Universal Instruments
Advanced Process Laboratory
September, 2009

A.R.E.A. Consortium 2010 Study Plans

EXECUTIVE SUMMARY

The Advanced Research on Electronics Assembly Consortium will continue to fund manufacturing relevant research to complement our systematic knowledge and understanding of critical aspects of assembly, rework and reliability. As in previous years our individual efforts all aim at the eventual development or update of practical tools such as data bases, process 'cook books', recommendations, design guidelines, or test protocols. A substantial fraction of our work will be relevant to SnPb assembly as well as to lead free.

A major concern in lead free assembly and repair is still the risk of damaging the new, brittle laminate materials. Damage is most likely to be incurred during mass reflow or rework, particularly in repair of field returns. We plan to continue our systematic tests of laminate structures and materials, focusing on one of the earliest and most critical indications of damage, a reduced resistance to pad cratering. Results will be incorporated into our large laminate materials and structures data base.

Solder pad finish issues continue to be a major source of sporadic defects. We have successfully addressed and resolved the Kirkendall voiding phenomenon on copper pads. We shall continue to address the sporadic occurrence of 'poor' electroplated Ni/Au and ENIG coatings. This effort will emphasize the development of practical screening tests. In addition we shall conduct systematic studies on the use of any new pad finishes made available to us.

Accelerated thermal cycling of lead free solder joints may easily be misinterpreted because of the complex effects of cycling parameters such as temperatures and dwell times, as well as systematic effects of solder volume, pad size, process parameters, etc. We shall continue to build up our comprehensive data base on thermal cycling of commercial and carefully designed model components, providing a unique set of systematic test results and parameter dependencies for use in model development. Based on a careful correlation with the microstructure evolution governing materials properties and damage we shall furthermore update our recommended test protocols and acceleration factors for extrapolation of results to life in service.

Similarly, we shall develop test protocols and acceleration factors for life in vibration, cyclic bending and repeated drops. Importantly, indications are that the solder damage mechanisms are often different in accelerated testing than in long term service. We shall research this issue and provide guidelines to prevent it. Of course, unlike in thermal cycling solder joint failure may just as easily occur by pad cratering or through the intermetallic bond to a pad. Assessment of life in service therefore requires us to establish accelerated tests and the means of extrapolating results for these mechanisms as well.

One critical concern currently not properly accounted for in accelerated testing is that of long term aging of the lead free solder. Lead free solder properties continue to change for years, even in high temperature storage, and the consequences for the reliability of an old lead free joint are completely unknown. We have shown empirical acceleration of aging effects to be neither practical nor accurate, so we shall develop a microstructure based understanding and means of assessing life in service instead.

Of even greater concern is the observation that damage in lead free solder joints under various repeated loads does not add up the way we commonly assume. This is true not only for simultaneous thermal cycling and vibration, but also for vibration with varying inputs. After a few cycles or impacts with a particular load the remaining life in cycling with a different peak load may be more than an order of magnitude lower than predicted. We shall conduct systematic studies of such effects and develop new guidelines for realistic life assessment, ESS procedures, etc.

We shall continue to support separately funded efforts at Binghamton University to understand the effects of Sn plating on the risk of whisker formation and growth. Within the consortium sponsored efforts we shall, however, focus on the applicability and effectiveness of various new conformal coatings.

It is the general experience that the performance of a thermal interface material in an actual assembly never quite reaches that predicted based on the data sheets. However, we have shown that processes can in fact be developed to make some high end materials surpass predictions considerably. We shall continue our development of materials understanding and process guidelines for the optimization of thermal bondline performances.

Finally, we shall continue our 2nd level assembly and rework studies, with the latter emphasizing effects of repair on the robustness and reliability of products returned from field service. Both assembly and repair processes may affect lead free solder properties quite strongly and they are almost certain to reduce the resistance of PCB and component substrates to pad cratering. A variety of practical assembly configurations will be addressed, and special attention will be paid to the potential for enhancing reliability by underfilling or ‘staking’ (corner/edge bonding).

