Growth Mechanisms of Tin Whiskers at Press-in Technology

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Abstract
Compliant press-fit zones apply external mechanical stress to copper and tin surfaces of plated through holes at printed circuit boards during and after performing the press-in process. This external pressure increases the tendency to create tin whiskers. These whiskers grow on much shorter time scales than whiskers caused by strain introduced by intermetallic phase growth. Also the length of these whiskers can exceed 2 mm under special circumstances and cause malfunction of electronic circuits. The results shown in this paper support the understanding for the growth mechanisms at different geometrical shapes of press-fit zones and therefore give strong impact on the risk analysis.

Introduction
A large number of studies about whiskers grown by intermetallic phase growth have been performed and collected for the convenience of the scientific and applied research community at the NASA tin whisker homepage [1]. Recently, very detailed studies about the driving forces of whisker growth and micro-scaled strain gradients as well as their relevance for whisker formation have been published [2-4]. Besides, it has been published that other material combinations causing lateral stress, e.g. in phase separating Si-Sn systems, show the growth of Sn nanowires varying in density, length and diameter as a function of the Si and Sn contents [5]. All these publications strongly contribute to the understanding of the whisker formation as a consequence of inner surface strain relieve. Theoretical models have been developed to describe and predict the whisker formation behavior [6, 7] and are in good alignment with specially performed experiments [8]. Less is known about the formation of whiskers driven by external mechanical stress even if first publications appeared already in the 50th [9].
More recently, international standardization efforts are ongoing to support the evaluation of whisker growth by external stress [10]. This paper describes whisker growth in plastically deformed chemical tin plated copper bushings of a plated through hole in standard FR4 printed circuit boards. The deformation is induced by the insertion of different compliant press-in zones. Degree and shape of this deformation differs with the geometry of these tin coated press-fit geometries. The induced stress to the surface of the bushing is large enough to initiate tin whisker growth. These whiskers occur within days reaching lengths of several hundred micrometers. Such stress induced whisker nucleation and growth process is described in [11] and fits well to our observations.

Sample build-up and experimental setup
Ten different compliant press-fit pins qualified for the same design of press-in plated-through holes have been investigated according to their whisker behavior. The zone types have been delivered by different suppliers supporting this project and their product for this study. All press-fit zones are made out of a standard copper alloy base material such as CuSn(4-6) bronze with 0,6 mm thickness of the stamping band. The stamped samples have been electroplated with a 1 µm Ni barrier layer and a 1 µm Sn surface finish. All tin galvanic chemistry used for this study is resulting in a matt tin surface and the chemistries are supposed to be whisker mitigating. Due to the selected set-up of Ni underlayer and matt tin surface the probability of surface whisker growth in the time frames of this work is minimized and can be neglected. 300 of each zone type have been inserted mostly by the suppliers themselves or by the authors according to supplier's specifications respecting international standards [12]. The used printed circuit boards (PCBs) have been coated with 1 µm chemical tin. Those series production PCBs have been designed with an array of press-fit through holes each of 1,05-1,08 mm final hole diameter (used drill bit 1,15 mm, copper layer about 30µm). For preconditioning, the PCBs have been put to a single standard reflow process for Pb-containing solder

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paste representing the case for the maximum remaining free Sn thickness on the board assuming that this will be also the environment for maximum whisker formation. The build-up samples have been stored for 6 weeks under uncontrolled ambient conditions in a cabinet. Relative humidity and temperature has been recorded to be 40 ± 4 % and 23 ± 1 °C during the storage time. In accordance to our observations it has been published recently [11] that the growth of these external stress whiskers is saturating within this timeframe. Following, the samples have been inspected according to their whisker growth. Therefore the assembled boards have been investigated using a metallurgical microscope with 50x magnification. The exit side of the press-in pins (tip of the press-fit zone) shows in the direction of the objective. The set-up has been illuminated from the entrance side in incident light geometry. Scrolling the focus plane through the bushing, the shadow of the whiskers can be detected. This projection of the whiskers has been imaged with a digital camera and the length of the whisker has been measured in x-y plane. An example of these observations is shown in figure 1:

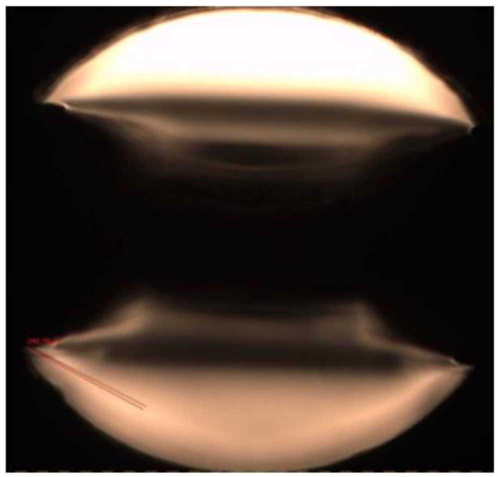

Figure 1- Plated through hole (bright) with a mounted press-in zone (dark). A pronounced whisker of 280 µm length is observed starting in the bottom left corner. The starting point of the whisker is found in the interconnection area between the pin and the bushing which is typical for a "press-fit whisker".

For better illustration of the data the whisker lengths are categorized in the following pages as shown in table 1.

Table 1 - Categorization of whisker length

Category	1	2	3	4	5
Length [µm]	no whisker	≤ 50	51 - 100	101– 200	> 200

Experimental results

The results of this study are summarized in figure 2. Please note that category 1 is not shown for better visibility of the findings. Three basically different press-fit zone geometries are distinguished which will be explained in detail later in this paper: cracking zones, eye of the needle zones and spring shapes. All press-fit zones show whiskers in category 5. Generally, cracking zones show the most and longest press-fit whiskers. More than one pin type of this group showed whisker length above 2 mm in the past that grow out of the press-fit via and bridge with a next neighbor via leading to parasitary current paths and malfunction in the field. An exemption in this group is pin number 4 who shows a much smoother deformation behavior than the other cracking zones. Eye of the needle pins cause in general much lower through hole deformations than cracking zones and a different all in all deformation dynamics during insertion which will be discussed later. This circumstances lead to a much lower whisker formation behavior. Note that in case of improper plating bath control or using bright tin galvanic, the whisker formation behavior can lead to much worse results. The group of spring shape pin types shows a deformation behavior in between the two other groups. The frequency of whiskers is rather high but very long whiskers leaving the press-fit via are not observed as described on the following pages.

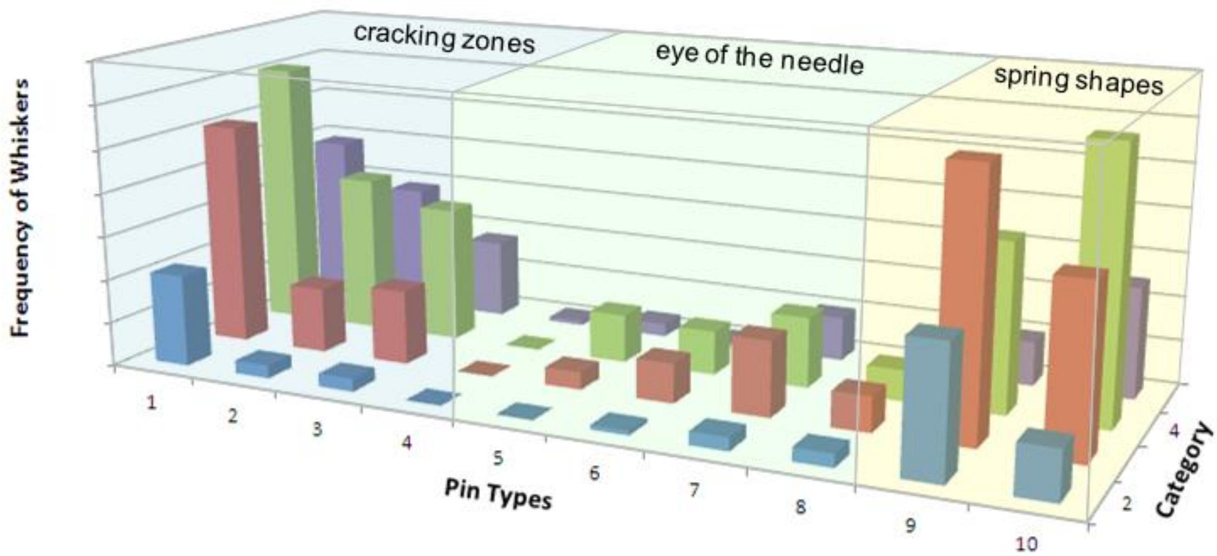

Figure 2 – Overview of whisker length distributions for ten different pin types. The areas of different background colors indicate the groups of cracking zones, eye of the needle and spring shapes.

Cracking zones

This group of pins is characterized by press-in zone types which feature a fillet or a production induced cold welded area that cracks during insertion. The example in figure 3a) shows such a partially massive zone that converts into a compliant zone after the cracking has started. Figure 3b) shows a cross-section horizontal to the PCB plane about 0,3-0,5 mm below the entrance side of the pin. The grey arrow indicates the cracked fillet. The white arrows indicate the positions, where the interconnection between pin and copper bushing of the PCB opens up. These are the positions where the whisker formation is initiated.

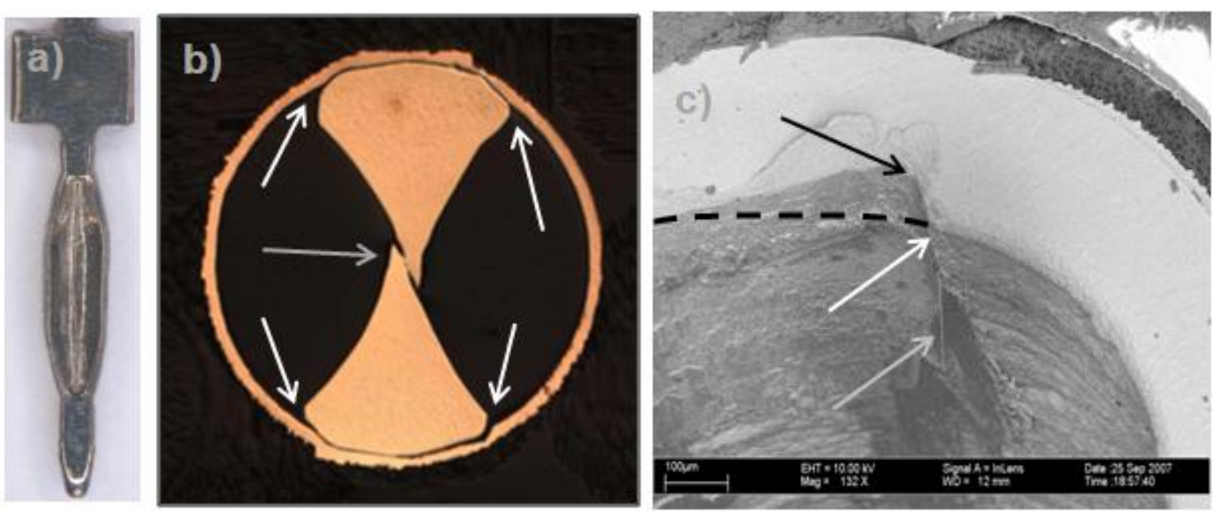

Figure 3 – a) Picture of a cracking zone. b) Micrograph of a cross-section parallel to the board surface at the position of the dashed line in a). The grey arrow marks the position where the web is cracked. The white arrows indicate the areas where the press-fit whiskers start growing. c) SEM micrograph of a press-fit via after the press-fit pin has been removed. The black and white arrows indicate the shape of deformation and the grey arrow marks a press-fit whisker.

