NPL National Physical Laboratory

Microelectronics NEWS

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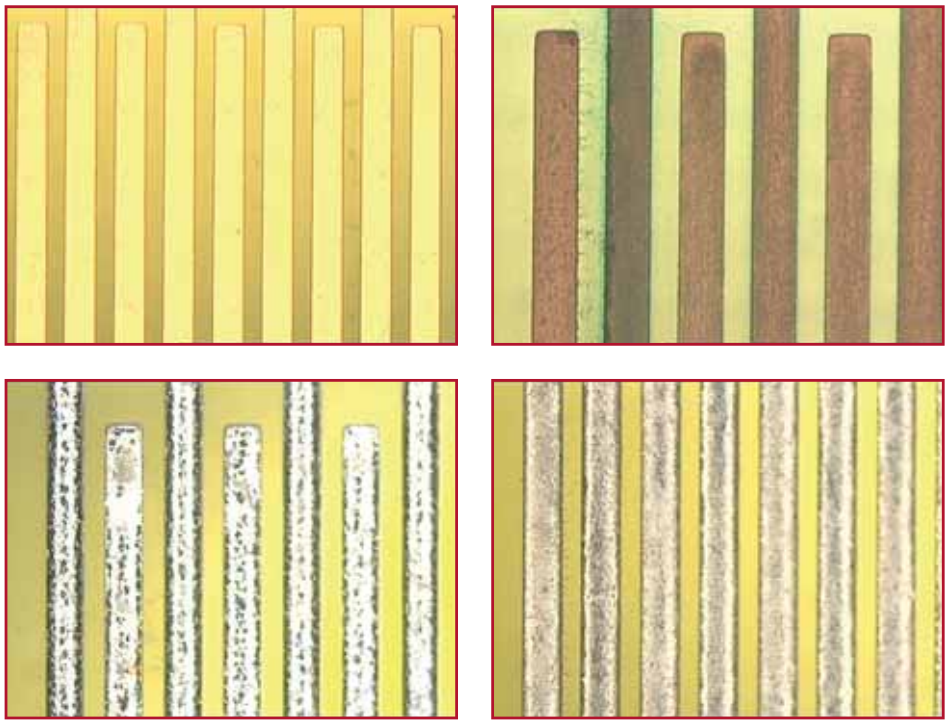

Dendrites formed on SAC and SnPb finished boards

This issue:

Lead-free Systems & Electrochemical Migration

To avoid electrical reliability issues, the contamination of lead-free assemblies must be lower than that associated with a conventional SnPb assembly process. That is the cautionary conclusion from a project just completed at NPL.

Contamination is a prime factor in influencing both circuit performance and long-term reliability. It facilitates electrochemical migration that can result in leakage currents, loss of continuity, or short circuits via the growth of dendrites. Whilst the situation is understood for conventional SnPb solders, there is a dearth of information regarding the new lead-free solders. But this deficiency has now been redressed by NPL who have used the surface insulation resistance (SIR) technique to investigate the effect of lead-free solder alloy and PCB finish (copper and AuNi) on leakage current and dendrite growth. Three fluxes, each at various concentrations, were used as contamination sources to provide leakage currents and subsequent dendrite generation.

The propensity of SnAgCu (SAC) solder to promote dendritic growth was assessed in terms of the critical flux concentration required to form dendrites, benchmarked against that of the conventional SnPb alloy. It appears that dendrite formation occurs more readily with the SAC alloy than with its SnPb counterpart due to silver migration, and hence contamination of lead-free assemblies must be lower than that associated with conventional SnPb assembly processes. Dendrites are also generated more easily with AuNi-finished boards than with their copper-finished counterparts due to nickel migration.

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Department for **Innovation, Universities** & **Skills**

Defects Database

Have you ever wanted access to a library of defect/failure images (of boards, assemblies, components, joints) to help defect diagnosis and implementation of corrective actions?

