

EIPC Winter Conference, Day Two

Thursday, February 17, 2011 | Pete Starkey, I-Connect007



On day two, the attendees all came back, some a little red-eyed as a consequence of going to the bar instead of straight to bed after dinner at the excellent Restaurant Fruh opposite the cathedral in down-town Cologne. Apart from a small number of stragglers who crept in a few minutes late, Konrad Wundt had a full house at 8:30 a.m. as he welcomed delegates to the second day of the EIPC 2011 Winter Conference.

The day commenced with a session focused on PCBs with embedded components, and first to speak was Dr. Marcus Riestler, of Maris TechCon in Germany, with a presentation entitled *Embedded Component Technology, To-Do's on the Path Toward Commercialisation*. From early concepts in the 1950s, through a period of extending the technical capabilities of PCB technology through the 2000s, ECT had reached the stage of development of marketable products, although the challenge was to introduce changes into a value chain which was very sensitive to disruption. Embedded components created value for the PCB manufacturer at the expense of the assembler, and raised all sorts of issues about yield accountability and product liability.



Dr. Riestler described alternative process sequences for chip embedment--chip first, with either face-up or face-down orientation, or chip last--each method had benefits and limitations. But once the chip had been embedded it was mechanically protected and reliability levels were good. He predicted that ECT would challenge the packaging market and become a new source of revenue for high-end PCB manufacturers. However, for emerging ultra-miniaturised 3-D packaging, semiconductor-based solutions would become competitive and the packaging industry was moving swiftly, although end-users were somewhat unsettled in their choices of manufacturing technologies. Design tools for ECT were becoming available, and ongoing development work was focused on yield improvement and testing issues.

Although Europe held a leading position in the development of ECT capability, there was clearly a need for meaningful standards for PCBs with embedded components as the technology became established in the market, and Dr. Riescher's presentation neatly prefaced Michael Weinhold's overview and update of the status of standards development.

"Europe is bigger than we think!" he remarked, adding that Europe is made up of 47 countries, 27 of which under European Union regulation, with 495 million inhabitants--the third-largest population group in the world. Although the existence of 24 official languages posed certain challenges in communications, the fact remained that Europe was a highly industrialised area with an enormous wealth of technical and engineering expertise.

Development of technologies for embedding devices within PCBs brought a requirement to define new manufacturability and test methods. Weinhold believed that standards should reflect what the industry was actually doing, and were best written by the industry. They should harmonise quality levels throughout the supply chain, ensure the safety and security of industrial and consumer products and include sustainability and energy conservation requirements. He saw standards as falling into two categories: Those for manufacturing and those for safety and security.

Referring to IEC procedures, he drew a flow chart describing a standards development process, then analysed each stage in detail: Selecting the subjects to standardise, defining the generic specifications, following the guidelines for standards definition and identifying the requirements for components to be embedded. IPC had established an embedded devices design subcommittee IPC D-51 and an embedded device process implementation subcommittee IPC D-55, and IPC-7092 Design and Process Implementation for Embedded Components would be a new work item. A third edition of the JPCA standard for device-embedded substrates JPCA-EB01 was in preparation, and JISSO were endeavouring to harmonise the total supply chain. Weinhold stressed that international networking enabled faster progress in standards development and urged the European industry to become involved, with the assurance that EIPC would be pleased to assist in finding the right connections.



Addressing the practicalities of embedded passives, Daniel Brandler from Ohmega Technologies discussed the electrical performance of embedded thin-film resistors in PCBs for lead-free assembly. He described how the resistors were formed by imaging and etching inner layers clad with a thin-film nickel-phosphorus/copper foil combination, and subsequently incorporated into the multilayer build, giving benefits in electrical properties, increasing reliability and freeing-up the surface for mounting packaged components.



Although the resistor material itself was extremely thermally stable, embedded resistors could fail by two different mechanisms: Thermo-electrically, where the resistor would behave like a fuse if overloaded electrically and failure would occur as burn-out in the centre of the resistor, or thermo-mechanically where failure would occur at the etched edge of a copper conductor because of delamination or weave disruption of the substrate material. It was difficult to detect failures by microsectioning and electrical methods were preferred for determining the stability of the resistor under thermal excursion.