Further evaluation using scanning electron microscopy (SEM) shows Figure 3c. Here, the press-fit zone has been removed. The dashed black line indicates the deformation free run of the via rim in case no press-in process has been performed. But large deformation has been observed with a compressive, almost 90° bending of the copper bushing (black arrow in figure 3c) and a lower angled streched deformation (white arrow in figure 3c). The grey arrow indicates a whisker. Note that at the plane of the whisker, the shape of deformation changes: Above this plane, the pin is inserted as an almost massive pin causing rather large deformation values and angles. The tin abration of the press-fit zone happens predominantly at the rim of the bushing which can be observed also close to the black arrow of figure 3c. With progressing insertion, the press-fit zone cracks, the diameter of the zone is reduced and the value and gradient of deformation is much smaller than above this plane. It isn't by chance that the whisker occures exactly at this changeover: when the fillet is broken and the diamter of the press-fit zone is reduced, the tin abrasion of the pin doesn't happen anymore at the rim of the bushing but in the plane where the shape of the deformation changes. Then, the tin of the press-fit zone is abraded at the inner wall of the through hole and delivers the material for the whiskers. To explain the origin of the whisker formation, more detailed investigation explained in the following sentences is necessary. Figure 4a shows a magnification of the whisker in figure 3c. At the footpoint of the whisker steps in the surface of the bushing are observed. Those slip lines occure at the deformation areas of highest compressive stress. In figure 4b these steps are enlarged: the step height is in the range of 600 – 700 nm which fits well with the thickness of the brittle intermetallic phase after one reflow process. Therefore, directly during insertion, pure and highly stressed copper surfaces are exposed and pure tin is abraded from the pin directly to these areas. In the described situation whisker length of above 2 mm have been observed within a period of only a few weeks. Also at the position of the stretched deformation (white arrow in figure 3c), abraded tin and a high amount of nodules are observed (figure 4c).

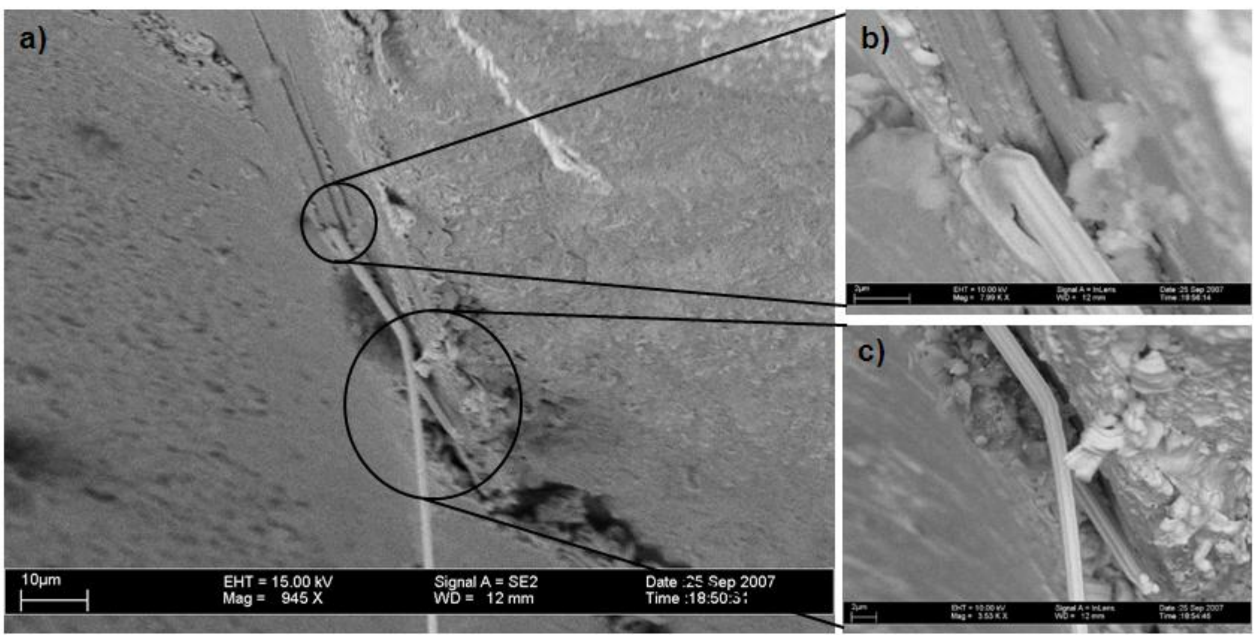

Figure 4 – SEM picture of the whisker formation area: a) position of the origin of the press-fit whiskers is shown in larger magnification in b). The details in c) show strong build up of nodules also at the stretched area of the deformation.

Due to the dynamic behavior of the deformation a cone of free space between the pin and the bushing builds up between the rim of the bushing at the entrance side of the pin and the position where the cracking occurs. This space allows a portion of the whiskers to grow out of the hole and enable the possibility of whiskers to bridge with neighboring pads. For these zones the use of pure Sn finish should be avoided and SnPb should be used instead until alternative lead-free and whisker-mitigating finishes are established.

Eye of the needle (EON) zones

When discussing about eye of the needle zones, a zone type is meant which consists of a longish hole stamped in the middle of the press-fit geometry. An example of such an eye of the needle zone is depicted in figure 5a. This group of press-fit geometries usually shows lower insertion and retention forces as well as lower deformations. See also the vertical and horizontal cross-section examples of figure 5b and 5c. It appears to be a consequence that also the whisker building tendency is widely reduced due to this fact. This circumstance might be a contribution, but the main reason for this behavior is the different insertion dynamics of the needle eye zone. In contrary to the cracking zones, there is no abrupt change of the zone diameter but a continuous deformation of the excess diameter of the press-fit zone during the insertion pathing the entrance ring of the through hole. The tin on the pin is abraded at this edge which can be seen as a thin tin flitter (white arrows in figure 5d), where the pin has been removed from the trough hole for better visibility. The inset demonstrates a tin abrasion in a detailed micrograph of a cross-section where the pin is still sticking in the hole (to the right of the inset). The size of the abrasion is dependent on the thickness of the tin plating and the details of the geometry of the eye of the needle zone.

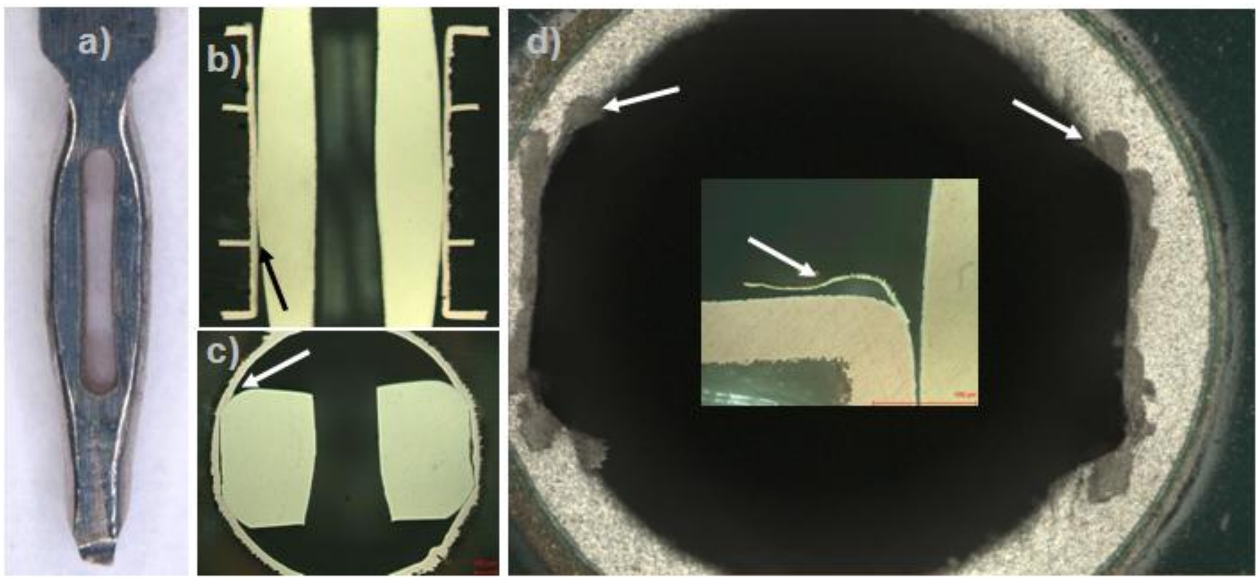

Figure 5 – a) Picture of a eye of the needle zone, b) vertical cross section c) horizontal cross-section d) top view (entrance side) of a press-fit via showing the tin flitters at the positions of hole deformation. The inset shows a vertical cross-section detail of such a splinter.

Nevertheless some whiskers that also exceed 200 µm are observed in a minor frequency on those pin types. As indicated with black and white arrows on figure 5b and 5c, tin agglomeration within the hole on the exit side of the pin and to the side of the interconnection happens. This tin is predominantly residual tin coming from the PCB. This circumstance in combination with the remaining stress in the through hole causes whiskers. The mechanism described here will also occur at the cracking zones additionally to the mechanisms explained in the previous section.

Spring shaped zones

This group of press-fit geometries consists of additional, predominantly elastic pieces that connect the two legs of the zone. An example of the spring shape zone type is shown in figure 6a. Here, the pin has the shape of a boat or bath tub. Other spring shapes consist in multiple springs along the zone. These connecting pieces do not crack or break during insertion. Spring shapes usually don’t show the tin abrasion at the entrance ring as pronounced as the EONs. The insertion and retention forces of these zones are medium high and show a pronounced deformation line along the press-fit via. An example is given in an SEM image where the pin has been removed (figure 6b). The detail of a whisker is shown in higher magnification in figure 6c. Also, the displaced tin along the deformation line is clearly visible. Even if the frequency of whisker occurrence is higher than at the EON zones, the potential for direct bridging is much lower than at the cracking zones since the very long whisker have not been observed yet and the whiskers are not leaving the hole as easy as with the characteristic cone of the cracking zones.