CONTENT

Thermal Cycling Data & Assessment of Life
Drop, Vibration, and Cyclic Bending
Acceleration of Aging
Combined Loading
Whiskers & Conformal Coatings
Thermal Interface Assembly & Reliability
Assembly and Rework/Repair
Component Underfilling & Edge/Corner Bonding
Practical Deliverables

REPORTS

COST

COMMITMENT TIME LINE

PROJECT GOAL

The principal goal of our efforts is to provide tools for the design of products, selection of materials, development of manufacturing processes, and testing to ensure an optimum combination of quality, reliability, low cost and high yields. The work will be conducted in a systematic, logical and scientific manner with supporting documentation of adequate test data to allow reproducible results in an R&D or manufacturing environment. Particular attention will be paid to understanding the mechanisms underlying processes and material systems behavior, allowing for the effective transfer of a particular process or technique to other related products.

This test plan was prepared by the consortium manager, Professor Peter Borgesen of Binghamton University.

CONSORTIUM STRUCTURE & FUNCTION

The AREA Consortium is organized and administered by Universal Instruments Corp., Binghamton, NY.

Two types of companies, Principals and Participants, will support the Consortium. A Principal is a corporation that provides financial support to the Consortium funded work and receives a complete copy of the progress reports and final documentation.

A Participant is a corporation that does not contribute financial support, but provides material and/or product development to the Consortium. A Participant will receive information covering his own materials and their relative quality. No proprietary information pertaining to competitive Participants involved in the study will be communicated verbally or in writing to other Participants in the study.

Wherever possible we will attempt to utilize properly supported data generated by Principals, Participants or other reputable sources. Efforts will be made to focus our research into channels that have not been addressed sufficiently by the Principals or other programs accessible to them.

The work outlined in the present plan will be conducted in the Advanced Process Laboratory of Universal Instruments, and at Binghamton University, by a team of researchers from both.

PLANS

The following offers an outline of our general plans for 2010 as formulated in September of 2009. Much more detailed plans will be developed, and updated on an ongoing basis, for individual projects in the areas described. Additional topics may also be added at a later stage if member interests and needs warrant it and resources allow it. However, the work promised below will be done.

We shall continue a systematic study of automated thermal interface assembly. A major part of our effort will be focused on the robustness and reliability of soldered assemblies. We shall address the risk of solder joints failing by pad cratering, as well as through the intermetallic bond to one of the pads, along the solder-intermetallic interface or through the solder. We shall complement this with a limited, focused study to quantify the efficiency of whisker mitigation by conformal coating.

We shall address failure due to drop shock and vibration, as well as because of thermal expansion mismatch induced loading. Importantly, we shall pay particular attention to the accumulation of damage and failure under the combinations of loads common under most service conditions. Current evidence points to dramatic failures of Miner’s rule even under quite simple conditions.

PCB Damage

We shall continue our quantification of the robustness of laminate structures under conditions representative of assembly, use, or rework. Emphasis will be on substrates for lead free assembly.

In general, damage to a laminate structure may include greater temporary and permanent warpage, enhanced moisture uptake and degradation of insulation and dielectric performance, IP separation, weakening of the resin and ‘cratering’, reduced copper (pad) adhesion, reduced solder mask adhesion and delamination, damage to the copper in PTHs and vias, reduced mechanical strength and fracture resistance, reduced chemical resistance, reduced CAF resistance, and cracking of the laminate. We have, however, shown the most common effect of damage, usually becoming significant long before any of the other ones, to be a reduced resistance to pad cratering. More specifically, the first serious effect of damage tends to be much faster cratering under repeated (cyclic) loads. We shall therefore focus on the quantification of the resistance of representative solder pads to cratering (next).

Importantly, we plan systematic studies on a range of new halogen free materials. The scope of these studies will only be limited by the number of materials and structures made available to us.

Pad Cratering

We shall continue to develop test protocols to address the two types of loading leading to solder pad cratering, a single overstress and repeated loads or cycling. We shall also develop a first model for the prediction of life in service. The risk of cratering may be strongly reduced by proper pad design, but this has to be weighed against routing requirements and the risk of intermetallic bond failure instead. We shall continue to update our design guidelines when appropriate.

A growing number of products tend to fail by solder pad cratering rather than through the solder itself. This is so even for SnPb solder joints, because of the new laminates introduced to be compatible with lead free soldering, but the reduced ductility of the lead free solders does make it worse. Cratering is most often the dominant failure mechanism under conditions of overstress and repeated drops or shock, but assemblies have also failed by cratering in vibration and even thermal cycling. In the latter case, at least, this could be traced back to crack initiation in cool-down from reflow.