Such a facility will become available following NPL's work to create a Defects Database as part of its continuing support for the industry. Typical defects include cracking of solder after thermal cycling; copper dissolution; whisker growth; delamination. The creation of the database is industry-driven, and the aim is to provide an on-line, interactive, searchable database of problems provided by industry in a confidential manner. The database will include information on:

- example defects or failures
- material-types
- probable causes
- product application
- service environment
- product volume
- percentage failure

In addition, to get a better understanding of industry issues from a suppliers' point of view, there is the opportunity to add new defects to the database and to contribute to three surveys to establish what are the most common problems. These surveys are aimed at:

- PCB manufacturers; materials suppliers
- Component manufacturers & distributors
- PCB assembly service providers

There are opportunities for organisations to be involved either directly as confidential contributors, or indirectly as users.Please visit: **http://defectsdatabase.npl.co.uk/**

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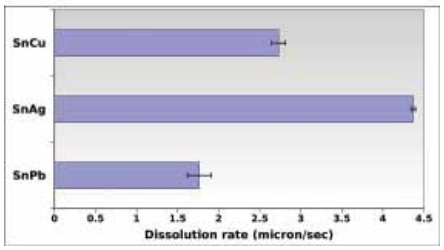
Copper Dissolution in Lead-free Alloys

Understanding the influence of copper dissolution on the reliability of lead-free solder joints will be a large step closer as the result of a new collaborative exercise.

Industry has long known that during soldering, copper on the PCB is dissolved by the molten solder. But the phenomenon is well understood for conventional SnPb solders and can be carefully controlled to avoid any reliability issues. However, the dissolution phenomenon is exacerbated with lead-free materials which are being more widely used due to the RoHS regulations. The loss of copper consequential (unknown) effect on reliability is a cause for concern, since the higher dissolution rates may result in unexpected open circuits and/or weakening of the board structure. Hence a new project is now underway, in which NPL has joined 17 industrial partners to:

- gain a clear understanding of the effect of copper dissolution in lead-free processes, for 5 different solders, using SnPb as a benchmark
- optimise various industrial processes re controlling copper dissolution (contact time; flow rate, pre-heating; bath temperature; form and geometry of the copper; effect of intermetallics)
- produce guidelines on how to minimise copper dissolution
- develop a test piece for measuring copper dissolution

Real industrial processes will be used, studying wave, selective and reflow soldering. The project is expected to report in late 2008.



Comparison of the copper dissolution rates in SnPb, SnAg and SnCu solders

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NPL in Demand Worldwide

A vital part of NPL's work has always been to raise awareness and participation in current research programmes, and to encourage knowledge transfer from the programmes to industry for implementation.

Nowhere is this more essential than in electronics interconnection, where there is a constant demand for NPL staff to present the results of their work on a worldwide stage. For example, in a short period in the of autumn 2007, NPL was invited to make five presentations at four major conferences:

- IPC/JEDEC Conference. 5-10 Oct. Berlin. Susceptibility of lead-free systems to electrochemical migration. **Ling Zou**
- IPC/JEDEC Conference. 5-10 Oct. Berlin. Time lapse photography of β-tin/a-tin allotropic transformations. **Davide Di Maio**
- IEC TC91 Plenary Meeting, 16-19 Oct. Soeul. **Chris Hunt**
- IPC Midwest Conference. 26-28 Sept. Chicago. XRF measurements of residual materials in electronics studio. **Chris Hunt**
- SMTA International. 7-11 Oct. Orlando. Fatigue damage prediction during thermomechanical cycling for lead-free solders. **Milos Dusek**

If you know of any colleague or other contacts in the industry who might like further information on any of these programmes, please contact us.