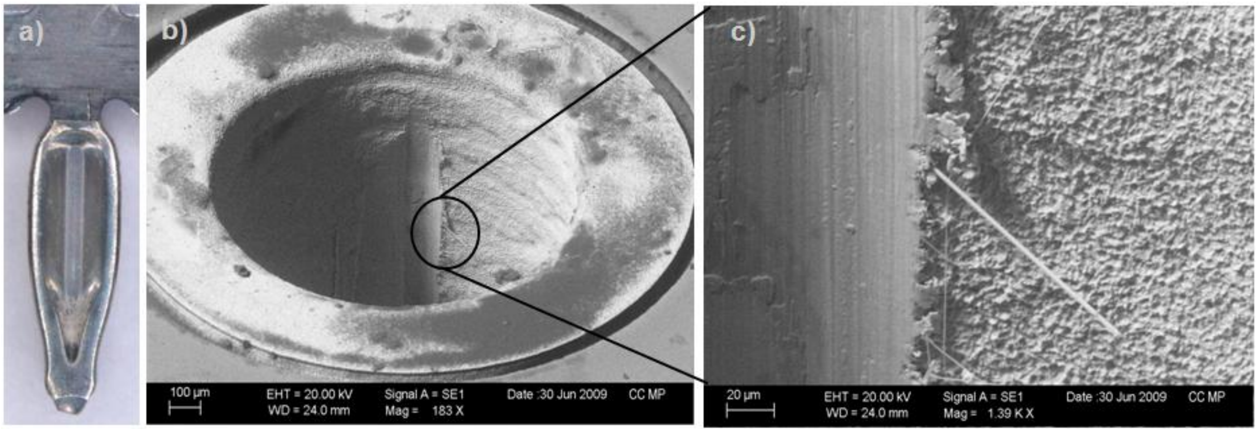

Figure 6 – a) Picture of a spring shape zone type, b) SEM micrograph of the via where the pin has been removed, c) magnified section showing the deformation line and whiskers.

Conclusion

Press-fit interconnections have shown to be highly reliable in all harsh environments in the car even beyond the reliability of solder joints. The key for this reliability is an efficient cold welding between the press-fit zone and the PCB through hole that builds up by pressure induced diffusion processes. The combination of chem. tin PCBs and tinned pins has shown to be optimum to reach this behavior. Before the use of pure tin finishes due to the lead-free legislations, SnPb has been used as standard plating for the pin. We investigated this also highly reliable surface combination to be almost whisker free as observed also by others [2]. For some of the cracking zones, the usage of SnPb is found to be appropriate to eliminate the formation of directly bridging whiskers. For eye of the needle and spring shape press-fit zones pure Sn surfaces will cause whiskers beyond 50 µm in length. But the potential of direct bridging is rather low, especially when the spacing to the neighboring contact surfaces is large enough. Whisker caused malfunction has not been observed for these geometries yet. To find alternatives to Sn and SnPb surfaces, a number of further surface combinations has been investigated in terms of whisker formation, manufacturability and reliability which will be published elsewhere.

Acknowledgement

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Literature

[1] http://nepp.nasa.gov/whisker/
[2] E. Chason, N. Jadhav, W. L. Chan, L. Reinbold, and K. S. Kumar, Appl. Phys. Lett. **92**, 171901 (2008).
[3] M. Sobiech, U. Welzel, E. J. Mittemeijer, W. Hügel, and A. Seekamp, Appl. Phys. Lett. **93**, 011906 (2008).
[4] M. Sobiech, M. Wohlschlögel, U. Welzel, E. J. Mittemeijer, et al., Appl. Phys. Lett. **94**, 221901 (2009).
[5] X. Xiao, A. K. Sachdev, D. Haddad, Y. Li, B. W. Sheldon et al., Appl. Phys. Lett. **97**, 141904 (2010).
[6] K. N. Tu and J. C. M. Li, Mater. Sci. Eng., A **409**, 131 (2005).
[7] Eric J. Buchovecky, Ningning Du, and Allan F. Bower, Appl. Phys. Lett. **94**, 191904 (2009).
[8] Chien-Hao Su, Hao Chen, Hsin-Yi Lee, and Albert T. Wu, Appl. Phys. Lett. **99**, 131906 (2011).
[9] R.M. Fischer, L.S. Darken, K.G. Caroll, Acta metallurgica, Vol 2, 1954.
[10] NP IEC 60512-x-x-, unpublished
[11] Jing Cheng, Paul T. Vianco, Bei Zhang, and James C. M. Li, Appl. Phys. Lett. **98**, 241910 (2011).
[12] acc. IEC 60352-5.

•Whiskers and Alternative Surface Finishes at Press-in Technology

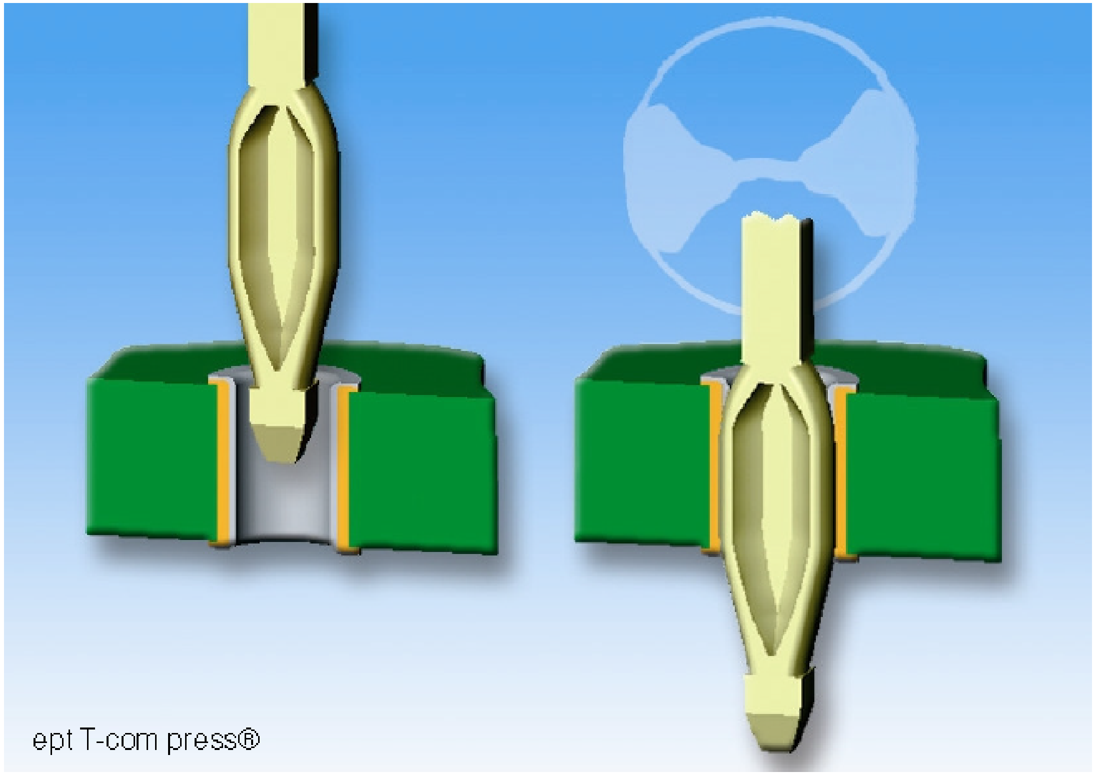
•Dr. Hans-Peter Tranitz

•IPC APEX EXPO, Feb. 28 2012, San Diego, USA

Agenda

- Press-in technology: Why this connection is so reliable?
- Sn whiskers on press-in connections: investigation and evaluation
- Description of most relevant whisker growth mode: example cracking zone
- Whisker performance at alternative surface finishes
- Investigations on selected alternatives
- Summary

Press-fit Technology: Introduction

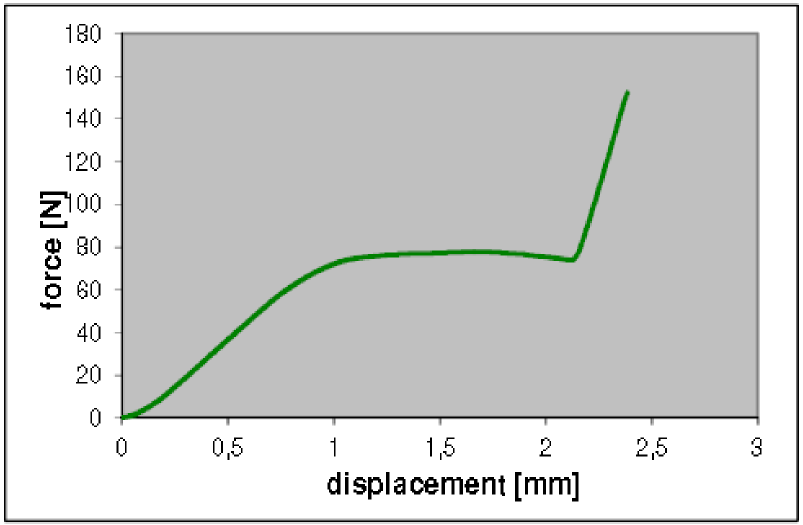


Compliant (flexible) press-fit zone is inserted to a specially designed PCB through hole

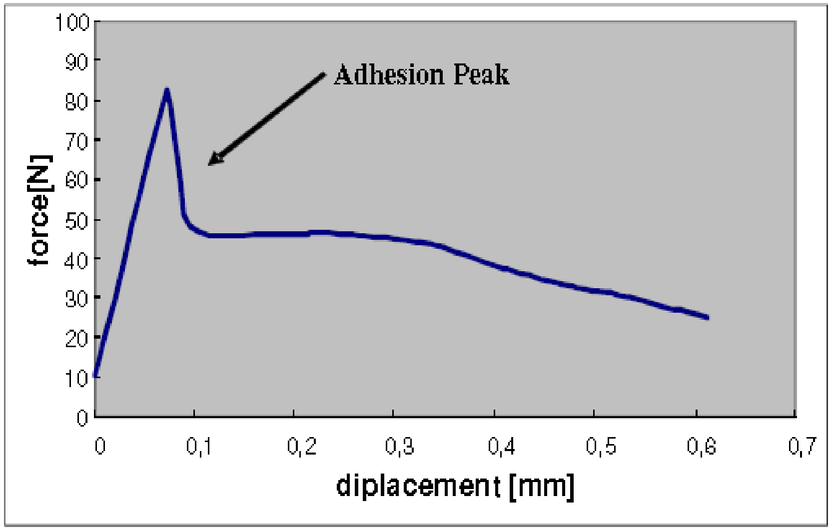
With friendly approbation of the author

Mechanical Properties: Insertion and Retention forces (examples)

Insertion Force



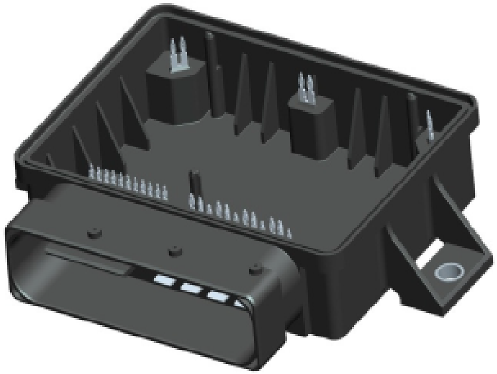
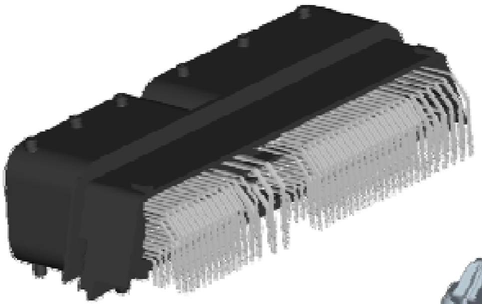
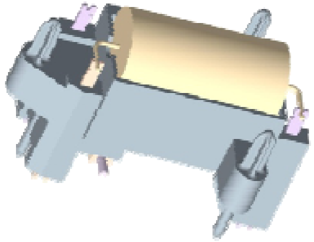
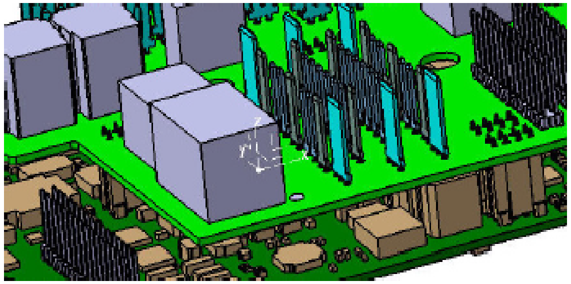
Retention Force