The risk of pad cratering depends quite strongly on laminate selection and processing, as well as on the pad design. So far the emphasis of our work has therefore been on the development of test protocols for the screening of materials and products and the ranking of alternatives. This requires us to establish an understanding of the different damage mechanisms involved and the resulting systematic effects of loading mode, loading parameters and history, pad design, solder mask design and properties, resin type and filler, resin thickness, glass fiber location, processing, temperature, humidity, etc.

All of this needs to be accounted for by the test protocols, but an even more important point is the definition of the ***type*** of loading of actual concern. In general, cratering may for example be a result of overstressing during cool-down from reflow, ICT, or a single drop in handling or transport. Alternatively, it may be caused by cyclic loading such as in repeated drops or even long term vibration. Failure due to an overstress follows very different trends in terms of the factors above and the resulting degradation mechanisms than does wear-out under repeated loads. In fact, any apparent correlation between strength and wear-out resistance is completely fortuitous.

Major industry efforts focus on the substitution of pad level testing for assembly level testing whenever possible, and proper definition of the former does in fact allow for correlations. We have developed a test protocol, based on a detailed mechanistic understanding, specifically to assess pad cratering due to a single overstress.

This test is of particular interest for manufacturers of products which are not likely to be subjected to more than one significant, isothermal load but which may very well undergo significant thermal cycling. Thermal cycling, and indeed long term vibration, usually only leads to failure of joints through the ‘bulk’ of the solder, but this has been seen to change after an overstress. Ongoing work will therefore extend the protocol to assess the risk of a single overstress damaging the pad, without causing immediate failure but so that life under subsequent cyclic loading is significantly reduced.

A separate protocol is under development to assess the risk of pad cratering under repeated, or cyclic, loads. This will be based on our continuously improving understanding of the mechanisms and factors involved (see above). We have shown pad level testing to become misleading for many applications unless certain differences from assembly level testing are carefully accounted for. These will be documented and incorporated in the protocol.

Even with the optimum design, materials selection, processing, handling and transport conditions pad cratering may still end up being the factor that limits and defines the overall solder joint life under certain cycling conditions. We shall therefore also develop a first model for the extrapolation of our accelerated test results to predict life in service.

Finally, we shall continue our systematic testing of different laminate types and structures. The overall goal here is to add further to our comprehensive data base on PCB materials, as well as to our general understanding.

Solder Pad Finish Issues

The most common solder joint defects not under control of the assembler are associated with the intermetallic bonds to the contact pads. To the extent that samples are made available to us we shall continue our studies of defects on electrolytic Ni/Au and ENIG pads, emphasizing the development of effective screening methods to account for the sporadic nature of the problems. In addition to this we shall address promising new pad finishes and their use with lead free solders.

The industry has lost billions of dollars due to the sporadic occurrence, usually after some aging, of so-called Kirkendall voids within the Cu_3Sn layers on copper pads. We have by now established the means to safely prevent this rather rare phenomenon. We have developed and documented both screening methods and the understanding required to control the electroplating of copper.

Two other, apparently related, sporadic problems associated with soldering to Ni/Au are generally encountered right after reflow. One is the so-called ‘missing ball’ problem where SnAgCu solder balls break off BGAs and CSPs in shipment or component testing. The other is the occasional brittle failure of joints during or right after cool down from assembly. In either case, failure is associated with the intermetallic structures formed on a Ni pad soldered with SnAgCu. The latter problem is also encountered, albeit much more rarely, on Ni pads soldered with SnAg or SnPb if the opposite pad is Cu. We have shown the root cause to be the quality of the plated Ni, and we shall continue to support electroplating research at Binghamton University aimed at reproducing and controlling the phenomenon. Meanwhile, however, we shall focus most of our efforts on the development of an effective screening method.

As is typical of plating related problems failures are usually confined to a few solder pads while joints on the rest seem robust enough for practical purposes. This is often also the case for various problems associated with electroless-nickel-immersion-gold (ENIG) pad finishes which are commonly lumped together under the ‘black pad’ label. These include not only ‘time zero’ failures but also premature failure through the intermetallic bonds in long term cycling. Indications are, however, that the few immediate or delayed failures on a particular substrate simply reflect outliers of a general distribution of inferior pad surfaces. In other words, we seem to be able to identify inferior batches of plating through appropriate testing of a few pads.