Brandler described a study whereby resistors incorporated into two laminate types had been tested for reliability under lead-free assembly conditions. A standard dicy-cured FR-4 Tg170 multifunctional epoxy laminate and a non-dicy Tg190 laminate formulated for lead-free assembly. Testing was carried out by subjecting samples to multiple thermal shocks according to IPC-TM-650 method 2.4.13.1, T288°C for 10 seconds, with control samples at T260°C for 20 seconds, and measuring change in resistance. Samples based on FR-4 laminate passed 20 cycles at T260, but failed after only two cycles at T288, whereas those based on the non-dicy "lead-free" material survived 20 cycles at T288. Microscopic analysis of the failed FR-4 resistors showed delamination between layers and cracking at the copper-nickel terminations, although this delamination might not have been detected had the electrical test not indicated the location of the failed resistor. These results indicated that embedded thin-film resistors could be used with confidence under lead-free soldering conditions provided that suitable laminates were specified.

Then came a presentation on behalf of the French Aerospace Valley DAS Systemes Embarques project PCB² - Passive Component and power on Board in Printed Circuit Board, by Thomas Cotxet, responsible for R&D programmes in the CIRE Group. Targets of the PCB² project were to design and develop innovative integrated technologies, at the PCB and electronic board levels, in accordance with end users' needs, and with respect to the market requirements in avionic and space fields, developing embedded systems offering more functionality with reduced size, weight and cost.



Cotxet stated the current objective: To enhance electrical and thermal performance by integrating passive components, in the form of resistive and capacitive thin films, into the PCB, and described the design and structure of resistive and capacitive test boards. He showed preliminary electrical characterisation results for the influence of temperature on resistor values and the effect of ageing on capacitor values, and described the construction of a 16-layer HDI test vehicle. Reliability data was expected by end of 2011, and an existing live design was currently being re-drawn to incorporate embedded passives, with a view to manufacturing actual circuits for evaluation.



The session entitled *Advanced Processing Technology* was moderated by PCB007 Editor Pete Starkey, and began with an explanation of the principles of a new conveyor system for use in the wet processing of thin-core and flexible materials, by Patrick Jahn of Schmid Group in Germany. The market demand was for a reliable transport system for flexible circuits and chip packaging substrates which avoided contact with rollers. Schmid's system was based on edge clamps which were transported through the process line by engaging in chains outside the active process area. The clampers were capable of handling materials as thin as 25 microns, with minimum stress on the edges, and versions were available for spray, immersion and electroplating applications. The clamping and unclamping operations were automated, and clamber bars were returned after use by an overhead conveyor. The cycle time permitted four panels per minute to be transported, and the system could handle panels maximum 610 mm x 533 mm and minimum 305mm x 305 mm. The first pilot line had been in operation in Taiwan for three years and had never lost a panel.

The next presenter was Glenn Oliver from DuPont Electronic Technologies with a paper on advances in flexible circuit design, with an emphasis on high-speed flex applications. He used a musical instrument analogy to set a context for understanding the significance of signal frequency. A \$9.95 wash-tub bass was okay for low notes, and the ultimate waveform it generated was not particularly critical, but if you were to invest \$2 million in a Stradivarius violin, you would expect the clarity and overtones to be perfect! Flexible circuits were being increasingly used for controlled impedance designs, and whereas mechanical attributes like adhesion, dimensional stability and flex life had traditionally been the most important performance considerations, dielectric constant and loss tangent had now become significant.



Oliver reviewed typical controlled impedance structures for flex, using coaxial cable as a point of reference, then went on to describe methods for calculating line widths and estimating losses. Of the key materials involved in a flex construction, it was factors like copper roughness and the presence of acrylic or, particularly, epoxy adhesives which contributed to high-frequency losses. New-generation materials were becoming

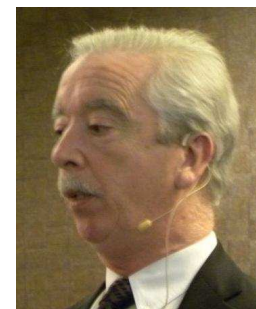
available, where the dielectric was a three-layer composite of polyimide and fluoropolymer, with RA copper cladding. Seventy-five micron core material with a 2:1 fluoropolymer to polyimide ratio had a dielectric constant of 2.3 and a dissipation factor of 0.002.



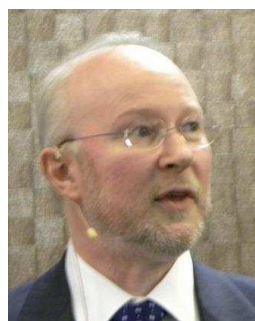
Dr. Andy Cobley from Coventry University in UK specialises in applications of sonochemistry and described how ultrasound could be used to enable low-temperature electroless plating. He began with an introduction to the principles of ultrasonic cavitation and the phenomenon of microjetting, which on a microscopic scale could produce extreme temperature and pressure effects at surfaces, capable of breaking chemical bonds and generating free radicals, as well as disrupting boundary layers and facilitating the movement of reactants and by-products to and away from the surface. Electroless deposition processes were used extensively in electronics manufacturing and current work was focused on the electroless nickel process as used in solderable finishes and EMI shielding.