- The remarkable reliability is based on the pronounced adhesion peak: evidence for material diffusion and cold welding
- Reason for large mechanical and thermal stability of the connection/transition
- Mandatory for common application with all different environmental conditions in the car

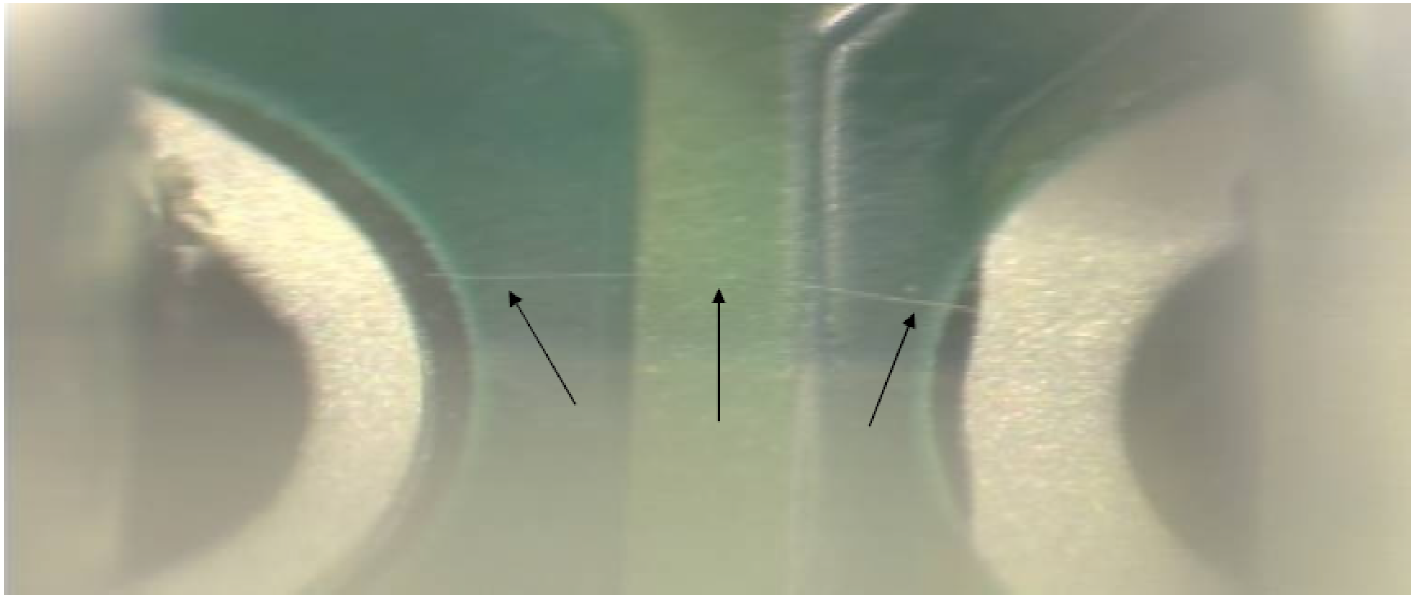
Press-fit Technology: Applications in Automotive Electronics

- Almost all PCB (FR4) based Electronics contains press-fit technology
  - **Chassis and Safety examples:** ABS-electronics, Airbag Satellites and Control Units, Sensors, Electronic Parking Breaks and Electric Power Steering
  - **Powertrain examples:** Engine- and Transmission Control Units, Sensors
  - **Interior examples:** Body Controller, Fuse Boxes, Immobilizers, Door Control Units and many more
- In summary **billions** of press-fit connections in all possible environments in the car and truck
- Press-fit into housing, connectors, component carriers, board interconnections, single standing pins, ….

Occurrence of short circuits

Whiskers potentially create short circuits or parasitary current paths. Fast growth of long whiskers can be observed in press-fit connections due to high mechanical stress **at pure tin surfaces**.



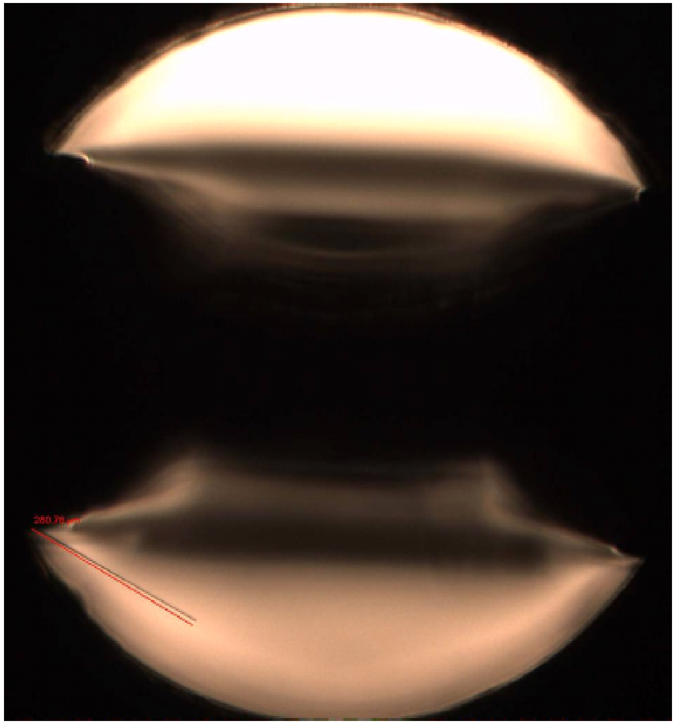
- Some 0-km and field returns identified at a control unit 2007
- Whiskers create direct parasitary signal path at sensor exits (very low current flow)
- Whisker length > 2 mm within 2-6 weeks after insertion in this case

Direct bridging of low signal electrical contacts

Comparative Study: Set-up of Investigation and Evaluation

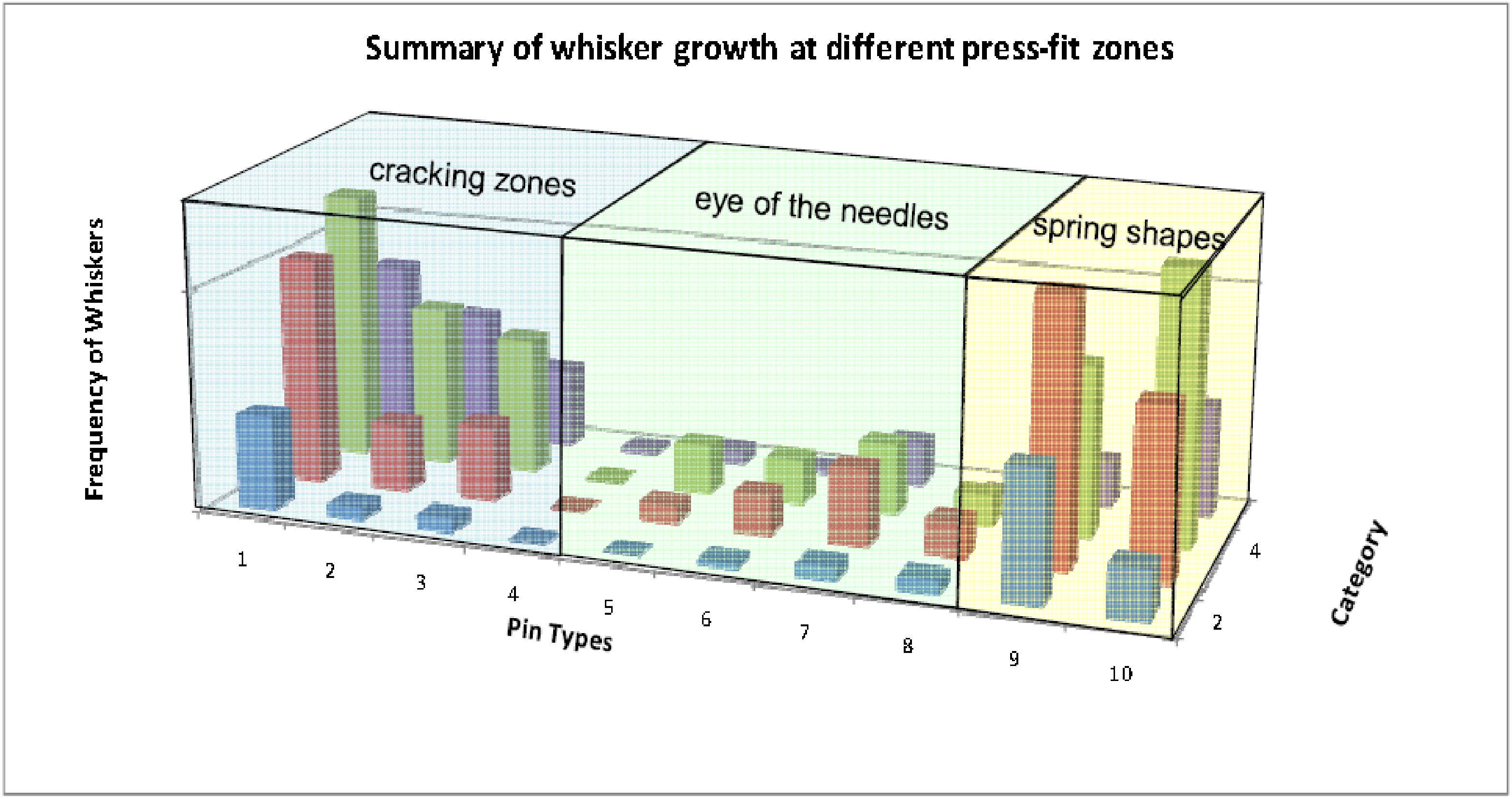
- Using series production PCBs of one product
- PCB pretreatment: series production reflow process (1x lead-containing reflow profile)
- Numerous types of series production press-fit pins with the same thickness of pure tin surface
- 300 pins of each type inspected: representative sample size
- 1000 h storage at 23 °C and 40% rel. humidity (cabinet)
- Whisker inspection with standardized method
- Categorization

Category	Length [µm]
1	0
2	< 50
3	50 - 100
4	101 - 200
5	> 200



→ **representative test set-up**

Whisker Growth on different press-fit geometries (10 variants)



Results:
- One cracking zone shows better performance (4) than the other pins
- All press-fit zones show whiskers > 200 µm