A consortium member has promised to supply a range ENIG samples which will be used to establish a base line of typical performances and, together with samples currently known to have problems, validate our screening test. The same test is currently being validated for use with electrolytic Ni/Au.

We have also been promised appropriately designed test vehicles with electroless-nickel-electroless-palladium-immersion-gold (ENEPIG) coated pads. Matching components will be assembled to these for a careful assessment in terms of soldering, joint robustness and reliability. This will be supported by systematic metallurgical studies.

Samples are furthermore solicited from consortium members and suppliers of other new pad finishes, including lead free HASL (specifically SN100CL). Previous studies of SN100C did not reveal any obvious problems, except perhaps for a small reduction in pad robustness, but further work will be planned around sample availability. There is also a special interest in high temperature UBM structures on chips and wafer level CSPs, metallizations that can survive 1000hrs at 150°C or even 500hrs at 175°C. We shall try to identify such structures and test them if we do.

Thermal Cycling Data & Assessment of Life

The behavior of solder joints in thermal cycling is complicated by the ongoing variation in temperature but reliability assessment is still simplified considerably by the fact that non-defective joints only fail through the solder. Nevertheless, in the case of lead free solder joints the suggestion that the actual damage mechanism may be different under some service conditions than in accelerated testing is a major concern. A systematic study will address this. Otherwise, the introduction of other failure modes through combinations or sequences of different loads is dealt with under other tasks (see **Pad Cratering** and **Combined Loads**). We shall continue to add to our lead free solder data base, extending it to include more different cycling parameters and component (joint) characteristics, thus establishing further systematic trends. Based on our learning we shall update our recommendations as to thermal cycling test protocols and simple expressions to predict acceleration factors.

We already have a good, systematic understanding of the performance of SnPb based assemblies in thermal cycling. This was established based on published knowledge and models together with our detailed characterization and testing of over 125 different components, most of them BGAs (up to 2577 I/O, 52.5mm) or CSPs (up to 328 I/O, down to 0.4mm pitch) but also QFPs, leadless components, and passives ranging from 2512s to 0201s. We do not have a strong, mechanistically justified confidence in extrapolations of test results to life in service, but industry experience over decades suggests that life predictions have been reasonable or conservative.

In the case of lead free solders we have shown common thermal cycling tests and data interpretation to be strongly misleading for some applications. Current reliability models do not account for strong systematic effects of solder joint dimensions and resulting microstructure. In the absence of field experience and data this is particularly critical for the prediction of long term life in service, but even the optimization of design, materials selection and processes may be affected. A major ongoing effort is therefore focused on the development of better accelerated test protocols and the quantitative understanding required for the interpretation of the test results. We have already made major progress and a current (preliminary) protocol seems clearly superior to published alternatives. However, we have much further to go.

An additional benefit of our efforts is the generation of useful test data. These come in two variations. For one we are generating thermal cycling results for a range of components of particular current interest. This includes a range of large CBGA and PBGAs, mostly flip chip based, as well as a resistor array, an LGA and a TSOP on a 12-layer PCB. It also includes a representative range of leadless assemblies, notably a variety of 0.4mm and 0.5mm pitch single and dual row components of different sizes with both stacked and single die. Before assembly components and PCBs were characterized in terms of construction, CTE, stiffness, and warpage in reflow.

A different set of experiments employs particularly simple, specially designed and fully characterized model assemblies. Test results for these offer a unique opportunity for the testing or calibration of any reliability models. We shall continue ongoing systematic thermal cycling experiments to further elucidate the effects of various thermal cycling and solder joint parameters. This will include cycle times up to 24 hours and the inclusion of joints with different microstructures (LGAs and passives). Results will be complemented by in-depth failure analysis and general metallurgical studies (see also **Acceleration of Aging** and **Combined Loading** below).

The primary output of these efforts will be significant updates and improvements to our test protocols, including the definition of more highly accelerated tests if possible, together with better acceleration factors. Our rate of progress is primarily limited by chamber (and event detector) capacity, and to a lesser extent by available test vehicles (both components and PCBs).