A conventional electroless nickel formulation, with a working pH of 5.2, was used in the trials. Under normal conditions, this would be operated at a bath temperature of 90°C. Experiments were conducted at 90°C, 70°C and 50°C, with and without ultrasonics at 20kHz at a power density of 42 watts/sq cm. Two approaches were used to study plating rate: Traditional weight gain and mixed potential theory. The latter method was based on the use of a potentiostat to plot oxidation and cathodic polarisation curves and produce an Evans diagram. The point of intersection of the two curves gave the mixed potential, and the corresponding current density could be used to calculate the plating rate. Results of the initial study had been encouraging. At a given temperature, the plating rate was always higher in the presence of ultrasound, and at 70°C with ultrasound, the rate was 1.5x that at 90°C without. Ultrasound also had the effect of reducing the phosphorus content and increasing the hardness of the deposit. The study clearly indicated that ultrasonics could significantly reduce the energy requirements of the electroless nickel process and contribute to its sustainability.

Bill Birch, President of PWB Interconnect Solutions in Canada, took the floor to describe how to electrically quantify product construction and material robustness. He made it clear that routine microsectioning gave information regarding quality, but not about reliability, and also that solder float testing was not representative of reflow conditions. He believed that the most reliable methods of monitoring product consistency and reliability were electrical, and had spent many years establishing interconnection stress testing as an industry standard.



To supplement IST testing, and to reveal instances of delamination within the structure of the PCB that were not apparent on visual inspection, PWB Interconnection Solutions had developed a "DELAM" test, which detected changes in capacitance using a dedicated contact fixture to take measurements before and after assembly cycles. Birch demonstrated that capacitance measurements from the DELAM equipment could be used to characterise individual materials and constructions, and compare them lot-to-lot, revealing any differences. Every material had unique characteristics, and once a baseline had been established for that material, changes were clear to see and causes could be investigated. Capacitance measurements were very useful when building controlled-impedance boards, where knowledge of where tolerances were being lost gave opportunities for improved process control. C-stage material had been observed to be much more consistent in dielectric properties than B-stage. Good correlation had been seen between dielectric thickness and capacitance values, allowing a good prediction of dielectric spacing and reducing the need for microsectioning. Birch informed delegates that the results of two years' investigational work on reliability, carried out in cooperation with the High Density Packaging User Group, were scheduled to be presented at IPC APEX Expo, April 2011.



Michael Weinhold picked up the theme of reliability issues in the following session and his first presenter was Isola's Director of OEM Marketing Alun Morgan, who examined the influences of materials and processes on conductive anodic filament (CAF) formation. CAF had been recognized for many years, and excess dicyandiamide in epoxy laminate had been identified as a cause. Resins had been reformulated to reduce free dicy and the problem had become less significant until increasing design density had seen it re-emerge as a problem; Morgan illustrated its effects with photographs of actual field failures. CAF occurred as a consequence of a separation of the bond

between a glass filament and the resin matrix, the absorption of moisture at the interface and the electrolytic formation of a conductive path between plated holes, which could result in a short circuit. The occurrence of CAF was a consequence of many factors: reliability was critically dependent on the laminator applying the right finish to the glass and ensuring complete wetting-out during pre-preg manufacture. Thermal cycling accelerated any tendency for the glass-to-resin interface to break down. Dicy-cured systems were intrinsically more likely to

induce CAF than phenolic-cured equivalents, since dicy residues were water-soluble and could contribute to electrolytic effects. All other factors being equal, work by NPL had demonstrated that the process capability of individual PCB manufacturers was a significant factor, and that selecting a CAF-resistant material did not guarantee a CAF-free product.