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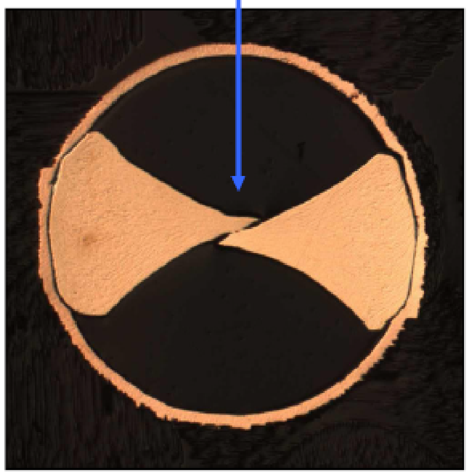
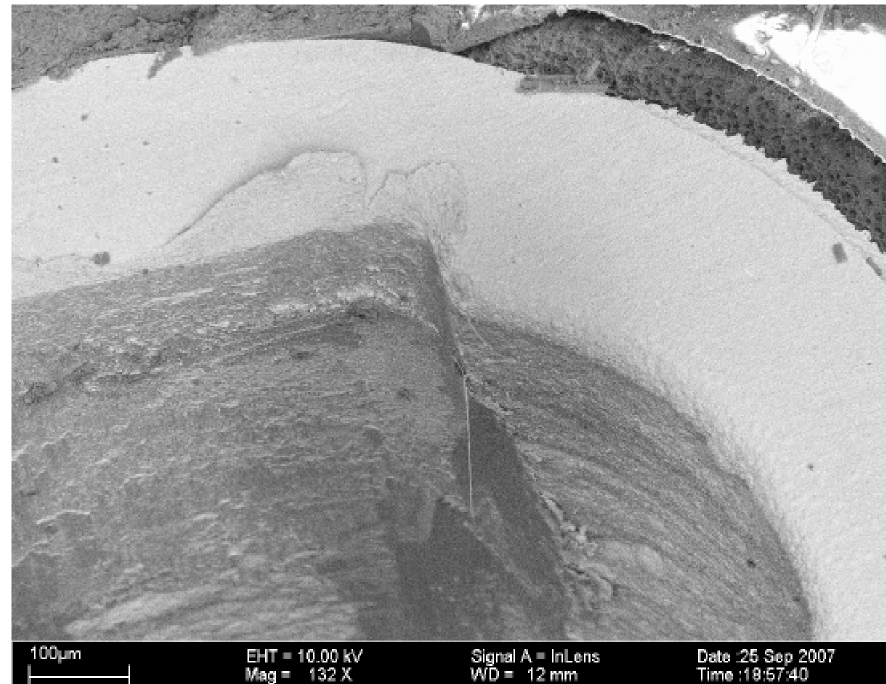
Whisker Behavior of Cracking Zones (example)

Some fillet or similar mechanism is cracking fully or partially during insertion

- pin removed
- entrance area: large inelastic deformation
- pin cracking in entrance area
- surface stress is a well known mechanism

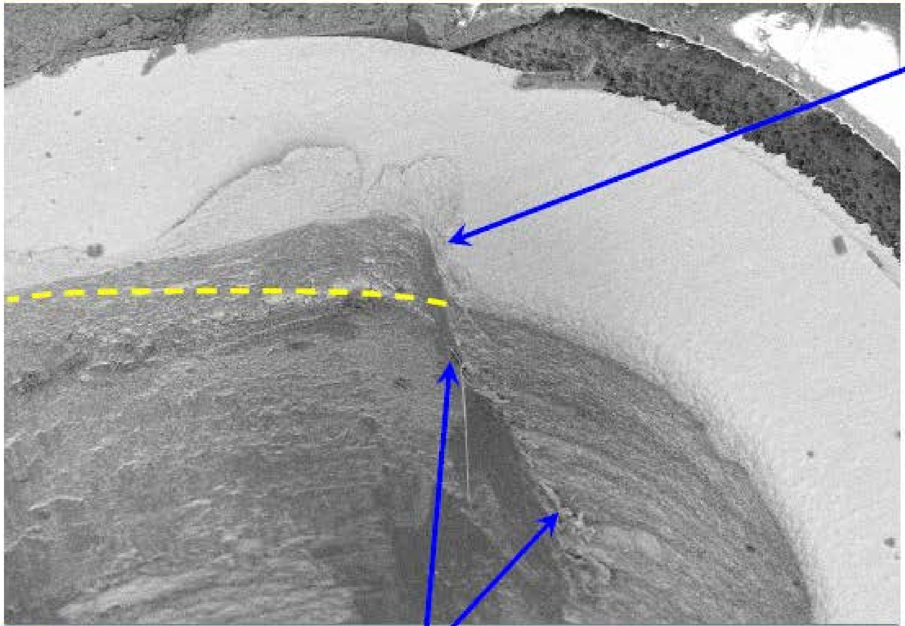
cracking during insertion





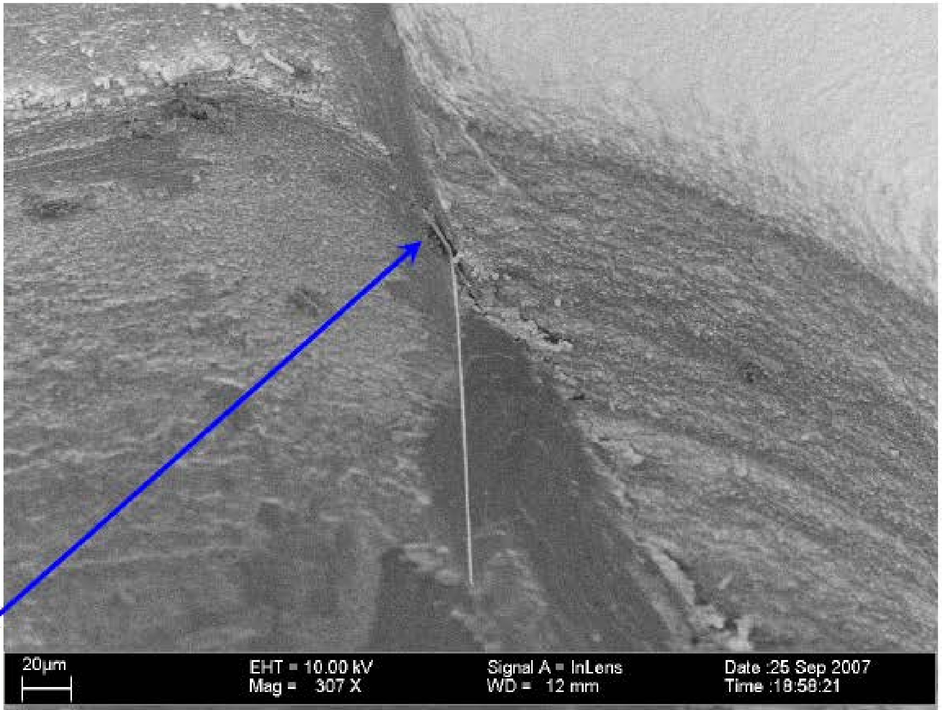
Cracking zones: Long whiskers grow in entrance area of the PCB

SEM (press-fit pin removed)



- Area of greater plastic deformation in the PCB
- Expansion of the copper material in the area where the pin enters
- Surface tension is a known mechanism for whisker formation

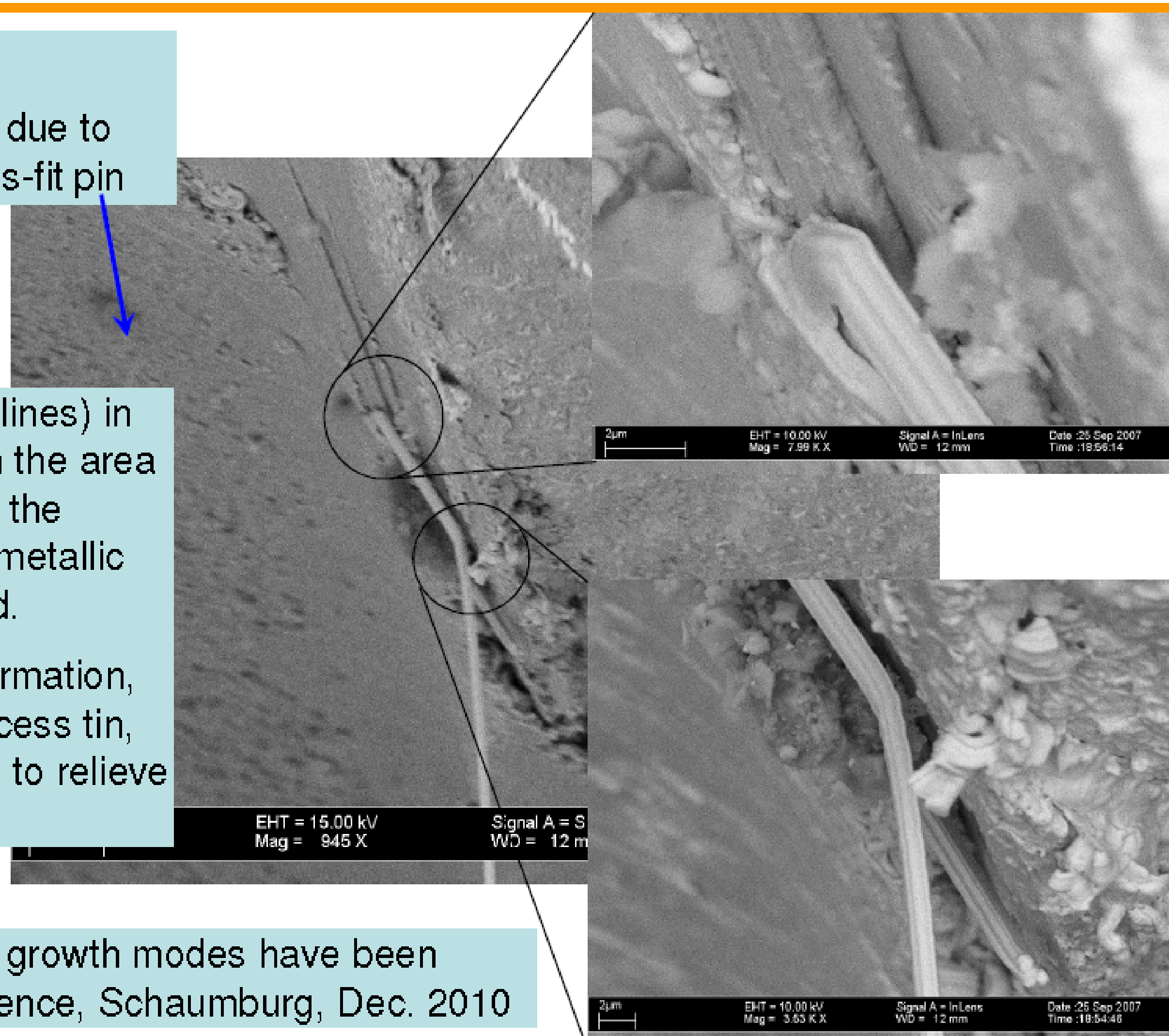
- The tin layer of the pin peels off "upward or laterally" against the press-fit direction and adheres to the PCB in the upper area of the through-hole



- Observed whiskers originate in areas of great deformation where the press-fit pin enters.
- Point of origin is the copper bushing of PCB

Details in the Area of Deformation

- Area of "stripped" cold welding
- Tin/copper material interlocking due to the contact pressure of the press-fit pin
- Top right: Expansion steps (slip lines) in copper, arise from pressing-in in the area of greater material stress. Here, the initially closed layer of the inter-metallic phase is probably also damaged.
- Bottom right: In the area of deformation, seed crystals grow using the excess tin, so-called nodules and whiskers, to relieve the surface tension.