Drop, Vibration, and Cyclic Bending

We shall also develop test protocols for isothermal cycling, including repeated drops, together with simple expressions to predict acceleration factors.

Unlike thermal cycling most isothermal tests may just as easily lead to failure of a joint by pad cratering or through the intermetallic bond to a pad, as through the solder. So far our efforts in this respect have therefore emphasized the optimization of pad strength and fatigue resistance, together with the elimination of defective intermetallic structures. This includes the development of pad level tests (see **Pad Cratering** and **Solder Pad Finish Issues**) that need to be validated against assembly level tests.

After optimization the solder joint life is however still determined by the competing failure modes. Even just identification of the critical failure mode, the first step in reliability assessment, requires a generalization of accelerated test results to the many other load levels possible in service. For this purpose, and for the purpose of approximate life assessment, we shall establish scaling approaches for both intermetallic and solder joint failure in cyclic loading and validate these against appropriately selected assembly level tests.

Vibration, cyclic bending, and the JEDEC drop test exhibit many similarities, the primary difference seemingly being the strain rates. However, generalizations between these or even just across a wide range of cycling parameters for a single test may be dangerously misleading, at least in the case of lead free solder joints. We have shown the number of drops to failure by cratering to be inversely proportional to the energy input across a range of conditions, but this is expected to be unique to failure in relatively few cycles. The complete breakdown of Miner's rule in milder cycling (see **Combined Loading**), whether failure is by pad cratering or through the intermetallic bond or the solder, must have serious consequences for life prediction.

Even more critical is, however, the indication that the rate controlling damage mechanisms for lead free solder fatigue are completely different in long term vibration or bending in service than in common accelerated tests. We shall quantify the cross over between mechanisms and account for it in accelerated test protocols.

Aside from our model components we shall also test various commercial ones in drop and vibration. This will include a representative range of leadless assemblies, notably a variety of 0.4mm and 0.5mm pitch single and dual row components of different sizes with both stacked and single die. Before assembly components and PCBs were characterized in terms of construction, stiffness, and warpage in reflow. The results will serve to validate and potentially improve on our test protocols, but they will also add to our systematic reliability data base. Finally, all our results will serve as references for testing of the effectiveness of various underfills and corner/edge bonds (see below) as well as for our in-depth studies of damage accumulation (see **Combined Loading**).

We shall also attempt to account for effects of long term aging and degradation under ambient conditions in our accelerated test protocols. Aging at ambient temperatures does, for example, tend to soften the solder, reducing the loads on pads and intermetallic bonds, as well as affect the solder fatigue crack resistance. However, aging and exposure to ambient humidity also reduces the resistance to pad cratering to a degree that depends on resin type, laminate processing and design. In addition, thermal aging tends to weaken the intermetallic bonds.

Acceleration of Aging

The assessment of the reliability of an old solder joint is not as straightforward as commonly assumed. The degradation of pad cratering resistance, which is most obviously linked to humidity exposure, is design and materials dependent (see **Cratering**). The intermetallic bonds tend to weaken as they grow thicker over time. However, the growth rates of the different intermetallic layers in a structure like Cu_6Sn_5/Cu_3Sn vary differently with temperature, so you cannot get the same aged structure faster by heating, i.e. simple acceleration is really not an option.

More critically, we have shown that heating does not simply lead to the same combination of solder properties faster either. Aging of lead free solder joints involves the simultaneous ripening of different types of precipitates, coarsening of dendrites, and grain growth. These mechanisms do not all have the same activation energies, so heating does indeed not simply accelerate the establishment of a given microstructure.

Indications are that long term aging may have order of magnitude consequences for failure modes such as creep rupture and there is a general, urgent need for assessments of the properties and reliability of 10-20 year old lead free solder joints. We shall therefore complement our systematic studies of the effects of accelerated aging on mechanical properties with quantifications of the corresponding solder microstructures. Correlating the evolution of creep properties and fatigue resistance with those of individual precipitate distributions, dendritic dimensions, intermetallic layers and Sn grain structure should allow us to better extrapolate test results to lower aging temperatures and longer times.