Paul Reid, IST Program Coordinator with PWB Interconnect Solutions, gave a fascinating insight into the effects of surface finishes on the reliability of PCBs. Interconnect Stress Testing had indicated that certain finishes could extend or reduce reliability, and the IST technique gave opportunities to precisely locate defects before ultimate failure, so that the failure mode could be positively identified. Using animated graphics Reid demonstrated how failures were initiated and propagated as the substrate material expanded and contracted under thermal cycling, and explained that finishes such as OPS, immersion silver and immersion tin had little or no effect, whereas electroless nickel could have a variety of effects. Under certain conditions, a uniform deposit of nickel in a hole could stop a crack in the copper plating from propagating, whereas if nickel coverage was incomplete, it could actually initiate cracks which could then propagate into the copper. In exceptional circumstances, nickel could rupture in the Z-axis on thermal shock, then the broken edges overlap upon cooling, and Reid had micrographs which showed this effect. Fused solder finishes could both cause and mask failures and, in particular, the thermal shock associated with the lead-free HASL process could cause barrel cracks which subsequently filled with solder. There was also a tendency for copper to dissolve in the solder, accentuating barrel-crack defects. For compliance, acceptance, qualification, acceleration and survivability testing, Reid advocated using the same finish as specified for the board. For interconnection testing he advised nickel, but for material ranking he recommended avoiding nickel, HASL or any other fused finish.



Alain Desire from Arlon MED in France discussed substrate requirements for reducing the operating temperature and improving the operating efficiency of high-power LED lighting systems. Market forecasts for high-power LEDs indicated that the 2011 demand of 877 million units would grow to 3988 million units by 2014, and users needed reassurance that systems would be reliable in terms of life-expectancy, aesthetics and power consumption. The key factor was operating temperature: high temperature reduced light emission which could be compensated by increasing power input, resulting in a vicious circle. And high temperature caused a shift in wavelength, resulting in colours not being as intended. Most seriously, every 10°C increase in junction temperature caused a 50% decrease in life expectancy. Desire used thermographic photographs to illustrate dramatic differences in hot spots and heat distribution between standard FR4 substrates, with a typical thermal conductivity of 0.3 W/mK and thermally conductive laminates with values of 1W/mK and 2W/mK, which could be supplied by Arlon MED. An area of caution was that because no unified test for measuring thermal conductivity of laminates, the data sheets of certain suppliers could give misleading results.

Hildo van Hetteema, Technical Service Manager Surface Engineering, from Huntsman Advanced Materials in Switzerland, described new developments in white photoimageable solder masks for LED applications, where colour stability, resistance to degradation from heat and UV, and freedom from micro-cracking were essential requirements. New solder masks were also available specifically for under-the-hood automotive applications, which were highly resistant to cracking at corners during thermal cycling. Van Hetteema then discussed organic electroluminescence and explained Huntsman's participation in Fast2Light, an FP7 project with 16 collaborating organisations working on the development of large-area deposition processes for fabricating light-emitting polymer-OLED foils for intelligent lighting applications. These foils were multilayered structures and the functional internal layers were susceptible to degradation by moisture. Reliable encapsulation to prevent moisture ingress was the major challenge to be overcome in order to make flexible OLEDs commercially viable, and Huntsman were responsible for providing specialist technology for the creation of organic barrier layers.



Final session of the Conference was moderated by Michael Weinhold, with a single topic: UL requirements – the status of the industry today. Birgit Neubauer having set the scene the previous day with her user's view of experiences and challenges concerning UL approval of PCBs, raised several contentious questions regarding the costs and complications involved in gaining and maintaining UL approvals and made some very constructive suggestions as to how communication and efficiency could be improved, it fell to Emma Hudson to put the case in UL's defence, which she did with great professionalism.



Hudson gave a detailed explanation of UL standards and procedures and clarified many of the myths and mysteries surrounding UL approval. Although she agreed that there had been some problems of communication in the past, these had now been recognized by UL and improved systems were in place. It still took typically between 6 and 12 weeks from receipt of samples to complete the certification process for full



recognition, and up to 6 weeks for flame-only recognition, but it was mainly at the front end that delays were caused, by fabricators not fully understanding the procedures for sample design, or the opportunities to use reduced-test programmes for certain materials and constructions. She urged PCB fabricators to use the Pre-Certification service for new and complex constructions, assuring them of support and cooperation from UL, and to use the UL IQ database for finding materials that could be added to existing approvals through reduced-test or no-test programmes and for checking competitor's recognition. It was a sore point with many of the PCB fabricators in the audience that the UL system was being openly abused by some far-eastern PCB suppliers, putting ethical suppliers at a disadvantage and resulting in a potential loss of credibility for UL. The question and answer session ran way over time, and Michael Weinhold eventually had to bring it to a close so that delegates did not miss their flights home.

Another superb EIPC event: excellent programme, top-class presenters, a full and attentive audience, willing to engage in debate and discussion, a great networking opportunity and an ideal venue. The EIPC staff are to be commended for once again ensuring that the conference proceeded with faultless organisation and management

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