- More details about the different growth modes have been reported at IPC Whisker conference, Schaumburg, Dec. 2010

Development of Alternative Surface Finishes on Pin and PCB Pure Tin Containing Alternatives

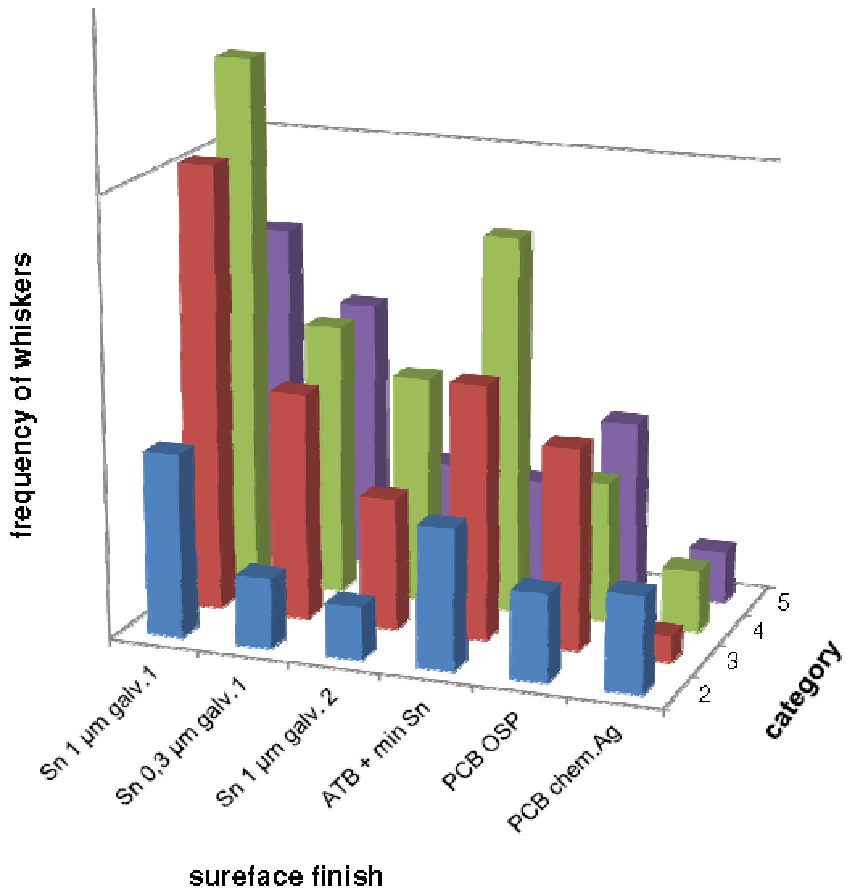
Analysis of alternative finishes:

- Using Pin Type Nr.1 (most whiskers)
- First four variants using imm. Sn PCB varying finishes on the pin
- Last two using OSP and imm. Ag PCB finish, standard Sn finish on the Pin

Results

- No significant dependence on tin thickness in the specified range (0,3-1,5 µm)
- PCB finish chem. Ag shows less whiskers than PCB finish OSP → pure Ag surface seems to have a mitigation effect

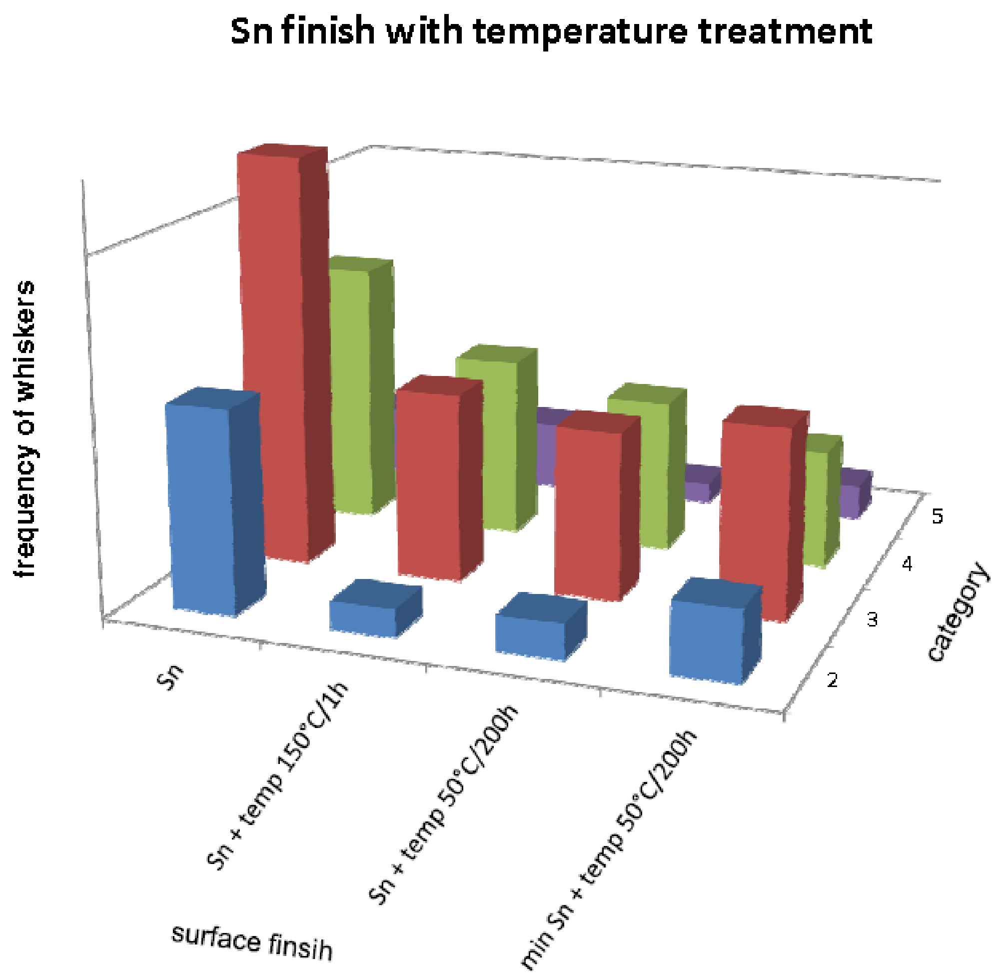
Pure Sn finish (over Ni)



Sn finishes with temperature treatment of the pins

Used materials:

- Pin Type 9 (variants 1-3)
- Pin Type 3 (variant 4)
- Imm. Tin finish on PCB



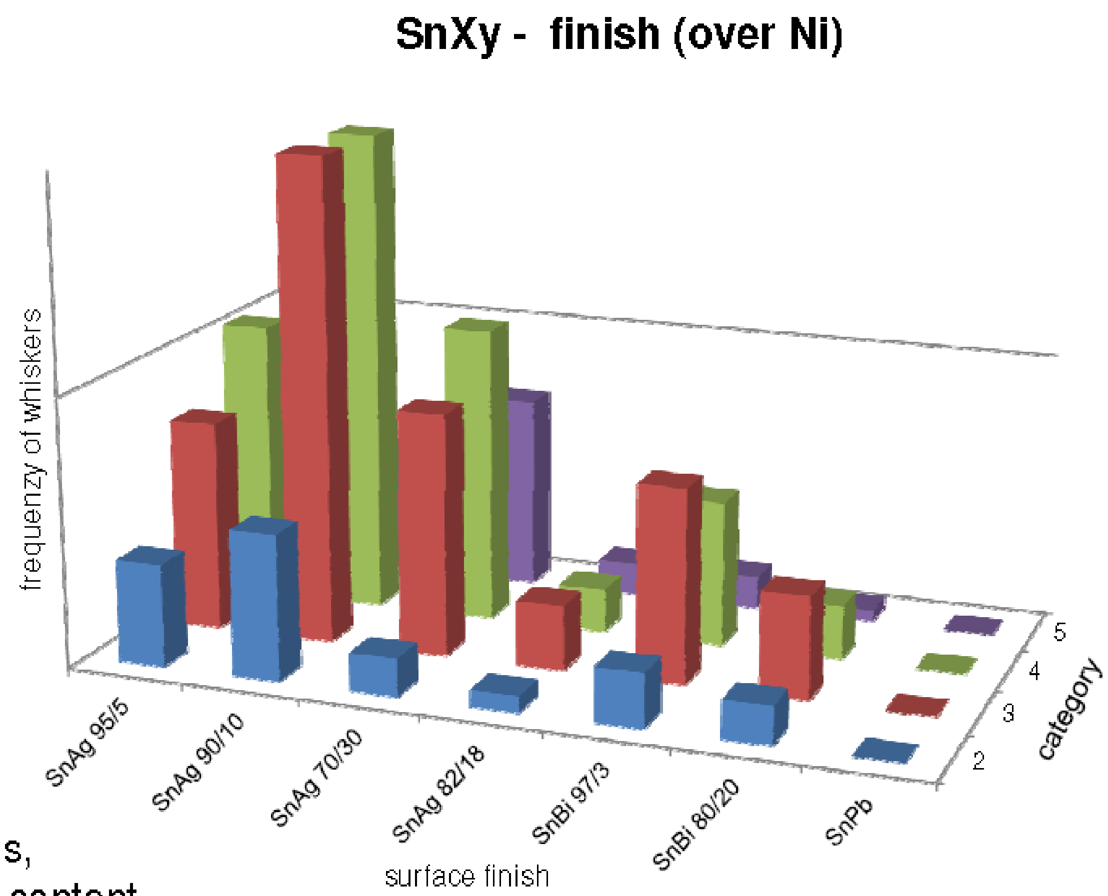
Results

- temperature pretreatment improves whisker frequency and risk for bridging
- 50 µm requirement of whisker length is exceeded within this investigation

SnXy finishes

Used materials:

- Pin Type 1 (variants 1-3 + 7)
- Pin Type 9 (variant 4-6)
- Imm. Tin finish on PCB



Results

- SnPb shows no whisker within this investigation
- All SnAg variants show whiskers, sometimes more than pure tin finish
- SnBi shows whiskers in all categories, tendency: less whiskers with high Bi content
- For SnAg and SnBi: lower press-in/push-out performance than SnPb

