Issue 6 August 2012

SFA Newsletter

Seasons Greetings!

Welcome you all to join as members of SFA! Please find the membership form inside; kindly fill in and contact Secretary of SFA through email.

Experts and experiences:

- Sri. A.K.Jha, VSSC, Thiruvananthapuram
- Prof.R.C. Prasad, IIT Bombay, Mumbai

message from our President

Dear readers,

Warm seasons greetings! I am happy to find the SIXTH issue of SFA newsletter coinciding with the famous festival season that gets underway in August in India. While all of us enjoy some of India's most popular and traditional festivals and celebrations, it is my humble appeal to all my colleagues to nurture brotherhood and revelry towards one another. It is appreciated that the local centres of SFA convene one-day meetings sharing valuable expertise to younger generations.

I wish all of you all the very best in your professional work, reminding of the quotation:"Some people dream of great accomplishments, while others stay awake and do them".

Best wishes to all the readers!

K.Tamil Mani
PRESIDENT, SFA

Edited by: Dr.T.Jayakumar & Dr.P.Parameswaran, Metallurgy & Materials Group, IGCAR, Kalpakkam

From the Desk of Editors

Seasons Greetings! You are glancing through the sixth issue of the Newsletter of Society for Failure Analysis (SFA). Our efforts to build the society have seen success, progressing well during the past few months with the conduct of several activities by our local centres at various places. The successful conduct of one-day workshop at Anna University, Chennai is an example.

We solicited articles for the current issue from failure analysis experts of our country who had worked on many case histories.

We thank the authors for their contributions which are as interesting case studies – one from space department and another from electronics industry- for the current issue.

We take this opportunity to appeal to the Indian industry to use SFA as a forum to share their experiences on trouble shooting. A great way to add content to this newsletter is to include a calendar of upcoming events. The details of important forthcoming international and national events are included; so also the books recently published on the topics of the subject.

We value your comments, which really boost our enthusiasm to perform better. Therefore, as always, your views and comments, mailed to tjk@igcar.gov.in or param@igcar.gov.in are welcome. We wish you all free from failures and a joyful life!

You may visit our web site for your comments/suggestions or any queries : www.sfaindia.org

Kalpakkam (T.Jayakumar)
31-08-2012 (P .Parameswaran)
Editors

*We encourage you to join the society, Kindly fill up the application form (enclosed at the end of the newsletter) and contact secretary: pjayapal59@yahoo.co.in; alternatively, post your application with draft to Dr Eswara Prasad, Regional Director, **RCMA,** CEMILAC, Kanchanbagh, Hyderabad, 500 058*

DRDO Technology Leadership award for 2011

Dr K Tamilmani receiving the Technology Leadership Award-2011 from the Honourable Prime Minister Dr Manmohan Singh, as Honourable Defence Minister Shri A.K. Antony and Padmashree Dr VK Saraswat, SA to RM looks on.

Dr K Tamilmani, Distinguished Scientist and Chief Executive, Centre for Military Airworthiness and Certification (CEMILAC), Bengaluru has been conferred with the DRDO Technology Leadership Award 2011. He received the award from the Honourable Prime Minister of India Dr Manmohan Singh on 31 July 2012. This is a Prestigious DRDO award, presented to exceptional scientists for their valuable technological contributions and leadership qualities in the critical projects of National importance.

As Chief Executive (Airworthiness) of Center for Military Airworthiness and Certification (CEMILAC), has led and outstandingly contributed to several prestigious military aircraft and helicopter programmes viz., LCA (Tejas), ALH, LCH, LUH, IJT, upgradation of many military aircraft like Jaguar, Sea Harrier, Mirage 2000, MiG 27 etc.

He has displayed commendable leadership in guiding 14 Regional Centers for Military Airworthiness (RCMAs) located in various parts of the country in addressing Airworthiness and Certification of Military Aircraft, Engines and Airborne stores.

His contributions go beyond aircrafts and helicopters. He has been instrumental in approving the process for converting the natural gas into aviation fuel and clearing for service use. This was a major revenue saver for the Indian Airforce considering, ever increasing fuel costs and depleting oil resources.

He is a strong believer in indigenization and has been instrumental in initiating several indigenisation programmes like Tyres for aircraft and helicopters, lubricating oil pumps, standard parts and many airborne systems/stores. This had a huge impact in foreign exchange saving.

He is a fellow of Aeronautical Society of India and presently holds the position of Vice President in the National Governing Council of AeSI and the President of Society for Failure Analysis. He is also a Senate Member of Vishsweshwaraiah Technological University, Karnataka. Congratulations!

About the society

Aims and Objectives of Society for Failure Analysis

The aims and objectives of the Society shall be:

To serve as National Society to promote, encourage and develop the growth of "Art and Science of Failure Analysis" and to stimulate interest in compilation of a database, for effective identification of root causes of failures and their prevention thereof.

To serve as a common forum for individuals, institutions, organizations and Industries interested in the above.

To disseminate information concerning developments both in India and abroad in the related fields.

To organize lectures, discussions, conferences, seminars, colloquia, courses related to failure analysis and to provide a valuable feed back on failure analysis covering design, materials, maintenance and manufacturing deficiencies / limitations.

To train personnel in investigation on failures of engineering components and their mitigation.

To identify and recommend areas for research and development work in the Country relating to failure analysis.

To establish liaison with Government, individuals, institutions and commercial bodies on failure analysis, methodologies and to advise on request.

To cooperate with other professional bodies having similar objectives.

To affiliate itself to appropriate international organization(s), for the promotion of common objectives and to represent them in India.