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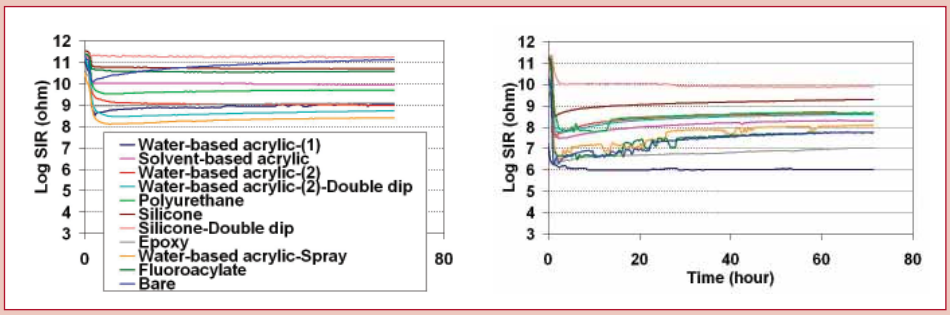
Conformal Coating Integrity

NPL has successfully developed a novel test method which will enable engineers to characterise conformal coatings and determine the degree of protection afforded underlying electronic circuitry.

Conformal coatings are being more widely applied to electronic assemblies for good protection, even in environments previously thought to be hostile for electronic equipment. They must be robust, protective and removable for access/rework. To have confidence in coatings to maintain higher levels of reliability in hostile environments, manufacturers and users need to be able to test them under conditions representative of harsh field environments. But the lack of a standard test method to evaluate coating performance against specific aggressive environments, has hindered wider use of the coatings.

The new method developed by NPL, is significantly different from other methods , and reflects more realistic uses of conformally coated assemblies. The new method combines special test boards, conformally coated using preferred industry processes, to which the chosen contaminants are applied. The boards are subsequently subjected to damp heat exposure and SIR (surface insulation resistance) measurements. The method has been successfully validated by measuring the protection performance of 7 different coating types (inc water-based acrylics; solvent-based-acrylic fluoroacrylate; silicone; polyurethane; epoxy) against solvent-based fluxes, a surfactant and SiO_2 gas. The major findings were:

- the SIR technique provides reliable data on the permeability of the coatings to both moisture and contaminants
- the SIR technique is a suitable discriminatory tool for assessing coating performance, and measuring the reliability of underlying circuitry
- the recommended test conditions are 40°C/93%RH with 50V bias (uncontaminated boards) or 40°C/ 93%RH with 5V bias (contaminated boards)
- the new test method provides realistic and usable information on the performance of coatings in specific harsh environments
- the coating protection performance is both material- and contaminant-specific, and is influenced by component type where shape (and coverage) is an issue



SIR data for various coatings on PCBs exposed to SO_2

Please see last page for details of a report covering this work.

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Honourable Mention Paper at Apex

Further international recognition of NPL's work in Electronics Interconnection was made at the Technical Conference, IPC Printed Circuit Expo/APEX, held in Los Angeles, February 2007.

Chris Hunt was presented with the Honourable Mention Paper Award for his paper, "The role of permeability and ion transport in conformal coating protection". Tom Newton, Director IPC PCB Programs, Standards and Technology said, "The task to determine the best papers is not an easy feat. More than 100 papers were originally screened for consideration as a Best Paper. As the Technical Committee reviewed the screened papers they evaluated each for technical content, originality, test procedures and data used to deduce conclusions, quality of illustrations, and clarity and professionalism of writing."

IEC Award for Chris Hunt

Congratulations to Chris Hunt who has been given the 2007 "IEC 1906 Award" in recognition of his "exceptional contribution to the work of the IEC".

The International Electrochemical Commission (IEC) is the global organisation that prepares and publishes international standards for all electrical and electronic technologies. Chris is a member of the Technical Committees that draft these standards, and the research undertaken by the NPL Electronics Interconnection Group helps to under-pin the standards. The IEC embraces all electrotechnologies including electronics, magnetics and electromagnetics, multimedia, telecommunications and energy production and distribution.

Founded in 1906 with Lord Kelvin as its first president, the IEC has a long history of service to the industry. The "IEC 1906 Award" commemorates the IEC's year of foundation and honours technical experts whose work is fundamental to the IEC.