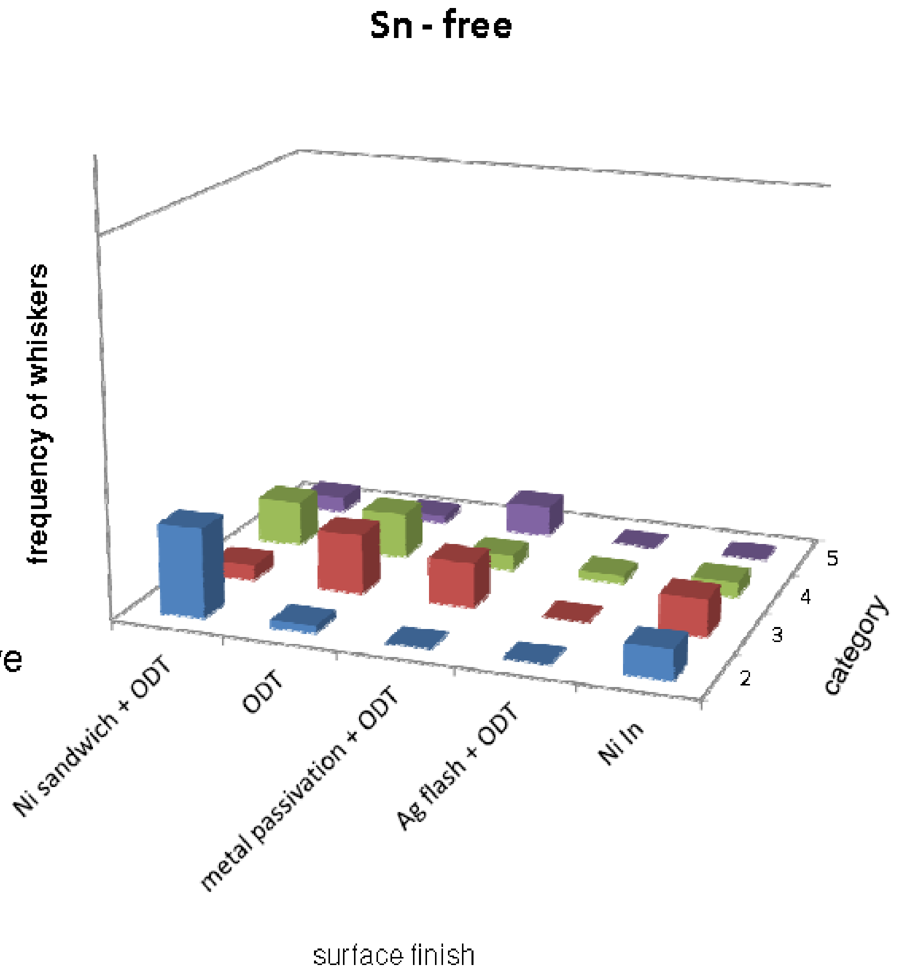
Tin free alternatives

Used materials:

- Pin Type 1 (variants 1-4)
- Pin Type 9 (variant 5)
- Imm. Tin finish on PCB

Results

- Tin free finishes show less whisker
- OctaDecaThiol as protection for oxidation
- **Ag-flash shows 2nd best whisker result**
  - Not a good press-in/press-out performance
  - Not usable for all pin types and all automotive applications
- **Indium substitutes Sn/SnPb:** widely reduced whiskers reduced length (max . 125µm)
  - Very good press-in/press-out performance: lower insertion forces and pronounced adhesion peak



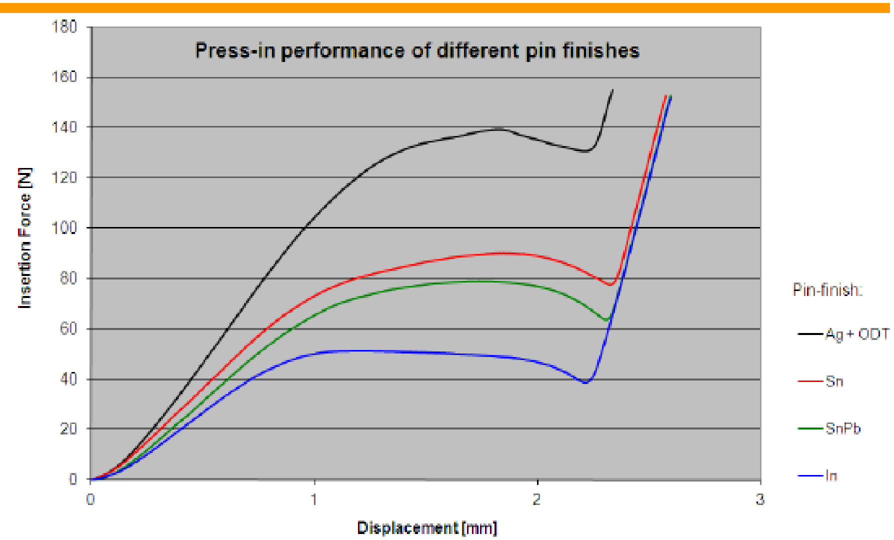
Press-in/Push-out performance of alternative finishes

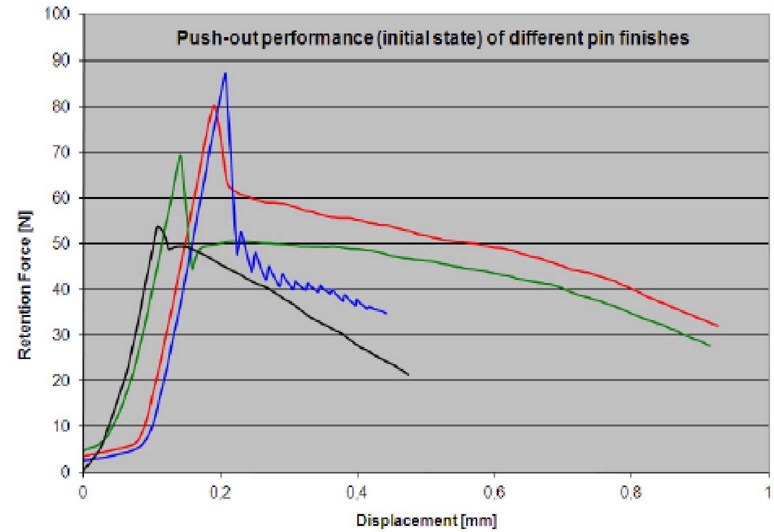
Used materials:

- Pin finishes see legend
- Pin Type 9
- Imm. Tin finish on PCB

Results

- High insertion forces for Ag-finish
  - Too high deformations of the PCB
- Low retention forces for Ag
  - Almost no adhesion peak
- Low insertion forces for In-finish
  - Low impact to deformation
- High initial retention forces
  - Higher than SnPb
  - Very good cold welding

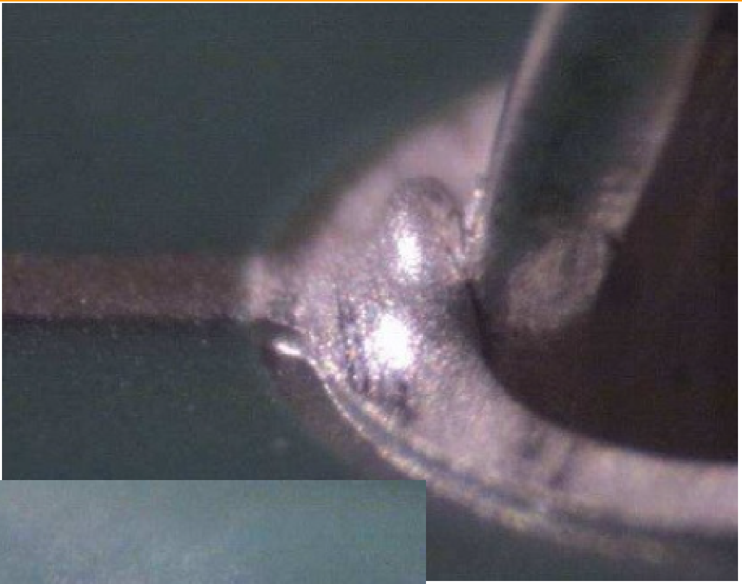


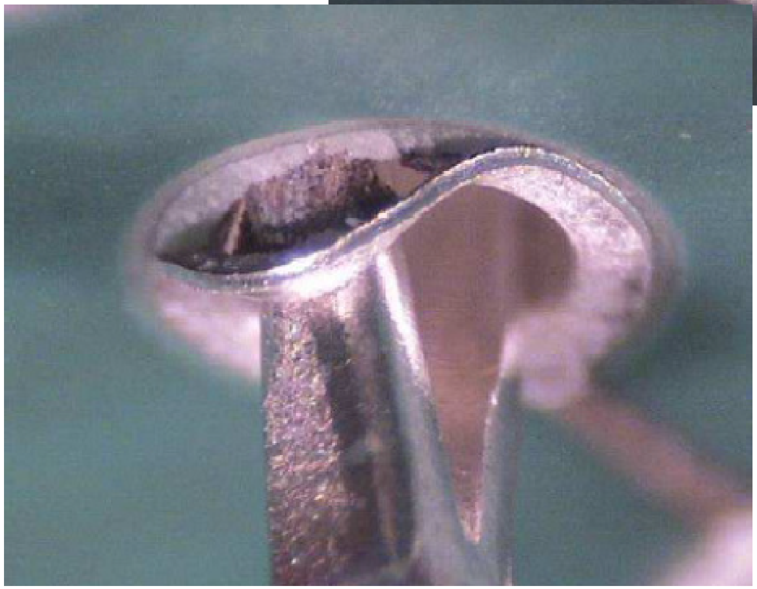


Too high deformations using Ag-flash + ODT

Used materials:

- Pin finishes Ag-flash + ODT
- Pin Type 9
- Imm. Tin finish on PCB





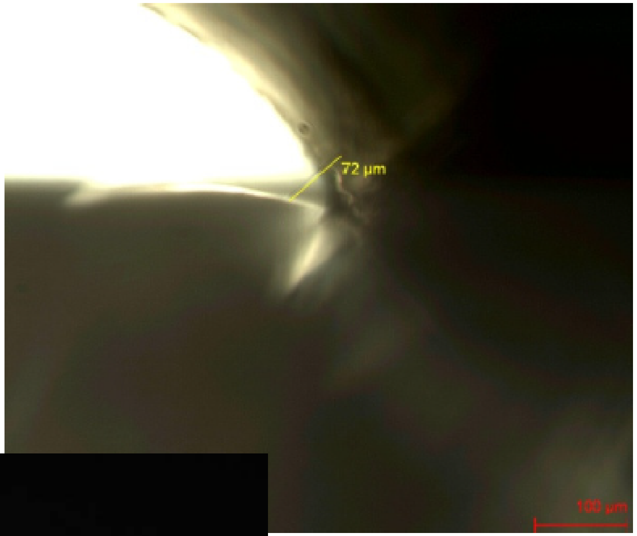
Results

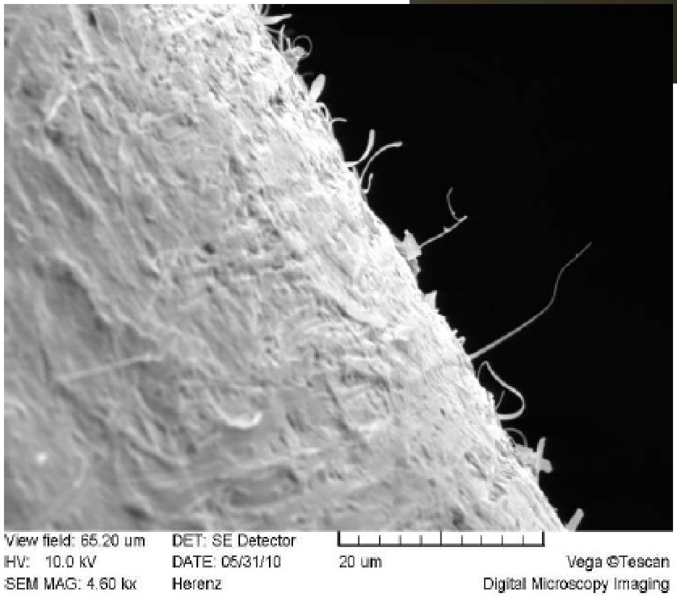
- Top: Entrance side of the pin
  - Pin builds up copper “bubbles”
- Bottom: Exit side of the pin
  - Residual ring is removed from the PCB resin and copper bushing is ripped apart.