To organize regional chapters in different parts of the country as and when the need arises.

To do all such other acts as the Society may think necessary, incidental or conducive to the attainment of the aims and objectives of the Society.

Know your local centers

Workshop on Role of NDT & Metallography on Failure Analysis, Anna University, Chennai

Anna University, Chennai and Society for Failure Analysis (SFA), Chennai centre organised a one day workshop on " Role of Non Destructive Testing & Metallography in Failure Analysis" on 11th Aug., 2012 at Anna university. Prof. Karunamoorthy, Professor & Head, Mechanical Engineering Department welcomed the gathering and expressed his happiness on interactions among the university and professional bodies. Inaugurating the workshop, Dr. T.Jayakumar, Outstanding Scientist and Director, Metallurgy & Materials Group at Indira Gandhi Centre for Atomic Research, Kalpakkam brought out the importance of non destructive testing and metallography in failure analysis of engineering components. Narrating a few case studies from his vast expertise and experience, Dr. Jayakumar highlighted how various conventional NDT methods and in-situ metallography are very useful for industries where decision making at a quick span is very essential.

Dr. Anish Kumar from IGCAR, Kalpakkam highlighted the advanced methods like thermal imaging in unique studies that were carried out at the centre, thus generating enthusiasm among the participants who have gathered more than hundred in number.

Followed by this, Sri. N.G. Muralidharan, formerly of IGCAR delivered a lecture on various case studies on failure analysis bringing out the essence of NDT and metallography in a lucid manner. Later, he also generated enthusiasm among the participants on the topic In-situ metallography which is basically an NDT method to metallurgically analyse engineering components so that a decision on their service life could be taken. This was followed by a lecture on Scanning Electron Microscopy and fractography by Dr. P.Parameswaran. He brought out the capability of SEM to visualise microstructures with better resolution discussed the replica method as an in-situ method to study fracture surface morphology and further explained how selection of materials and processing conditions play an important role in determining failures in smaller components like manifolds, valves etc.

I've failed over and over and over again in my life and that is why I succeed.
Michael Jordan

To answer the "HOW" and "WHY" of metal failure

Abhay K. Jha
Head, Material Processing Division, Materials and Metallurgy Group,
Vikram Sarabhai Space Centre, Indian Space Research Organisation
Trivandrum 695 022

1.0 INTRODUCTION:

Very often question arises: why metal fails? We say metal failed when one of the three conditions is met. Either component becomes completely inoperable or is still operable but is no longer able to perform it's intended function satisfactorily or serious deterioration has made it unreliable or unsafe for continued uses. Failure of metal resulting in component failure is unavoidable event in the service life of the components which incur heavy economical loss or even many a time human loss. It represents an adverse situation wherein a component fails to perform its intended function satisfactorily. Failure need not accompany fracture all the time, as in the case of excessive elastic deformation due to improper selection of material or error in design etc. In this case, the components fails to meet the very purpose of the intended function, however fracture of metal does not occur. In all such cases of metal failure with or without fracture needs detailed investigations, this uncovers the cause or causes leading to the failure. A failure analyst leads to a rational scenario of sequence of events involved in the failure and assigns the responsibility, either to designer, fabricator, or …… etc. Based on correct, fact-based evidences, a failure analyst reaches to the root cause of failure and suggests remedial measures which preclude recurrence of similar failure.

A failure analyst's job becomes troublesome when he or she could not get the details of the sequences or the history in a true sense. However he uses various analytical tools to reach the fact. The numerous analytical techniques available include mechanical testing, non destructive testing like magnetic particle, liquid penetration, eddy current, radiography, stress analysis using finite element analysis, metallography and others. Metallography serves as one of the effective tools used by the failure analyst to collect the signature of the mechanism left behind failure. This is the tool, which allows a failure analyst to study the metallurgical features of the failed components and correlates with the sequence of the failure.

This paper highlights the comprehensive coverage of both the "How" and "Why" of metal failure with specific emphasis on the significant role of the metallography.

2.0. Cracking in weldment of propellant tank

2.1.BACKGROUND:

Medium strength Al-Zn-Mg Al alloy AFNOR 7020 is extensively used in propellant tanks of satellite launch vehicles. The cylindrical tanks are fabricated by

TIG welding of sheets (4.5 mm thickness) and rings into larger diameters pressure vessels (2100 mm diameters and 6000 mm length). End domes are fabricated through petal construction. Nozzle openings in domes are provided by welding nozzles, which are machined from forgings, to petals. In recent past, one tank, which was successfully pressure tested twice, developed cracks on nozzle welded (shrink fit weld) to one of the fore end side. Figure 1 shows schematic of the tank and location of the crack is shown with more details in figure 2.

2.2 OBSERVATIONS:

Analyses for chemical constituents confirmed material as afnor 7020 aluminium alloy except for marginally higher Mg content (1.6 as against maximum 1.4 %) Visual observation revealed the crack along the fusion line towards the ring side of circumferential weld. The length of crack was 60 mm. at the penetration side and 40 mm at the reinforcement side in the weld overrun region. Polished and etched (Keller's) specimen revealed crack initiation from the pit root (figure 3)

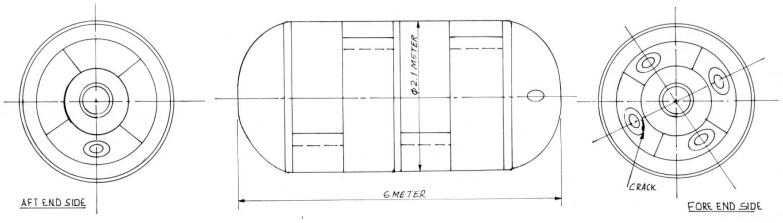


Figure 1. Schematic diagram of tank, domes of aft end and fore end and location of the crack.