Relative Reliability of ECA Joints

In order to achieve higher levels of recycling some electronics assemblers are assessing the use of low temperature curing electrically conductive adhesives (ECAs) in conjunction with low cost recyclable substrates.

These systems also have a major advantage of being compatible with current PCB processing procedures. However, there has been no test method for assessing the reliability of such systems which differ fundamentally in construction from conventional solder/glass-reinforced epoxy substrates, and hence have different failure modes.

Work at NPL has now identified a new test method suitable for measuring the relative reliability of electrically conductive isotropic adhesive joints on subtractive thermoplastic substrates. It combines thermal cycling (500 cycles; 55 to 125^{O}C; 5 mins dwell; 10^{O}C/min) followed by 500 hours of damp heat conditioning at 85^{O}C/85%RH, and has been shown to produce failures earlier than do other test procedures. The new method, with its potential for rapid relative reliability testing of comparable ECA, is suitable for identifying the most appropriate material (with high recycling potential) for use in lead-free assembly.

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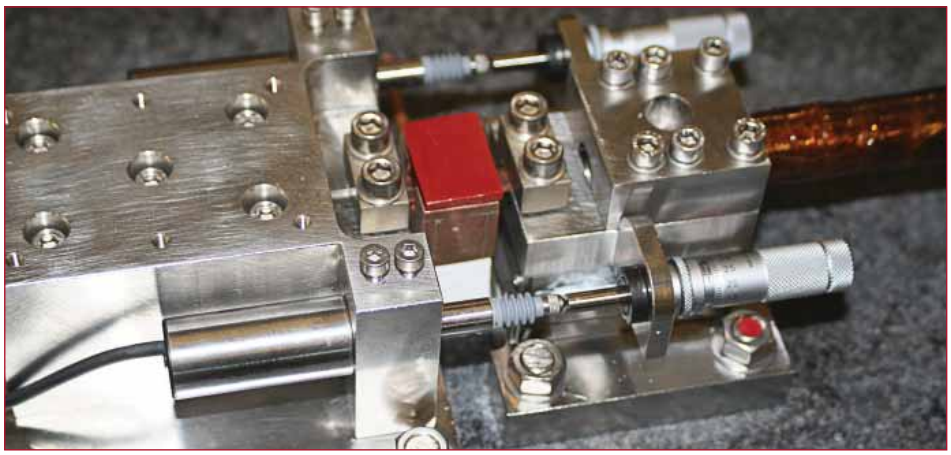


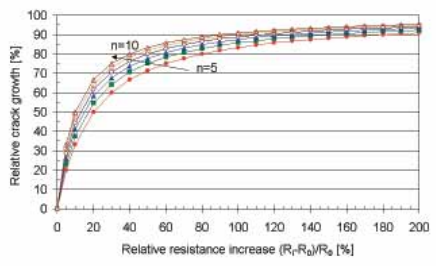
Test specimen

Low Cycle Isothermal Fatigue of Lead-free Solders

NPL has developed a new approach to the gathering of materials data necessary for FEA modelling of lifetime prediction for new lead-free solder joints.

Although the mechanical behaviour of lead-free joints is known to be different from that of the conventional SnPb joints, there is a lack of credible data suitable for modelling purposes. This is a cause of concern for the industry, especially the high reliability sector, which is changing to lead-free soldering materials and processes. Hence the need to generate such data to evaluate likely lead-free solder performance, has assumed some urgency.

The approach adopted by NPL is based on a new instrument, the IPTM (Interconnect Properties Test Machine), which applies defined loading under precision (displacement and force) control to measure materials properties. It also overcomes previously identified limitations. It permits materials data to be obtained from solder samples that have volumes and geometries similar to those of real solder joints, and from joints loaded in shear, mirroring the practical situation in the field. The instrument can also accommodate various solder alloys and surface coatings, and allows direct microscopic examination during the test at room temperature. A 4-point measurement system for resistance monitoring has also been evaluated and found to correlate well with load decreases recorded during fatigue testing of solders. The resistance measurement is directly related to the development of a crack, and hence resistance data can be used to predict crack growth rates. The results indicate that lifetime can be measured using the load decrease and/or the resistance increase. Measuring these parameters directly, for different solders and conditions, and relating them to real assembly performance, will greatly aid modelling of lifetime prediction for lead-free solders.