Combined Loading

Based on a quantitative understanding of the effects of aging and combinations of load conditions we shall eventually establish a greatly improved approach to accelerated testing, modeling and prediction of life in long term service. Along the way we shall propose new guidelines for ESS testing of lead free soldered assemblies.

It is extremely rare for service conditions not to involve more than one loading condition, if not simultaneous then at least sequential. However, solder microstructures and the associated properties do not only evolve due to aging, they change much faster under a cyclic load. This is a primary reason for the, sometimes spectacular, break down of Miner's rule in the case of lead free solder joints. Failures of this rule are in fact quite common, but so far we have not found any of the existing non-linear damage accumulation rules to apply either.

We shall continue to emphasize simple sequences of the same type of loading, say cyclic bending or vibration, with different amplitudes. Such experiments have led to 'remaining life' values more than 10 times lower than predicted by Miner's rule, a fact that may be of great concern for the application of ESS procedures to lead free soldered assemblies. In fact, we have shown that the common approach to validation of an ESS procedure may not prevent much greater reductions in service life than anticipated.

We shall complement these studies with experiments involving sequences of vibration and thermal cycling. Based on such simple experiments, supported by detailed quantification of the associated solder microstructures, we expect to be able to quantify and generalize the rate of damage propagation as a function of the simultaneously evolving solder properties.

Only when we have developed a quantitative understanding of life under various loading sequences shall we proceed to address the much more complex issue of simultaneous loading conditions. In general, our overall progress will be limited by chamber (and event detector) capacity, and to a lesser extent by available test vehicles (both components and PCBs). However, we expect to propose preliminary new guidelines for ESS testing in early 2010 and to continue to improve on these over the course of the year.

Whiskers & Conformal Coatings

The growth of whiskers from an open Sn surface, or perhaps even from the surfaces of solder joints, continues to pose a critical challenge in a range of high reliability applications. In spite of the very large body of work already done in this area major advances towards a quantitative mechanistic understanding may still be possible. However that would require resources far beyond those of the AREA Consortium.

Instead, we shall focus on a quantification of the effectiveness of various conformal coatings in suppressing Sn whiskers. Emphasis will be on new coatings, including also their effects on resistance to shock and vibration, and we shall address the repairability of any coating claimed to be so.

Thermal Interface Assembly & Reliability

We shall also continue our systematic studies of thermal interface assembly, using filled adhesives etc. as well as tapes. Automated assembly processes may affect the actual performance of thermal interface materials (TIMs) quite strongly. In fact it is common for the effective resistance of a bondline to be higher, often much higher, than predicted based on the materials data sheets. Importantly, such deviations vary strongly from one material to the next depending on the properties and assembly process. In one case we have been able, through the development of a special process, to improve the performance of a high-end material to more than 3 times better than predicted, and further optimization should be possible. In general, we shall continue to optimize processes and compare materials. This will include the optimization and assessment of ongoing performance, i.e. the reliability of realistic bondlines under conditions of surface mount assembly, repair, humidity exposure, aging, and thermal cycles.

Assembly and Rework/Repair

We shall continue our ongoing studies of 2nd level assembly and the resulting reliability, based on which we shall update our quantitative process guidelines (‘cook-books’). We also plan to complement and update our comprehensive ‘cook-book’ on rework, including particular challenges in repair. Returning electronics assemblies for repair after years of service attention is usually not paid to degradation of the PCB and component substrates. However, the new laminates introduced to be compatible with lead free soldering are often prone to pad cratering even before degrading due to aging and exposure to ambient humidity. In addition some are weak at elevated temperatures, raising the risk of significant damage in repair. Such damage may not be immediately noticeable but still lead to rapid failure under even quite mild cyclic loading.

Ongoing work aims to develop a high yield and high reliability assembly process for a generic thermally dense multi-package module with various height components. Subject to the availability of parts and equipment, promised to us by consortium members, CSP assembly experiments will furthermore be extended to include pitches down to 0.3mm as well as wafer level devices supplied with a wafer-applied underfill material. Systems in package (SiP, MCM) assembly will include the low cost attachment of passives directly to a wafer level CSP. Also, the applicability of vapor phase reflow to large, complex lead free assemblies will be explored.