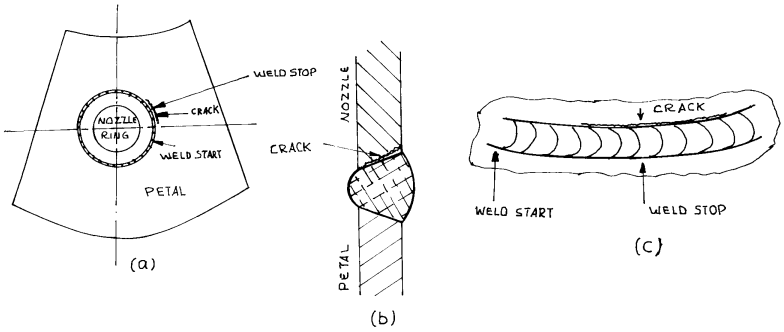


Figure 2. Schematic diagram depicting location of crack

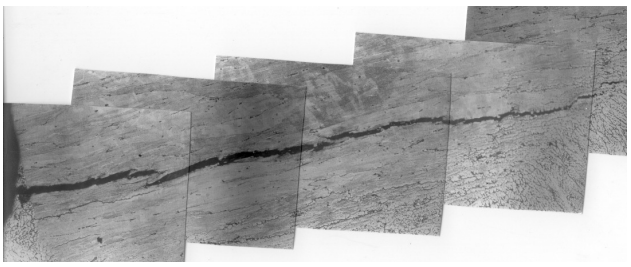


Figure 3. Optical micrograph showing crack initiation from pit root. 75 X

and followed the path of solute enriched region (figure 3). The decohesion at the interface of coarse second phase particles facilitated the crack propagation. Microstructure of the weld pool and the fusion line were typical of weld structure

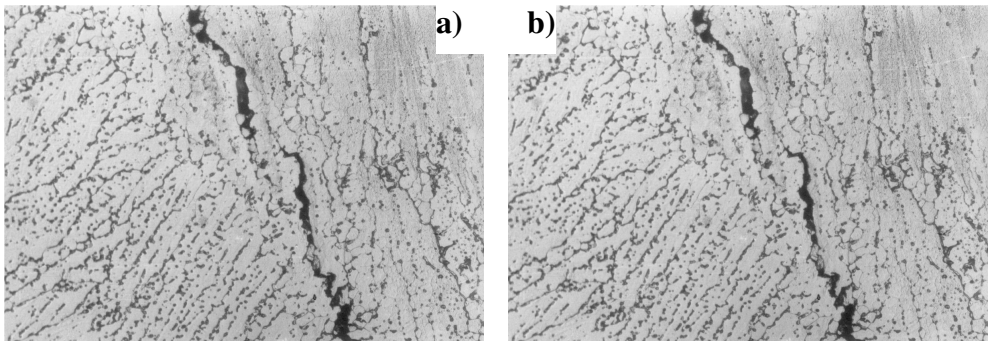


Figure 4. Optical micrograph showing (a) crack path through solute enriched region, 150X and (b) crack tip showing dissolution of solute enriched phase, 375X

Failure is success if we learn from it.
Malcolm Forbes

Microstructure of forged ring revealed second phase aligned along the grain flow direction as well as recrystallised grains (figure.5). The fractographic features viewed under scanning electron microscope revealed predominantly intergranular features (figure 6.a) with crack arrest marks (figure 6b).

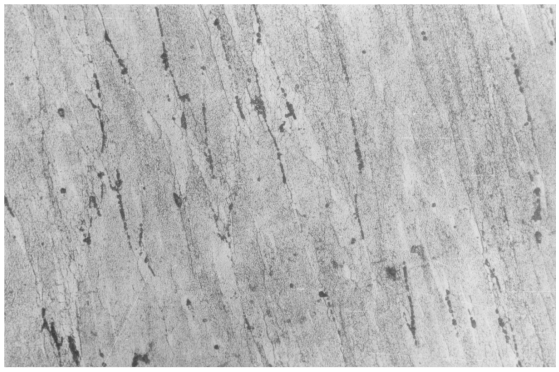
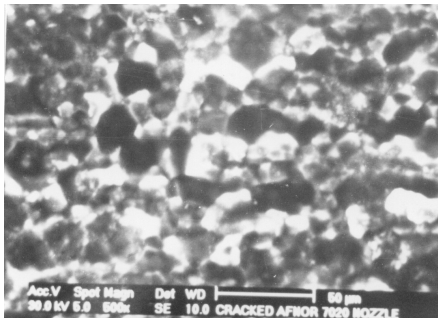


Figure 5. Optical microstructure of forged ring revealed second phase aligned along the grain flow direction as well as recrystallised grains.



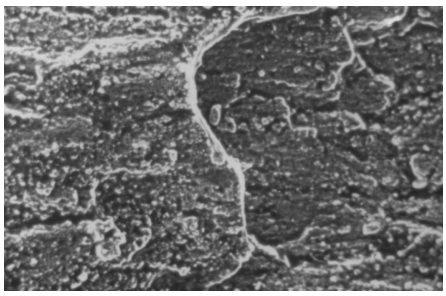


Figure 6. SEM photographs showing (a) predominantly intergranular features and (b) crack arrest marks

3.0.CONCLUSIONS

Cracking initiated from the root of the pit, followed the path of solute enriched dendrite caused intergranular mode of fracture. This confirmed cracking due to stress corrosion cracking. The stress introduced during welding as contractional strain in accommodating the nozzle facilitated the cracking phenomena.