A model relation between relative resistance increase and crack growth for number of layers n=5 to n=10

Early results are encouraging and suggest that lead-free solder at high temperatures have increased lifetimes. The work has also identified a route to predict a fundamental variable of solder.

Please see last page for details of a report covering this work.

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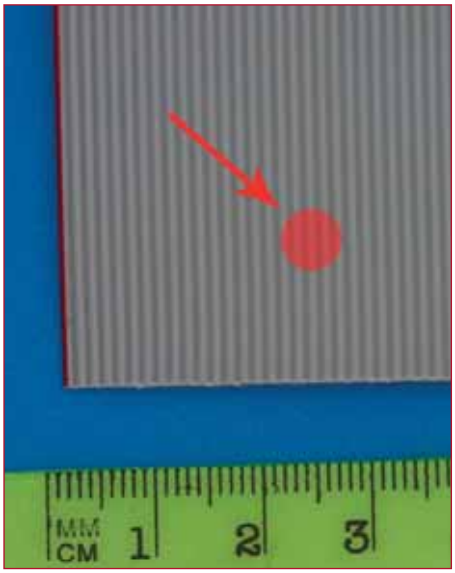
XRF – Proven RoHS Screening Tool

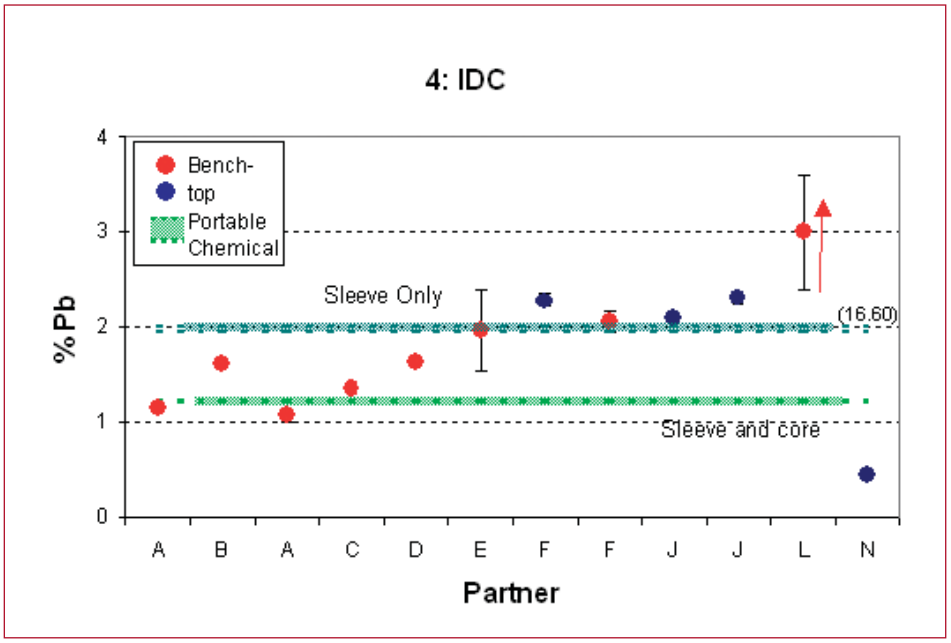
A significant step towards RoHS compliance is to ensure only RoHS-compliant materials are used, and a potential frontline inspection tool is XRF (X-ray fluorescence) spectroscopy. The results of a short NPL-industry study to benchmark commercial instruments (Issue 23, Winter 2006) has now provided some cautionary findings for engineers in the industry.

The results indicate that XRF systems offer a viable method of screening RoHS compliance and tin whisker mitigation. The systems offer low unit cost, low running cost, fast results and small sample requirements. However, care should be exercised in the choice and use of these systems. Also, in order to prevent incorrect interpretation of the data, they require skilled operators having a thorough knowledge of the instrument and a good understanding of the structure and materials of test samples.