Finally, over the years we have assembled over 100,000 flip chips for the purpose of researching assembly, including underfilling, and reliability issues, and we have established a systematic mechanistic understanding of both. This has resulted in the development of detailed 'cook-books' on flip chip assembly, flip chip underfilling and, separately, no-flow assembly of flip chips. Intended as step-by-step guides for both new underfill process engineers and experienced people they offer suggestions for selecting dispense equipment and underfill materials, as well as practicing with both, developing the actual processes for any given product, and finally failure analysis/trouble shooting. To the extent that there is interest and new issues warrant it we shall continue work to update these documents.

Component Underfilling & Edge/Corner Bonding

We shall continue to optimize processes and assess the robustness and reliability of new underfill and edge/corner bond materials, adding to our empirical data base. This will include a wafer-applied material supplied with wafer level CSPs (see above). Results will provide for updates of a ‘cook-book’ describing the use of pre-applied corner dots, corner and edge bonds, as well as complete underfilling.

A growing number of applications require the underfilling of components such as BGAs and CSPs, not only for mechanical robustness but also to improve life in thermal cycling. This is often a challenge. Notably is it easily possible to end up ***reducing*** the overall reliability, rather than improving it. To further complicate matters many of the applications in question involve very expensive products, requiring repairability even after years of service. Also, so far no reworkable underfill has been found to improve the thermal fatigue life of lead free joints.

Practical Deliverables

The primary focus of our work will be on making our knowledge and results directly, practically useful to the Principals in their daily work. This will be done in the form of data bases, process ‘cook books’ and recommendations, as well as design guidelines and test protocols.

We shall continue to provide data sets particularly suited for anybody to calibrate their modeling of thermal cycling: fully quantified properties of BGA components and substrates together with resulting thermal cycling results for selected lead free solder alloys. This will include both specially designed model assemblies and a range of leadless component and large BGA assemblies.

Along with this we shall improve and update practical test protocols for the thermal cycling of lead free solder based assemblies. This will include the current best approach to an assessment of acceleration factors, i.e. extrapolation to life in service. We shall also develop and update practical protocols for mechanical (isothermal) testing. Notably, this will include protocols for fast pad level tests of cratering due to overstress and repeated loading, respectively.

We shall furthermore develop protocols for thermal preconditioning together with guidelines for the extrapolation of test results to lower temperatures and much longer aging times.

We shall update our protocols for pad level testing of cratering under an overstress and in cyclic loading, respectively.

Step-by-step ‘cook books’ will be developed or updated as needed, covering

- no-Pb assembly
- no-Pb thermal cycling test protocols and acceleration factors
- no-Pb isothermal cycling test protocols and acceleration factors
- pad cratering test protocols
- pad finish defect screening tests
- backward compatible assembly & reliability testing
- PCB materials selection and testing
- PoP, MLF, QFN, LCC, LGA assembly and reliability testing
- component underfilling and testing
- lead free rework and repair
- flip chip assembly & reliability
- flip chip underfilling
- no-flow assembly of flip chips

REPORTS

We will continue to provide access to the reports and data generated via a protected web site. Three annual on-site meetings will be held in the greater Binghamton, NY, area for purposes of scientific/technical discussions and for us to update members on specific technical issues or general project status. Presentations made at these meetings will be repeated in web casts accessible to member companies afterwards. In addition, members are encouraged to contact and/or visit us individually for more effective communication and knowledge transfer. As before we will also solicit the involvement of suppliers as Participants but limit their access to knowledge generated on their products.

COST

Renewal of consortium membership will cost $50,000.00 for a year. New members will be charged $75,000.00 for the first year. This is designed to reflect the fact that a great deal of the basic knowledge development was supported by the current Consortium Principals and that there should be value attached to that knowledge for new members. It also accounts for the extra efforts required to bring new members up to speed.

COMMITMENT TIME LINE

The activity above shall begin on January 1, 2010 and will be complete on December 31, 2010. New members are asked for a commitment in the form of a purchase order by November 15, 2009 to prevent any budget shortfalls. We are, however, not requesting payment until the 2010 calendar year. Also, this payment can be made on a schedule commensurate with your budget cycle. The November 15, 2009, ‘deadline’ does not mean that you cannot join after that, but it does mean that the budget will be largely established by that date. Still, later commitments will allow us to further expand the areas of investigation and/or reach greater depths in our investigations.