Acknowledgements

The author wishes to thank the Director, VSSC, Thiruvananthapuram for permission to present this work

Failure analysis of LM76 temperature sensor

Devendra Mohan Alhat [a],Ajit Bhandakkar[a] ,S.N. Singh [b], R.C. Prasad [a]

[a] Department of Metallurgical Engineering and Material Science, Indian Institute of Technology Bombay, Mumbai 400076,India.

[b] Roop Telsonic Ultrasonic Limited, A/41, Nandkishore Indl. Estate, Off. Mahakali Caves Road, Andheri (E), Mumbai-93, India

Abstract

LM76 integrated circuit (IC) mounted on a glass epoxy PCB is used for sensing temperature in ultrasonic cleaner and sending the signal to a controller for controlling the system parameters. Reliability of such temperature sensors is very important since an inaccurate temperature measurement could lead to an inefficient system management by the controller and this may even result in systemic failure. In this paper, a premature failure of the pins of the IC has been investigated using Scanning Electron Microscope (SEM) and Energy Dispersive X-ray analysis (EDAX). The reason for premature failure is attributed to poor fabrication, sharp bend design in the pins of the IC leading to residual stresses, improper cleaning of the flux (Mg), etc. The ways to prevent such failures in future is suggested

Keywords: LM76, temperature sensor, failure analysis, ultrasonic cleaner

Background

Failure analysis is a critical element in the development of engineering processes and products. Identifying defects as well as controlling yield-limiting failure mechanisms is fundamental to any manufacturing unit. The LM76 is a digital temperature sensor with a Serial Bus interface used to measure temperature with an accuracy of ±1°C. The component consists of an integrated circuit (IC) mounted on a glass epoxy printed circuit board. A premature failure of the pins of the LM76 temperature sensor has been investigated. All possible failure modes and mechanisms as well as the effect of environmental conditions are described here.

Applications

LM76 temperature sensors are extensively used for temperature sensing in personal computers, system thermal management, office electronics, ultrasonic cleaner, etc. The reliability studies of these components are very important to avoid systemic failure in certain cases. The component under investigation is used as a temperature sensor for ultrasonic cleaner which vibrates with 20 kHz. It passed the information through a serial interface to the computer. The ideal operating environment temperature of the IC is 700°C.

Circumstances leading to failure

The component failed prematurely during service. The failure was predominantly observed in the IC pins, which had sharp bends.

Visual inspection of the failed component

Figure 1 shows the IC and the printed circuit board (PCB) before failure and Figure 2 shows them after failure as could be perceived by the naked eye.

Old accountants never die, they just lose their balance

I honestly think it is better to be a failure at something you love than to be a success at something you hate. **George Burns**

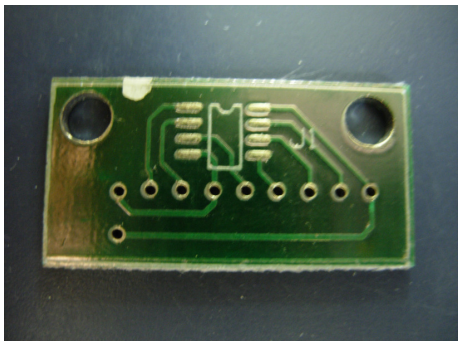
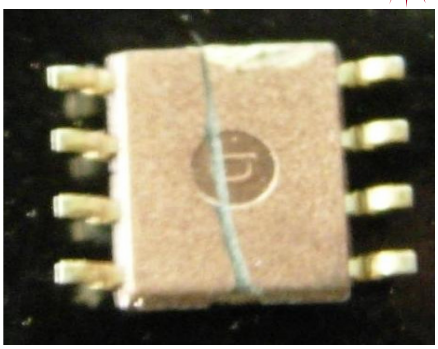


Fig. 1(a) PCB before failure



(b) IC before failure

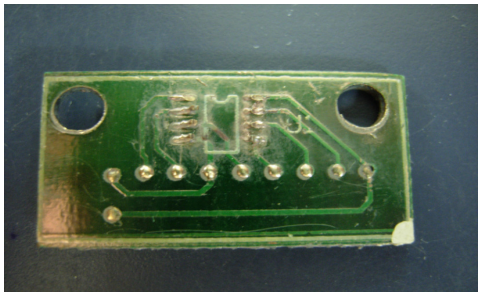
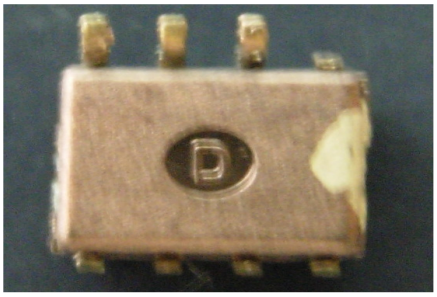


Fig. 2 (a) PCB after failure



(b) IC after failure

SEM and EDX analysis

The SEM and EDXS of the failed regions of the IC were carried out after coating with gold. The images obtained during SEM are shown in Fig. 3 and Fig. 4. Fig.3 shows the pin of the IC which had a bend. The SEM images at lower magnification before and after failure are shown in Fig.3(a and b). However, fractographs of the fractured region shown in Fig.3b, at higher magnification show the presence of microcracks (Fig.4a.). Fig.4b shows the presence of white particles. Fig 5 shows the EDX spectrum of the IC pin before failure. Here the higher amount of Si is observed as it is used in bond/connecting wires. EDX analysis of white particles shown in Fig.4 b confirms that they contain Mg, Sn, Pb in substantial quantities, as depicted in Fig 6 and Fig 7.

