in lightweight materials, miniaturization, intelligence and electrification.

The first introduction of electronics into the automobile was in 1930, with Motorola's car radio, costing over $100 before installation, which was a major job occupying two men for several days and involved substantial modification to the bodywork and interior trim. The installation manual had 28 pages of instructions!

Once in-car entertainment had become established - radio, 8-track stereo, cassette tape and CD player along the way - the next generation of automotive electronics was engine management, with the Bendix Electrojector electronic fuel injection system in 1958, although the early electronic components were not reliable in under-the-hood service. The technology progressed through the 1960s, and the Bosch D-Jetronic became the industry standard in1975. ABS braking evolved through the 1970s and 1980s, became the norm in the 2000s, and was an early example of the synchronisation of a group of inputs to execute a function as a system.

Presently, vehicle electronics could be grouped into four functional domains: powertrain, including engine control, transmission control and start/stop systems; control/body, including air conditioning and climate control, dashboard, wipers, lights, doors, seats, windows, mirrors, cruise control, park distance control, alarm, keyless entry; multimedia/entertainment, including multimedia, infotainment, GPS and in-vehicle navigation systems, CD/DVD players, rear-seat entertainment; and safety, including rollover sensors, airbags, belt pre-tensioners, antilock braking, electronic stability programs, automatic stability controls, adaptive cruise controls, tyre pressure monitoring systems and auto lane keeping. Morgan referred to an announcement be Toyota that they will integrate between 60 and 100 electronic control units into these four functional groups. He discussed layers of increasing integration, from the low-level electronic system platform, up through intelligent actuators and integrated vehicle control, to direct vehicle-to-vehicle interaction and the control of vehicle

groups and fleets. The Internet of Things was driving the next generation of development, although there would inevitably be some issues related to the security of data and the protection of privacy that would have to be resolved.

Morgan switched his focus from electronic functionality to road safety trends. European statistics indicated a 26% reduction in annual road fatalities between 2009 and 2013, whereas the USA only achieved 3%, for reasons he could not explain. The fatality reduction forecast for intelligent vehicle safety systems indicated that electronic stability control and lane keeping support had by far the greatest potential for reducing fatalities. Electronic stability programme sensors and systems for anticipating problems could take corrective actions faster, and with more functionality to control the vehicle, than even the most skilful of human drivers. And he illustrated their capabilities with scary but very convincing video case studies. Elegant collision avoidance radar systems were becoming available, having evolved from early prototypes in the mid-1970s, and the achievement of accident-free driving as the objective, and systems were migrating to higher operating frequencies as a means of offering a homogeneous concept for deployment in the mass market at affordable cost. The car was becoming an intelligent vehicle that understood what was going on around it as well as within it. On a salutary note: the more complex the electronics, the more to potentially go wrong - recall figures had shown a steep rise through the 2000s, and were plateaued at an uncomfortably high level.

Recently introduced all-electric vehicles - Morgan's example was the Tesla-S - were mechanically far simpler than conventional vehicles: in essence, an assembly of batteries constituting the floor pan and an electric motor driving each wheel, with digital control of motors, brakes and steering, and active, traffic-aware cruise control effectively offering "autopilot" capability.

REPRIME Project

Dr Steven Brewer
C-Tech Innovation

From automotive electronics, attention turned to metal finishing and printed circuit processing: **Dr Steven Brewer** from **C-Tech Innovation** described the objectives and achievements of the REPRIME project, funded by the Home Office to investigate the application of advanced ultrasonics to enable the replacement of poisons and explosive precursors used in industrial metal finishing processes and the manufacture of printed circuit boards. The Home Office was conscious that quantities of chemicals which could support terrorist activities were held by SMEs in relatively unsecure locations, and wanted to work with industry associations to find alternative materials via technical solutions rather than by legislation. Objectives were to overcome the barriers to the use of cyanide-free technology, to demonstrate cyanide-free zinc and zinc -nickel plating on an industrial scale, to extend the work to cyanide -free copper, gold and silver plating, to reduce hydrogen peroxide use in the printed circuit industry and to ensure that the technology could be easily and cheaply retrofitted to existing equipment.

Research into the Application of Advanced Ultrasonics to Replace Poisons and Explosives used in Industrial Metal Plating Processes

It had been demonstrated in a pilot line that the use of ultrasound enhanced the deposition rate of cyanide-free zinc electroplating plating chemistries and improved coverage and distribution on complex shapes. Ultrasound enabled the use of reduced concentrations of hydrogen peroxide in etchant solutions used in PCB manufacturing, and gave improved bath life with reduced frequency of replenishment and no adverse effect on downstream processing. The project had been successfully completed, and was being rolled out to industry with continuing support from the Home

Office, the Surface Engineering Association and the ICT. Update information was available on the project website www.reprime.co.uk.

