Humidity Effects on Sn Whisker Formation

ECTC NEMI workshop June 1, 2005

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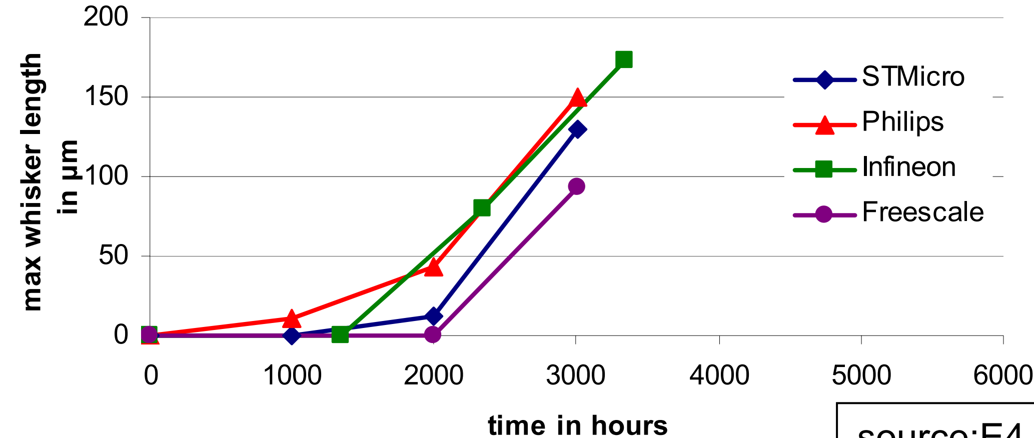
Outline

- Overview on experimental approach
- Results from cross referencing
- Influence of relative himidity
- Ni-underlayer
- Effect of board mounting
- Correlation of corrosion to whisker formation
- Summary of findings
- Theoretical approach
- Conclusion

Overview on Experimental Approach

- 4 companies, 5 assembly locations, 4 base materials, 4 electrolytes, 4 test locations,
- test conditions:
  - as plated
  - reflow simulation 215 °C / 260 °C
  - board assembly SnPb and SnAgCu
  - clean & non-clean after board assembly
  - 60 °C / 93, 90, 85 % RH
  - non-condensing condition / forced condensation
- test package TQFP-64 – 132, 5-10 components per test leg
- → more than 600 leads per datapoint
- Total of > 60000 leads in inspection

Results from cross referencing



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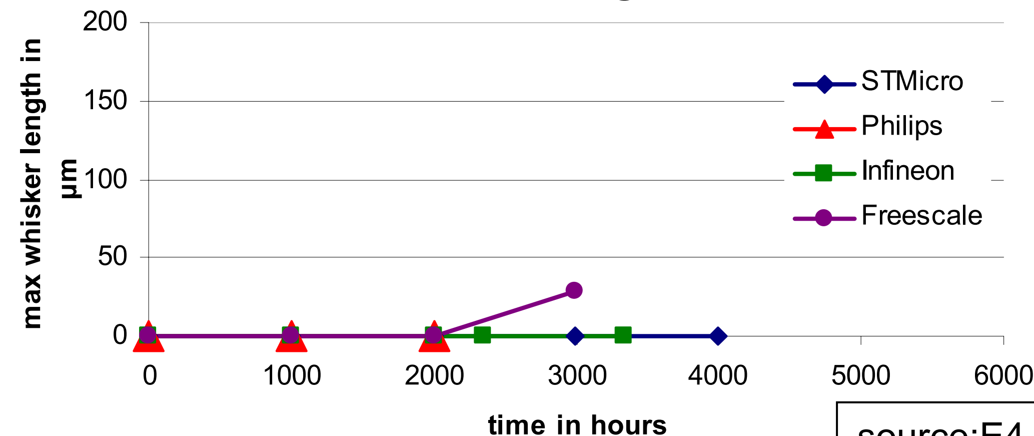

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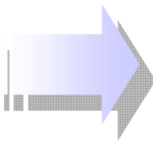
Test condition:
60 °C / 93 % RH



Very consistent whisker growth for both growth rate and incubation time

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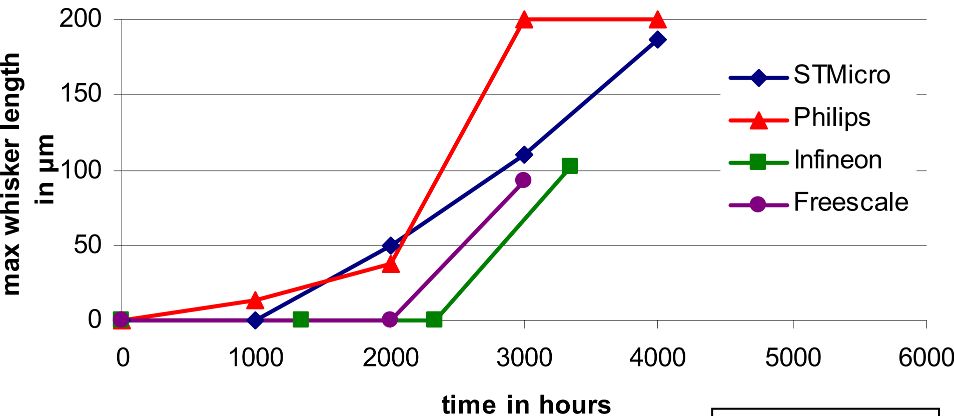
Results from cross referencing