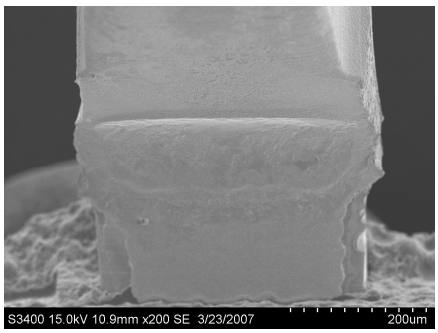


Fig. 3 (a) shows the region of component before failure occurred

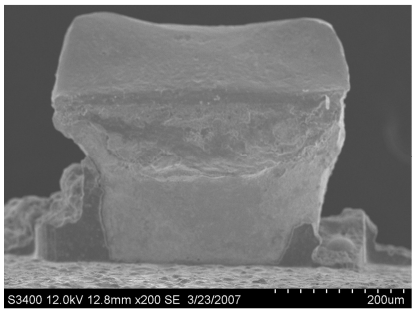


Fig.3. (b) Shows the same region after failure

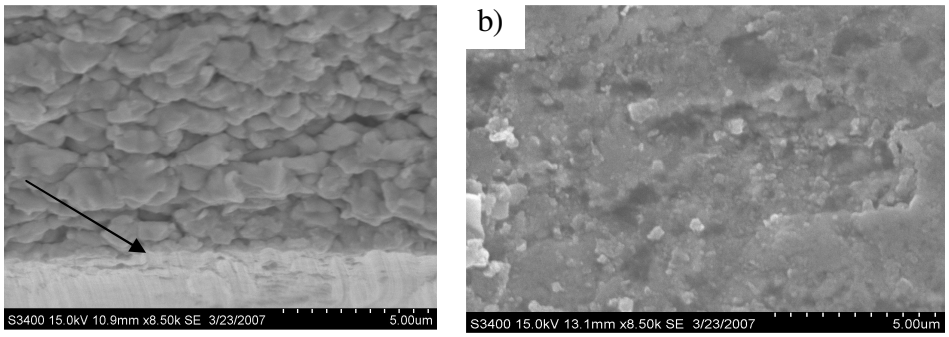


Fig. 4 (a) bend region of the IC leg (interface between the soldered and the pure region shown by arrow) The pure region shows the presence of microcracks which may be one of the factors enhancing the failure. (b) fractured region exhibits presence of white particles which on analysis by EDX spectroscopy confirms that they contain Mg, Sn, Pb in substantial quantities.

Success is not the result of spontaneous combustion. You must set yourself on fire. - **Reggie Leach**

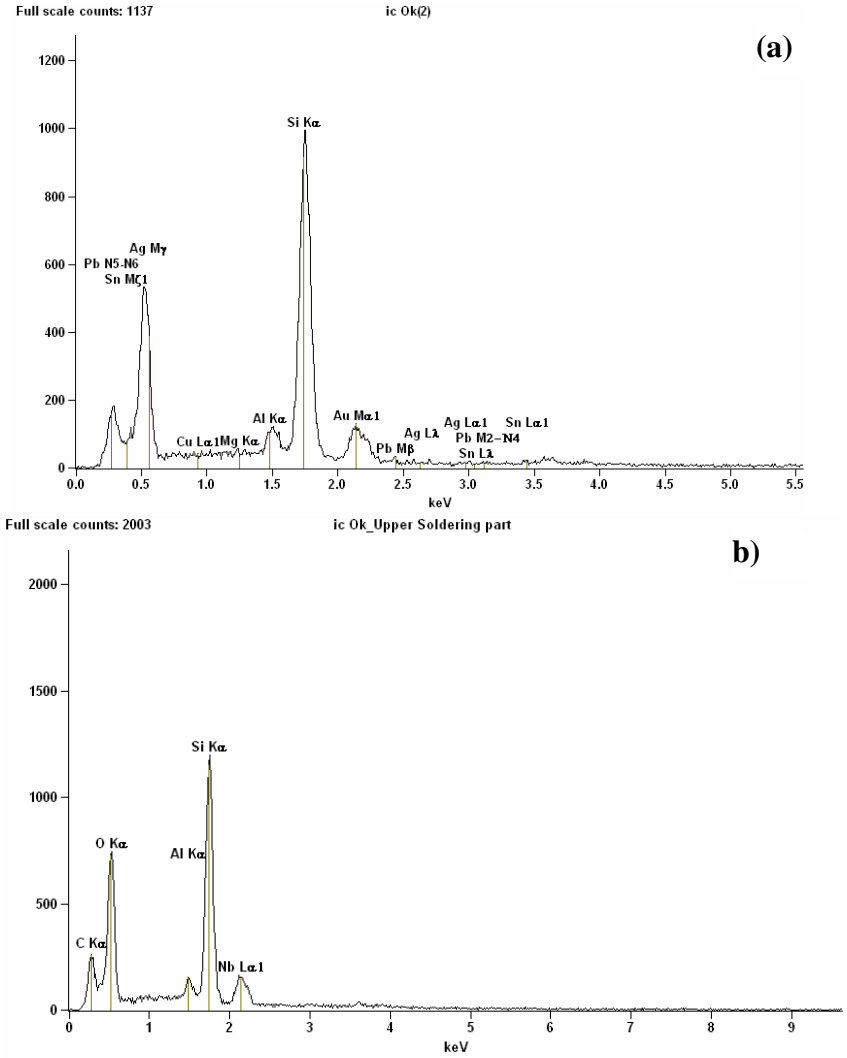


Fig. 5 (a) EDX spectrum of the IC pin before failure in the region far away from bend of the pin
(b) EDX Spectrum of the IC pin before failure in the region of the bend of the pin