Tec-speed™

product portfolio

Tamara den Daas-Wijnen
Ventec Global Account Manager

Tec-speed Product Porfolio Presentation

Tamara den Daas-Wijnen, Ventec's Global Account Manager OEM Marketing, introduced the tec-speed™ product portfolio, which positioned Ventec's comprehensive range of high-speed low-loss PCB laminates under a clear single-brand identity, symbolised by a sharp-pointed pyramid with standard-loss material at the base and ultra-low-loss at the apex. "Upwards is the direction we are going, as a technology leader - no longer a me-too!" was her comment. She described in detail the characteristics and properties of two examples from the range: tec-speed 3.0 (VT-464L) and tec-speed 6.0 (VT462S). tec-speed 3.0 was a high-Tg halogen-free low -loss material for telecom and networking applications, with Dk 3.7 and Df 0.009 at 50% resin content, which had better electrical properties and was more thermally robust than competitive products.

She quoted reliability results for a 32-layer 4 mm thick construction with 0.3mm holes at 0.8 and 1.0 mm pitch, withstanding 10 lead-free reflow cycles at 280°C without failure, and explained how Ventec's glass treatment and resin-impregnation procedure led to remarkable improvements in CAF resistance. Similar thermal reliability results were achieved with the ultra-low-loss tec-speed 6.0 material. The electrical performance characteristics of tec-speed 6.0 were interesting, particularly the fact that at 10GHz its Df decreased with increasing resin content - a consequence of the resin having lower dielectric constant than the glass.

Ms den Daas-Wijnen concluded her presentation by commenting that the whole of Ventec's supply chain was accredited to AS9100C - the only laminate manufacturer able to make that claim. And the Ventec App was now available, with instant access to data for the whole product portfolio.

Global PCB and Electronics Industry Outlook
Francesca Stern
Industry Analyst

Outlook for global PCB and electronics industry

Industry analyst and ICT Council member Francesca Stern delivered her annual outlook on the global PCB and electronics industry, reviewing world trends in electronics and PCB production, and how they related to the industry in the UK.

Global electronics production, including components, for 2015 totalled $US 1861 billion, with China accounting for 38%, the rest of Asia-Pacific 22%, Japan 7%, the Americas 18% and Western Europe 11%. Principal end-use markets were cell-phone, standard PC, digital TV and automotive. Standard PCs and tablets were showing negative growth, but there was continuing growth in medical electronics and huge growth in Internet-of-Things applications.

Electronic equipment production in Europe and North America remaining strong in 2015 in the industrial, instrumentation and automation sectors. There had been little growth in the military sector, but it was forecast to increase slightly in 2016. Growth in infrastructure equipment for 4G long-term-evolution had slowed in 2015, but industrial and instrumentation electronics production grew in China. UK electronics production, which had grown 3% in 2014, had fallen by1% in 2015.

PCB production in Europe had declined by 3% and some recovery, but no growth, was expected in 2016. Growth had been low in North America and there had been further decline in Japan. Exchange rate fluctuations could lead to distortions of the figures;

for example, measured in domestic currencies, there had been positive growth in Asia, but negative if measured in US dollars. The outlook for 2016 was that it would be similar to 2015, with a recovery towards the end of the year, and the next surge expected in 2017-2018.

Ms Stern commented on recent updates to the Open General Export Licence (OGEL) by the UK government, which made it easier to export PCBs to most worldwide destinations for military contracts, and other more sensitive counties including China for aerospace and industrial-grade PCBs. The Export Control Organisation (ECO) was currently looking for feedback from PCB companies as to how these changes were affecting their business.

MACFEST Project

Dr Andrew Ballantyne
University of Leicester

[PCB Surface Finishing and Electronics Assembly Using Deep Eutetic Solvents]

Dr Andrew Ballantyne from **University of Leicester** presented a review of the applications of deep eutectic solvents in PCB surface finishing and electronics assembly, and an update of the MACFEST project. He explained that deep eutectic solvents are types of ionic liquids in which organic cations are combined with halide anions and complexing agents to make an

anionic complex. The specific example used in his research work was composed of ethylene glycol and choline chloride in 2:1 molar ratio and known as Ethaline 200, which was relatively inexpensive and environmentally benign. Ethaline 200 had low vapour pressure and good thermal stability, and exhibited unusual solvation properties with metal salts. Its benefits had been demonstrated in metal finishing applications such as electropolishing, electroplating and immersion plating, as well as metal recycling and energy storage. It had also shown remarkable properties as a flux, enabling soldering direct to electroless nickel and other difficult-to-solder metal surfaces.