Fifteen XRF systems (11 benchtop; 4 portable) were evaluated using 40 typical components and assemblies,



Typical PVC IDC cable with area of analysis shown



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ranging from contaminated plastic components, through bulk solder alloys , to solder joints and solder-terminated components. Among the findings were:

- PIN (semiconductor diode) and SiLi detector based systems are suitable for RoHS compliance measurements in plastics and solders, but proportional counter systems are not.
- Systems using PIN or SiLi detectors could distinguish non-compliant components (containing typically 2000+ ppm of banned substances) from compliant components (typically <500 ppm of banned substances). For intermediate levels the use of additional techniques is required for discrimination
- The PIN and SiLi detectors could distinguish compliant and non-compliant systems containing >1000ppm cadmium.
- Whilst proportional counter based systems could detect RoHS-banned elements at levels >3% e.g. such as found in plastics, below this level the results were questionable, and their use for such applications is not recommended
- For tin whisker mitigation lead levels > 4% are required in the solder. All the systems could detect lead at or below this level, providing the sample was large enough to fill the measurement window 315

Please see last page for details of a report covering this work.

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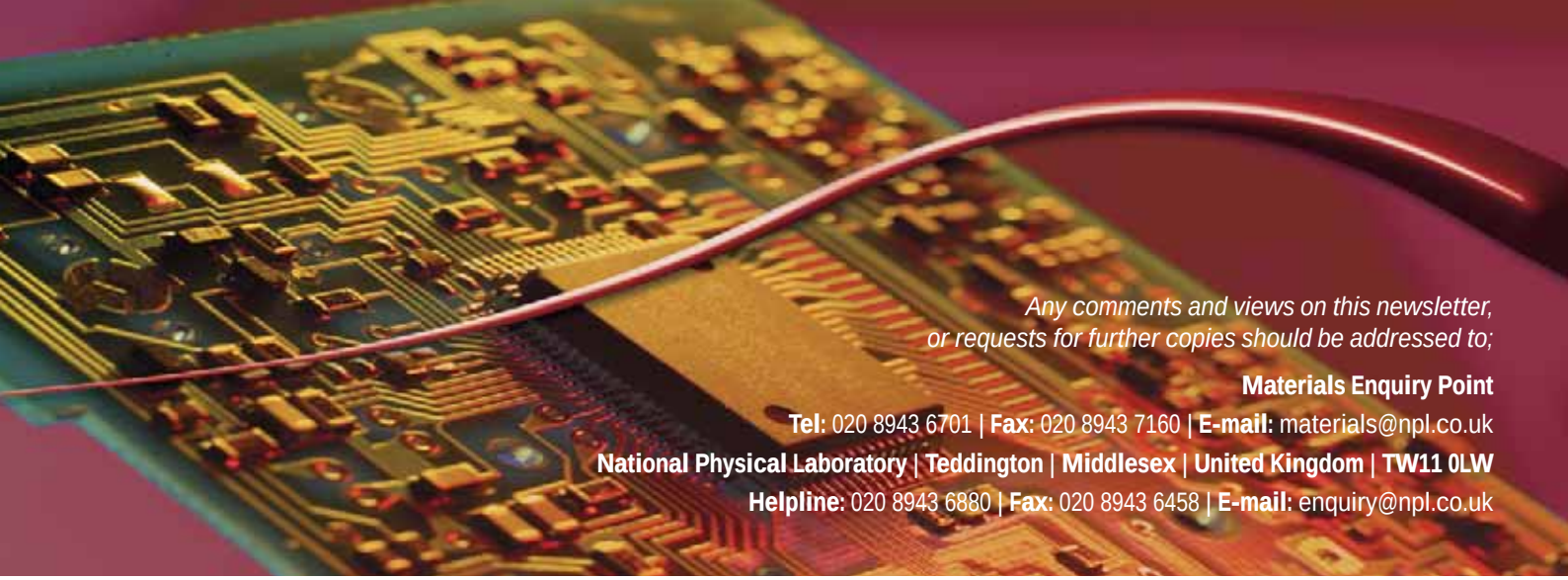