Ag Surface Whiskers

Used materials:

- Pin finishes Ag-flash + ODT
- Pin Type 9
- Imm. Tin finish on PCB
- Microscope and SEM pictures





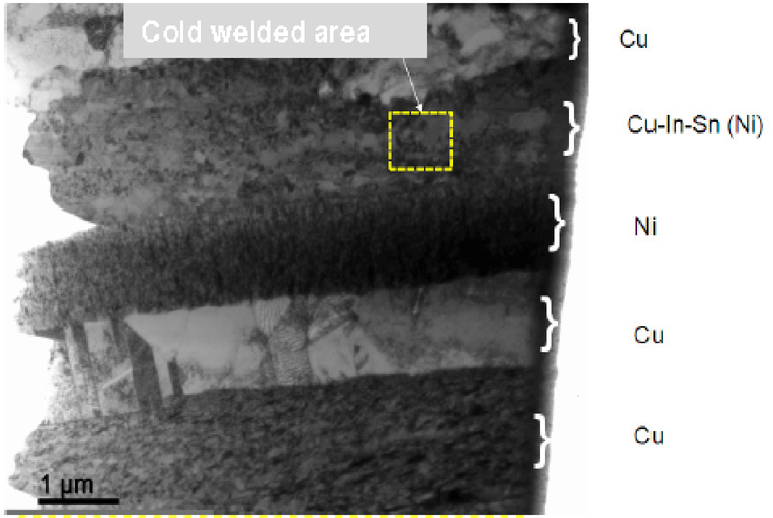
Results

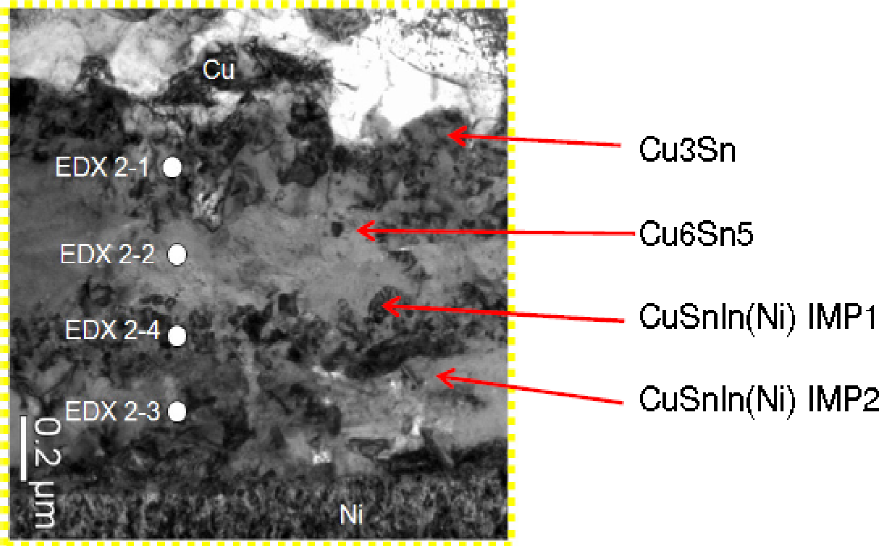
- Ag surface whisker < 100 µm have been observed
- 50 µm criterion is not always fulfilled

Investigation of Indium surface finish

Used materials:

- Pin finish Indium with Nickel underlayer
- Pin Type 9
- Imm. Tin finish on PCB
- FIB preparation of a cross-section
- TEM investigation of the FIB cut





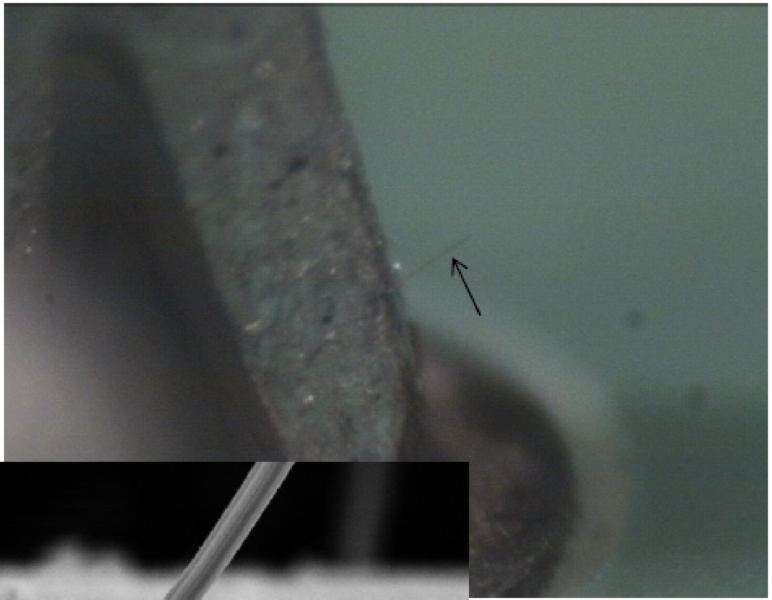
Results

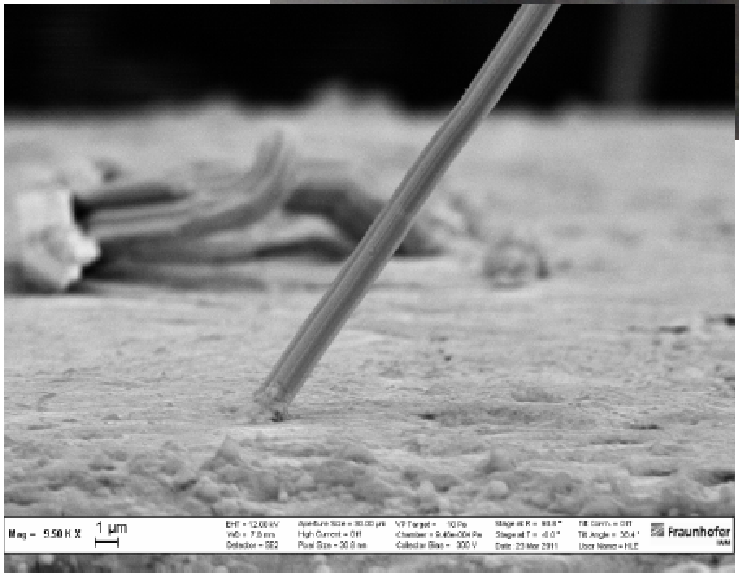
- Perfect mixing of materials
- Not possible to distinguish between joining partners
- Build up of InSnCu IMP

Indium Surface Whisker occurrence after environmental testing

Whisker

- Pin finish Indium with Nickel underlayer
- Pin Type 9
- Imm. Tin finish on PCB
- Microscope and SEM pictures





Results

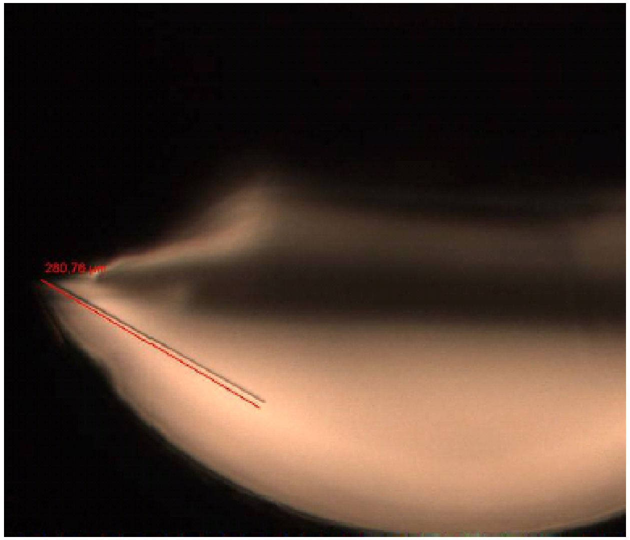
- Surface Whiskers occur under mixed gas conditions
- Whisker observed on stamping edges only
- Length exceeds 200 µm in some cases
- Mitigation method “Advanced Indium” under investigation, first results are promising

Summary

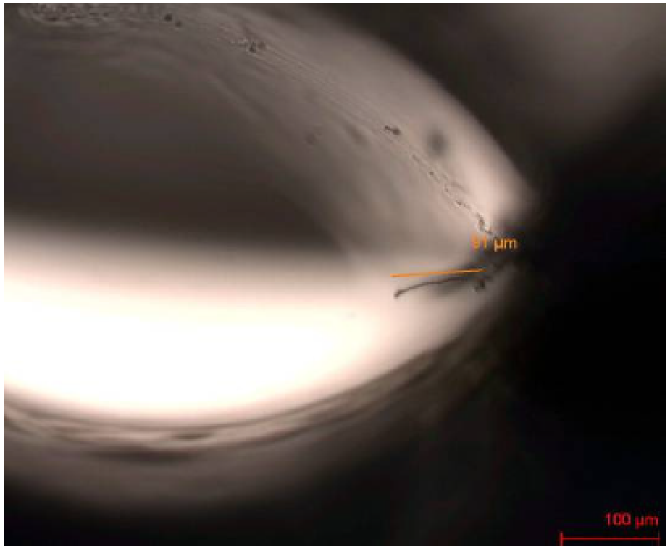
- The press-in connection containing free tin on pin and/or PCB results in whiskers larger than 200 µm on a large variety of press-fit zones.
- For automotive industry, the cold welding is necessary in harsh environmental reliability conditions.
- Ag-finish shows better whisker performance but poor reliability of the connection
- In-finish shows good cold welding in initial state but surface whisker under harsh corrosive conditions, additional countermeasures under development
- From today's technical point of view, SnPb is the only solution that efficiently mitigates whiskers and showed good press-fit performance in the past. But also here, whiskers longer than 50 µm can be observed.
- Appropriate whisker acceptance criteria beyond "< 50 µm" are needed in the common international standards.

External Pressure Whiskers

Sn Press-fit whisker



SnPb Press-fit whisker



- Up to 2 mm in length
- About 1,5 µm in diameter
- Up to one every few press-fit zones

- Up to 200 µm in length
- About 10 µm in diameter
- Up to one whisker every few hundred press-fit zones

- The 50 µm criterion is not applicable if we look in detail

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- Sebastian Dunker

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Continental

•Thank you for your attention!