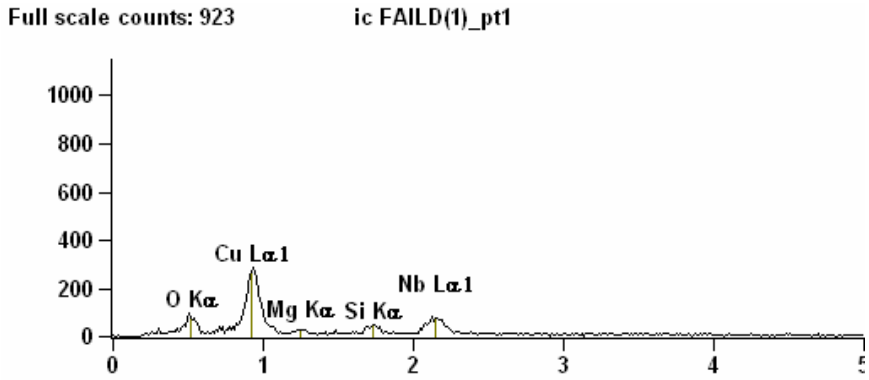


Fig. 6 EDX spectrum of the IC pin after failure in the region of the bend of the pin

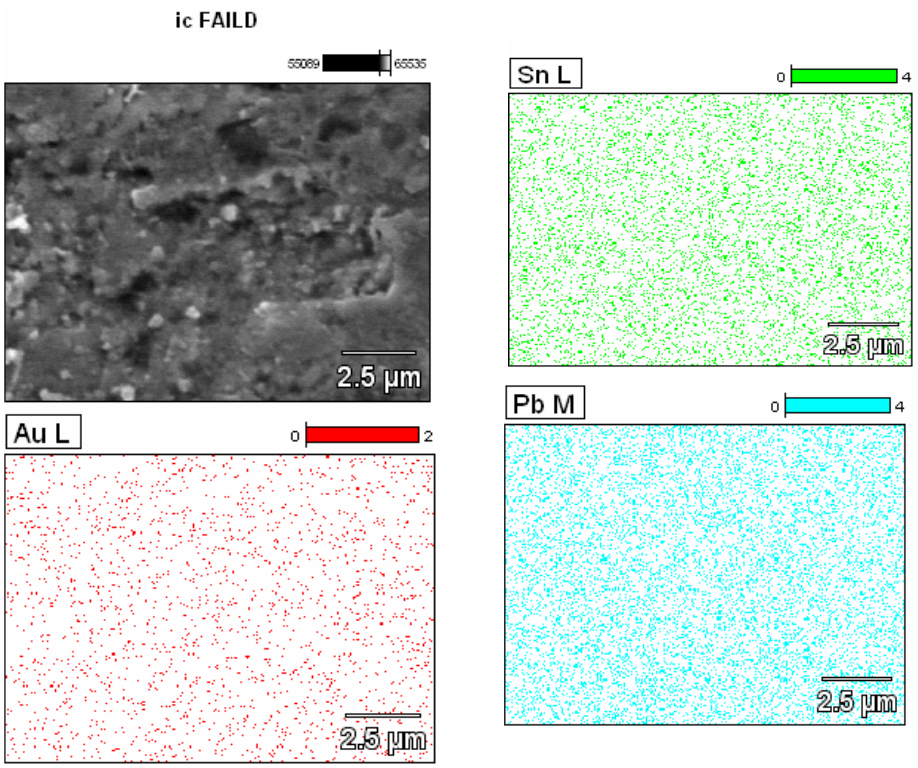


Fig. 7 EDX elemental mapping of Sn, Au and Pb in the white particles observed in the failed sample

Discussion / Probable cause

The SEM fractograph Fig. 3a shows the presence of microcracks in the region near the reflow soldering in the component which is not yet failed (just fabricated or unused component). This region also shows the presence of elements like Mg, Si, Al, and Nb. The region of failure is just adjacent to the bend joint in the leg of the IC pin, where reflow soldering is done. The region of failure shows brittle fracture. This region does not show the presence of Pb in the component which is not yet failed (just fabricated or unused component). However, the same region in a failed component shows the presence of substantial amount of Pb, which is used

during reflow soldering, elsewhere. Mg is found in the bend region of the pin of the component which is not yet failed (just fabricated or unused component). Ideally, flux should have been removed before the actual IC is put into use. A strong possibility of migration of this Pb to the microcracks due to ultrasonic vibrations of the component is predicted and this is confirmed by SEM and EDX spectrum of the failed region in the failed component. This appears to be only source from which Pb can come. The SEM shows the presence of white particles in the failed region. The EDX spectrum of these particles confirms that these contain Mg and Pb. A possibility of leaching of Mg by Pb in this region is also suspected which can lead to substantial crack growth rates. Another possible cause of failure is propagation and growth of the microcracks present in the region next to reflow soldered region in the IC leg by various mechanisms. These cracks grow due to cyclic loading (fatigue) caused by ultrasonic vibrations and also the migration and penetration of Pb in this area. Also the resistive heating of the pin provides the activation energy needed for the intermetallic formation. As the crack grows, the resistive heating increases due to the decrease in the cross sectional area through which the current flows, as the original region where the current could flow earlier is now occupied by empty spaces (cracks). At intermetallic thicknesses greater than 20 µm, brittle fracture between Cu_6Sn_5 and Cu_3Sn are reported to be the most common failure mechanism [1]. The component that we investigated shows the presence of substantial amount of Cu and Sn and the failure in this region is also brittle. In such systems, Au is found to cause embrittlement failure by forming $AuSn_4$, as is reported by others [2]. However, this does not apply to our investigation as the presence of Au is negligible in the failed region.