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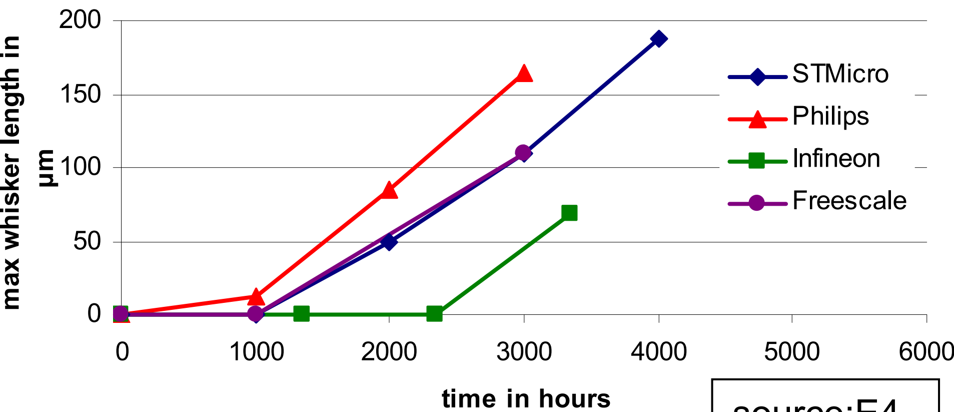

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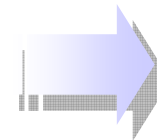
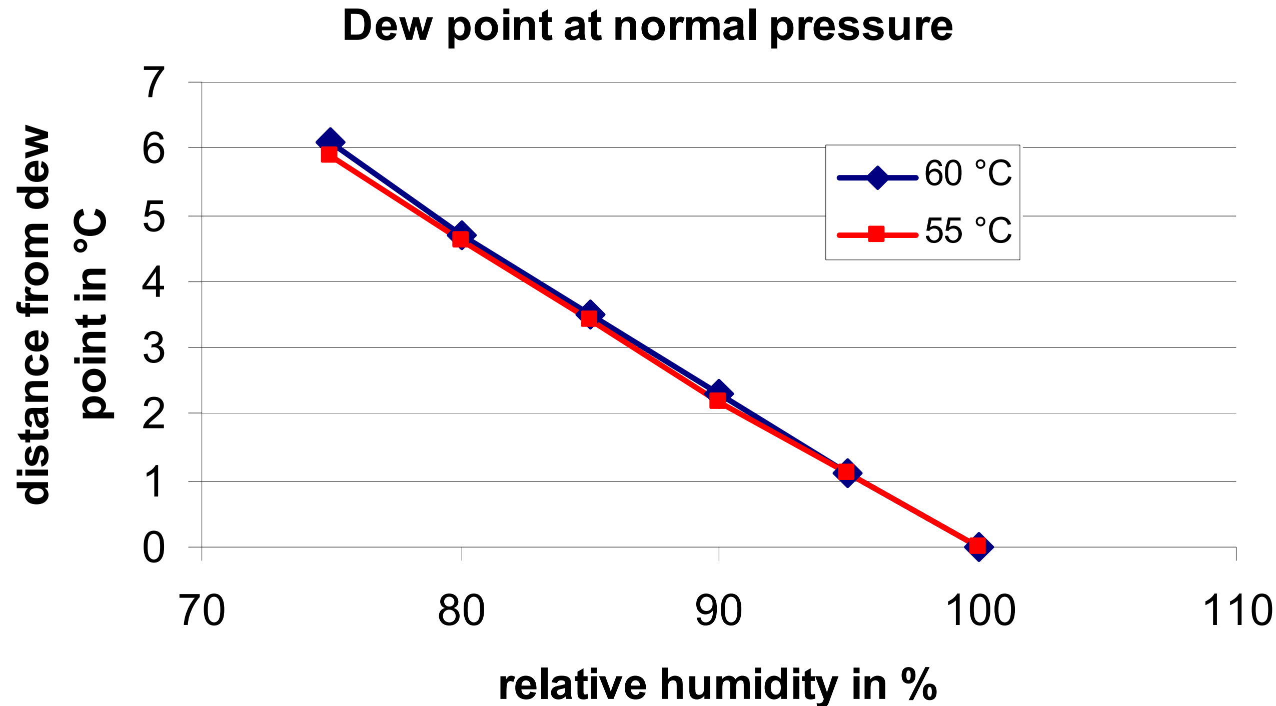
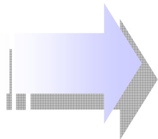
Test condition:
60 °C / 93 % RH