The MACFEST Project, which was co-funded by Innovate UK, aimed at producing a "Universal Surface Finish" for electronics, capable of reflow soldering and wire bonding with gold, copper and aluminium. Required attributes were high reliability, good planarity and long shelf life. Deep eutectic solvent technology was being employed to improve functionality and to reduce safety and environment concerns. The first 15 months of the 24-month project had been completed.

Using a proprietary electroless nickel with an amorphous nodular structure and 8% phosphorus to form the base layer, immersion palladium had been deposited from Ethaline at 80°C to a thickness of 70-100 nanometres in 30 minutes. The palladium deposit had been over-plated with gold from a second Ethaline-based formulation at 50°C for 9-15 minutes. The source of gold could be either gold chloride or sodium gold thiosulphate, and bright uniform deposits had consistently been achieved from a chemistry free from acid and cyanide. This "ENIPIG" - electroless nickel, immersion palladium, immersion gold - finish had shown excellent solderability, with no evidence of "black pad" or "mud-cracking" effects on the nickel surface associated with acid attack when traditional aqueous chemistries were used.

ICT Research Projects

Dr Andrew Cobley
Coventry University
ICT Chairman

The final speaker was **ICT Chairman Dr Andrew Cobley**, from Coventry University, who reviewed current research projects in which the ICT was a collaborator. REPRIME and MACFEST had been discussed in earlier presentations, but two new projects were in their early stages.

The first was Selective Electroless Catalysis in a Magnetic Field (surprisingly, no acronym!), led by Coventry University. The concept was to use a magnetic field to selectively catalyse a material prior to electroless plating, using a template of magnetised iron rods placed against the reverse face of a thin substrate to attract catalyst selectively to the opposite surface. Proof of concept was being funded by Higher Education Innovation Funding (HEIF). A patent had been filed, and a PhD student would be working full-time on the project from September 2016. Other sources of funding, for example Horizon 2020, were being explored.

Acronyms again! The second project, SYMETA - SYnthesizing 3D METAmaterials for RF, microwave and THz applications - was being led by Loughborough University and funded by EPSRC. This project was looking at creating new materials for additive processes, to form substrates and conductive meta-atoms, and would take a radical new approach to high frequency circuit manufacture. Developing a more rational and sustainable use of materials would reduce waste, timescales and cost of manufacturing processes.

The main contribution of the ICT to these projects was as a dissemination partner, and the benefits of involvement were that the ICT could influence the direction of research and quickly inform its members of the latest R&D developments, as well as creating opportunities for ICT members to engage in and obtain funding for research.

Dr Cobley wrapped up the proceedings, thanking speakers for sharing their knowledge and experience, delegates for their attention, Ventec Europe for their generous support, and Bill Wilkie for once again organising a splendid event. Delegates made the most of the networking opportunity, and an impressive number of motorcycle enthusiasts emerged from the group to spend a while admiring the exhibits in the museum before departing.

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

Pete Starkey
I-Connect007
June 2016

Book Review:-

Materials and Processes for Spacecraft and High Reliability Applications

Author: Barrie Dunn

By **Martin Goosey**

Author

Barrie Dunn, EMPS co-founder and Professor, School of Engineering, University of Portsmouth

Book Review

"Materials and Processes for Spacecraft and High Reliability Applications", by Barrie Dunn, Springer book (published 2016), Heidelberg, Germany, hardcover ISBN 978-3-319-23361-1

The objective of this book is to assist scientists and engineers select the ideal material or manufacturing process for particular applications; these could cover a wide range of fields, from light-weight structures to electronic hardware. The book will help in problem solving as it also presents more than 100 case studies and failure investigations from the space sector that can, by analogy, be applied to other industries. Metallography and microstructural analysis are key features of the book. Difficult-to-find material data is included for reference. The sciences of metallic (primarily) and organic materials presented throughout the book demonstrate how they can be applied as an integral part of spacecraft product assurance schemes, which involve quality, material and processes evaluations, and the selection of mechanical, electronic materials and component parts.

In this new edition, engineering problems associated with critical spacecraft hardware and the space environment are highlighted by over 500 illustrations including micrographs and fractographs. Space hardware captured by astronauts and returned to Earth from long durations in space are examined in the metallurgical laboratory. Information detailed in the Handbook is applicable to general terrestrial applications including consumer electronics as well as high reliability systems associated with aeronautics, medical equipment and ground transportation. This Handbook is also directed to those involved in maximizing the reliability of new materials and processes for space technology and space engineering. It will be invaluable to engineers concerned with the construction of advanced structures or mechanical and electronic sub-systems.

Dunn is an Honorary Professor in the School of Engineering, University of Portsmouth, UK and an expert to the European Commission. He was former Head of Materials and Processes at the European Space Agency, Noordwijk, the Netherlands and has decades of experience in the space industry.

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