Conclusion / Remedial methods

The microcracks present due to faulty fabrication parameters grow and cause destructive failure of the pins. Also the cyclic fatigue loading experienced by the pins due to high frequency ultrasonic vibrations of the IC results in faster crack propagation if the pins are too stiff. Migration of Pb from the reflow soldered area can contribute to enhanced crack growth rates. Another possible cause of failure is the sharp bend of the pins connecting IC to the PCB. This may result in high residual stresses when the pins are bent to the desired shape during manufacturing. This is a result of improper design. The possible solution to avoid premature failure may consist of thorough cleanup of Pb from the region of crack formation after reflow soldering. Also proper care must be taken after soldering to avoid microcrack formation during cooling. Lead free soldering techniques like polyphthalamide (PPA) based soldering [3] and others described by W.Falinski et.al [4] may be tried out for lead free reflow soldering .

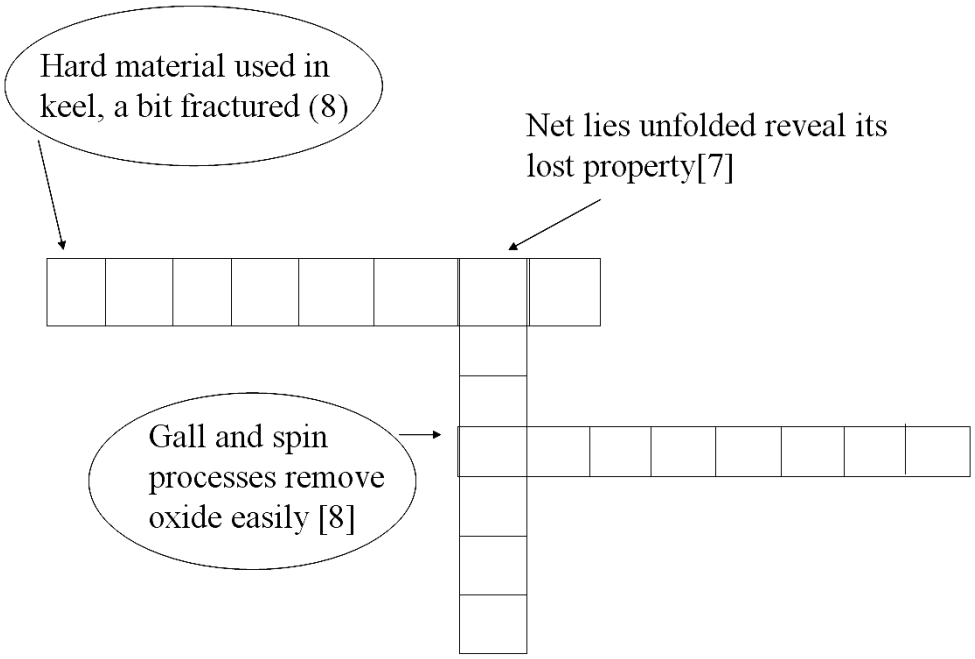
Acknowledgement: The authors would like to *acknowledge the support from Roop Telsonic Ultrasonix Limited, Mumbai for providing the failed* samples.

References:

1. X. Deng, R.S. Sidhu, P. Johnson, and N. Chawla, "Influence of Reflow and Thermal Aging on the Shear Strength and Fracture Behavior of Sn-3.5Ag Solder/Cu Joints", Metallurgical and materials transactions A, **vol. 36A**, 2005, 55, Physical metallurgy and materials science.
2. D.F. Susan, P.T. Vianco, R.P. Grant, P. Hlava, A.C. Kilgo, and G.L. Zender, "Microscopy of Solder Joint Failures Due to Gold Intermetallic Embrittlement", Microscopic Microanalysis 11, (Suppl. - 2), 2005, 1600-01, Microscopy Society of America.
3. K.J. Steffner, "Lead-free soldering", Kunststoffe Plast Europe, **vol. 95**, n 9, 2005, 195-8, Carl Hanser Verlag, Germany.
4. W. Falinski, G. Koziol, H. Hackiewicz, J. Sitek, "Preliminary trials of mass lead free reflow soldering", Elektronika, **vol. 45**, n 8-9, 2004, 209-12, SIGMA NOT, Poland.