Any comments and views on this newsletter, or requests for further copies should be addressed to;

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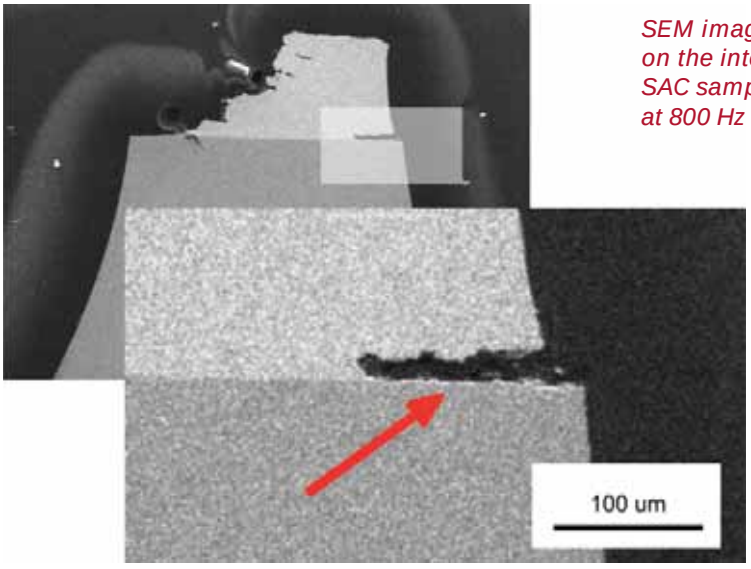
High Frequency Testing of Joints

The behaviour of solder joints in a high frequency environment is better understood as a result of another project carried out at NPL, which particularly highlighted that the high frequency response of lead-free alloys falls behind that of conventional SnPb alloy.

There are many applications in which electronic devices are subjected to vibration. Yet, while there has been much research into the effects of low-cycle fatigue, there has been little regarding high-cycle fatigue. This project addressed this imbalance, generating data on SnAgCu (SAC) lead-free joints, using conventional SnPb solder as a benchmark. The NPL work adopted a general approach using a model solder joint to which controlled vibrations (400 and 800 Hz) were applied, whilst recording joint lifetimes and the materials' response to the vibration. The encouraging findings included:

- the test method is a valuable tool for studying solder performance under high frequency vibration
- the method is particularly useful for ranking various alloys in terms of vibration performance
- the SnPb alloy performed better than lead-free alloys, especially at 800 Hz.
- the higher the concentration of silver in the lead-free solder, the better the performance at 400 Hz
- annealing degrades performance at both 400 and 800 Hz
- lifetime of solder alloys and their ranking are frequency-dependent
- different crack propagation modes are operative at different frequencies
- fracture occurs near, but not through, the intermetallic interface;



SEM image of a crack on the interface on a SAC sample vibrated at 800 Hz

The method has the advantage of tests being easy to repeat with a range of conditions, targeted at specific industrial applications, and hence identify the solder performance for these conditions. The equipment is also easy to modify for testing at high temperatures.

Please see last page for details of a report covering this work.

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New NPL Reports

- Low cycle isothermal fatigue properties of lead-free solders NPL Report DEPC-MPR 058
- Test method for conformal coating protection performance of electronic assembly in harsh environments NPL Report DEPC-MPR 060
- Susceptibility of lead-free systems to electrochemical migration NPL Report MAT1
- High Frequency vibration tests of SnPb and lead-free soldering joints NPL Report MAT2
- Relative reliability measurements for electrically conductive adhesive joints on subtractive thermoplastic substrates NPL Report MN 02
- XRF Measurement of Residual Materials in Electronics NPL Report MAT4

Reports are available from **ling.zou@npl.co.uk** , please provide full contact details.

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