Inconsistent whisker growth for growth rate and / or incubation time

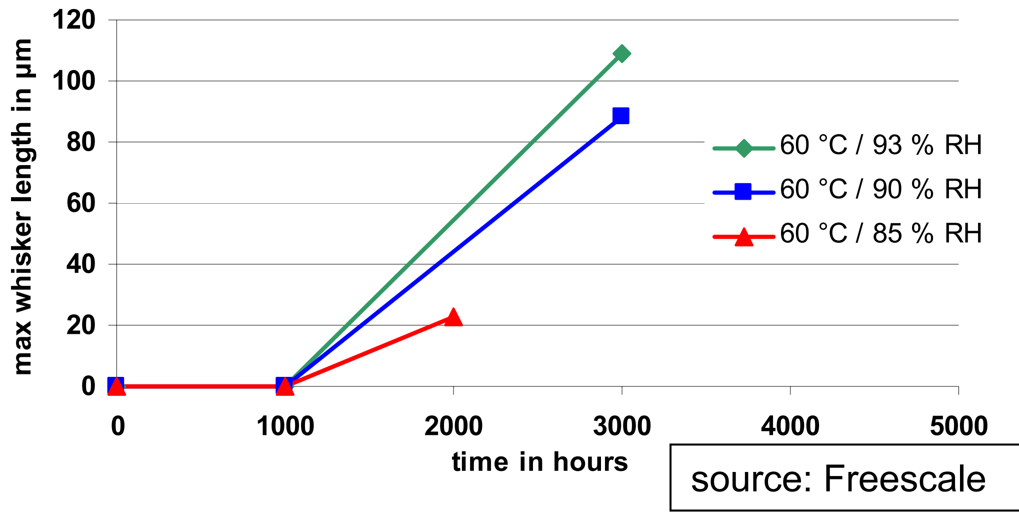
Influence from relative humidity

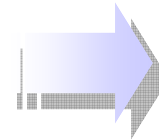




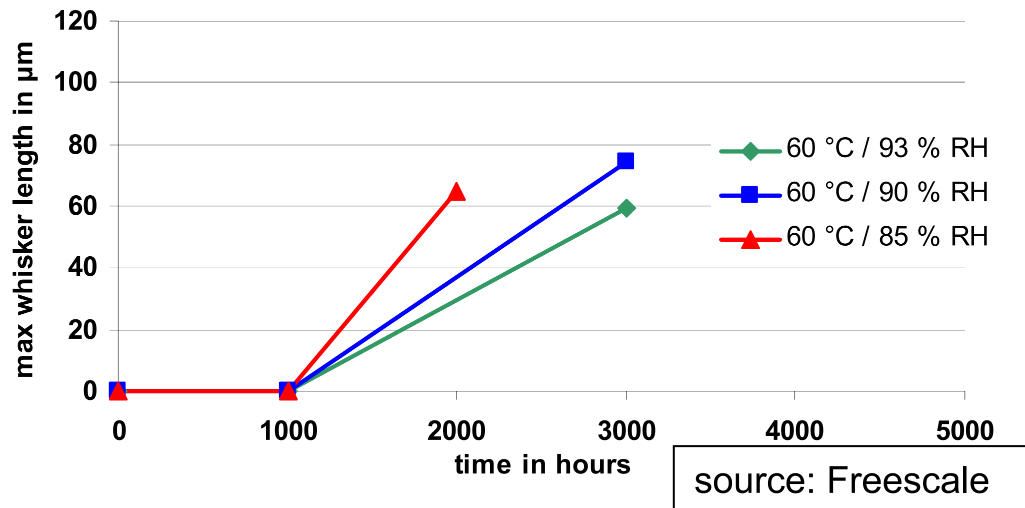
At 60 °C / 85 % RH the dew point is ~ 3,5 °C below the set temperature. In well controlled humidity chambers condensation should not happen.