Cross word puzzle on failure analysis terminology

See page 16 for answers:



Society for Failure Analysis

Application Form

Society for Failure Analysis
C/O Centre for Military Airworthiness & certification, RCMA (Materials)
Hyderabad550 058

Phone: 040-24340750; 24348377;
Fax : 040-24341827
E-mail: rdrcma.mat@cemilac.drdo.in

Please √ applicable **member** ☐ **Life Member** ☐

1. **Name in Block Letters**

   First Middle Last

2. **Date of birth**
3. **Father's Name/ Husband's Name**
4. **Present Occupation /Designation and office address:** ☐ ☐ **Phone: Mobile: Fax: Email:**
5. **Academic & Professional Qualifications**:
6. **Home address:** Phone: / Mobile: / Fax: / E-mail
6. **Address for correspondence:** **office** **Home**
7. **Professional Experience**:
8. **Endorsement by SFA Member** ☐

Name ☐	Membership No. ☐	Signature ☐

9. **Primary Field of Interest: (please mark 1,2,3 in the in order of preference**)

Strategic	**Power**	**Foundry**	**Welding**	**Heavy industry**	**transport**
Design & Failures	**Quality control**	**Petrochemical**	**Consultancy / services**	**Materials and manufacturing**	**Education**

10. **Name of the Chapter you intend to be attached**_____
    (Please refer to Chapters' list)
11. **Subscription details:**

Payment should be made by cheque / DD favoring **"Society for Failure Analysis"**, payable at Hyderabad. Outstation cheques not accepted.

Amount Rs. Cheque / D.D. No Dated

Bank Name Branch

Category	Amount Payable		
	Admission Fee (One time)	Yearly Subscription	Total on joining
Member	Rs 100	Rs 250 (annual)	Rs.350/-
Life Member	Rs 100	Rs 2000	Rs.2100/-

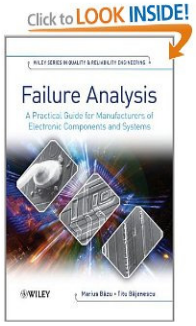
12 **Declaration by the applicant**

If elected, I agree to accept to pay the prescribed yearly subscription, to abide by the Articles of Association of the Society and to promote its aims and objects.

Signature of the Applicant

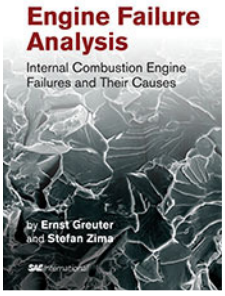
13.	**Office Use Only**					
	Membership No.		Date of Enrolment		Chapter	
	Amount Paid (Rs)		Receipt No. / Date			

Books



Failure Analysis: A Practical Guide for Manufacturers of Electronic Components and Systems (Quality and Reliability Engineering Series) Marius Bazu, Titu Bajenescu:

Failure analysis is carried out to investigate product or process reliability for ensuring optimum performance of the components and systems. Reliability engineers need practical orientation around the complex procedures involved in failure analysis. This guide acts as a tool for all advanced techniques, their benefits and vital aspects of their use in a reliability programme. Using twelve complex case studies, the authors explain why failure analysis should be used with electronic components, when implementation is appropriate and methods for its successful use.



Engine Failure Analysis
Internal Combustion Engine Failures and Their Causes
AUTHOR(S): Stefan Zima, Ernst Greuter
Published By: SAE International
Published: June 2012
Pages: 582

Translated from a popular German reference work, this English edition sheds light on determining engine failure and remedies. The authors present a selection of engine failures, investigate and evaluate why they failed, and provide guidance on how to prevent such failures.

Microelectronics Failure Analysis, 6th Ed. AUTHOR(S): Richard J. Ross
Published By: ASM International
Published: October 2011
This updated reference book, prepared by experts in their fields, contains dozens of articles covering a wide range of topics involving the failure analysis of microelectronics. It places the most important and up-to-date information on this subject at your fingertips.

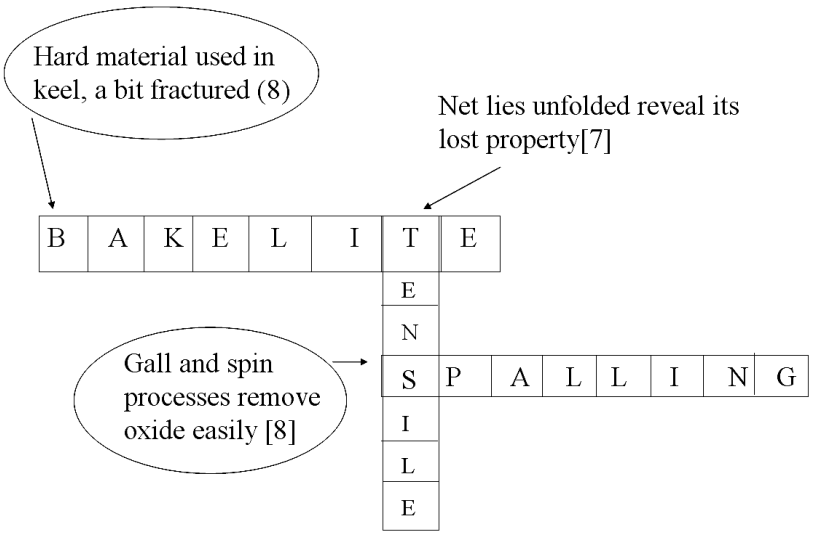
- Techniques Roadmap
- Failure Analysis Operations and Management
- Appendices: Failure Analysis Terms, Definitions, and Acronyms
- Industry Standards

Events in the pipeline

Wear of Materials 2013
19th International Conference on Wear of Materials
Portland, Oregon, USA | 14-18 April 2013
www.wearofmaterials.org

38th International Symposium for Testing and Failure Analysis (ISTFA): Phoenix, Arizona, USA November 11-15, 2012: http://www.asminternational.org/content/Events/istfa/

Answers to the crossword:



We are on the Web now!
Please visit www.sfaindia.org

For Private circulation only

To

From
Society for Failure Analysis (SFA)
C/O Centre for Military Airworthiness &
Certification, RCMA,
Kanchanbagh
Hyderabad-550058