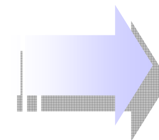
Influence from relative humidity





Apparently whisker growth dependent on humidity at constant temperature





Whisker growth not correlated to humidity at constant temperature

Note: information on whisker density will result in consistent picture (See Peng Su´s presentation)

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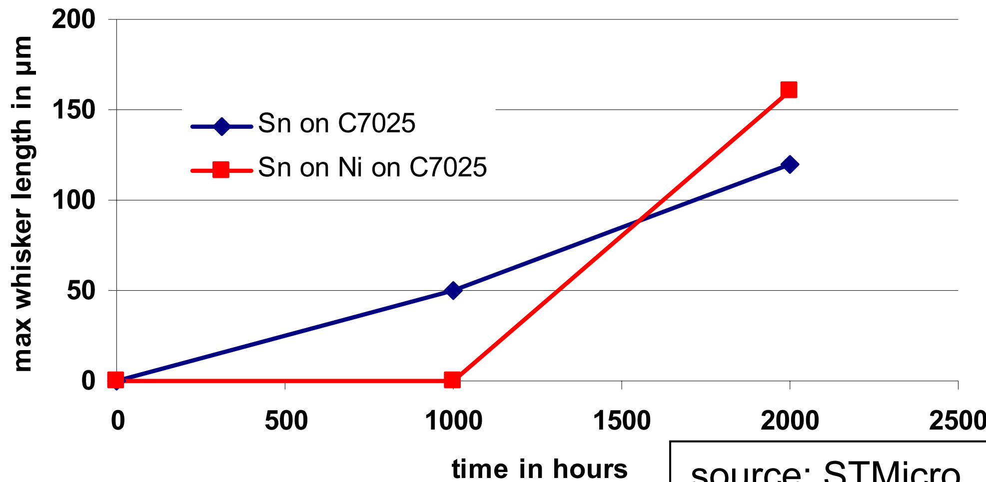
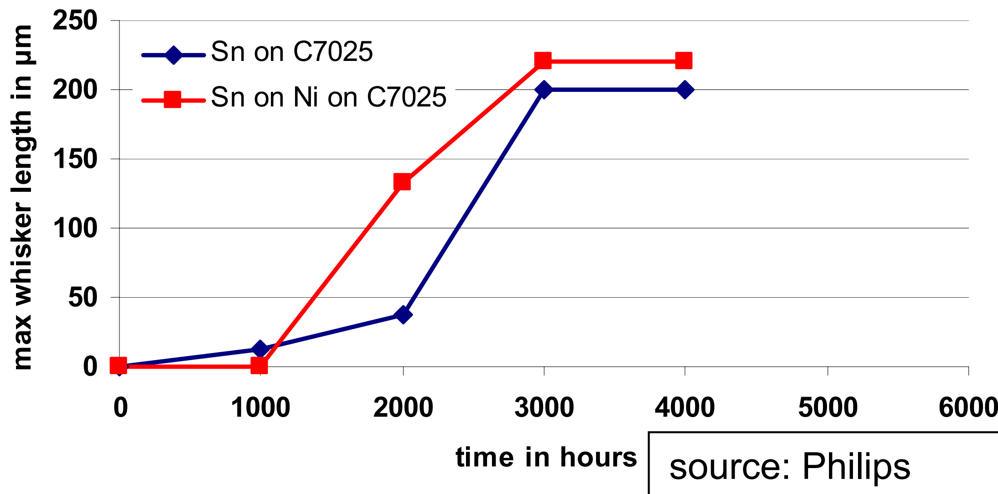
Nickel underlayer



source: STMicro

1 µm Ni underlayer

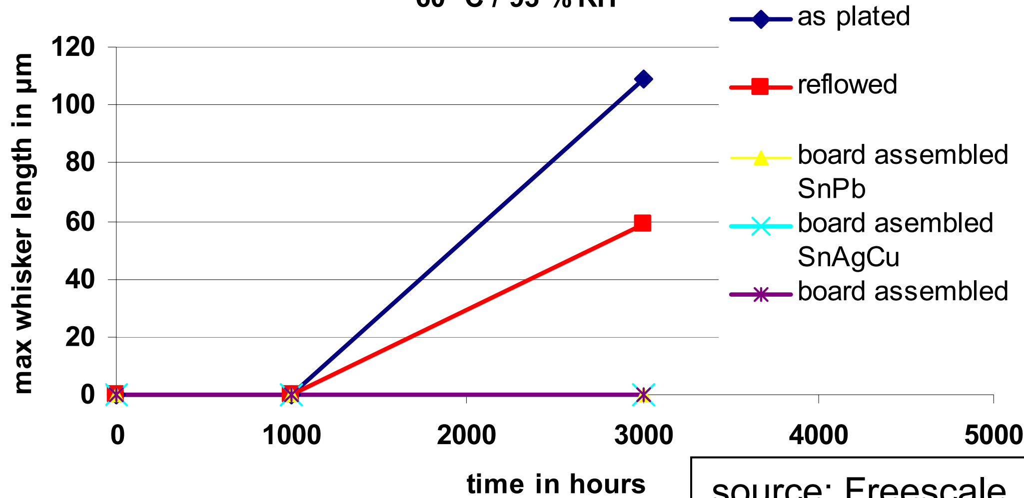
Whisker growth is comparable with and w/o Ni-underlayer in high humidity / high Temp testing



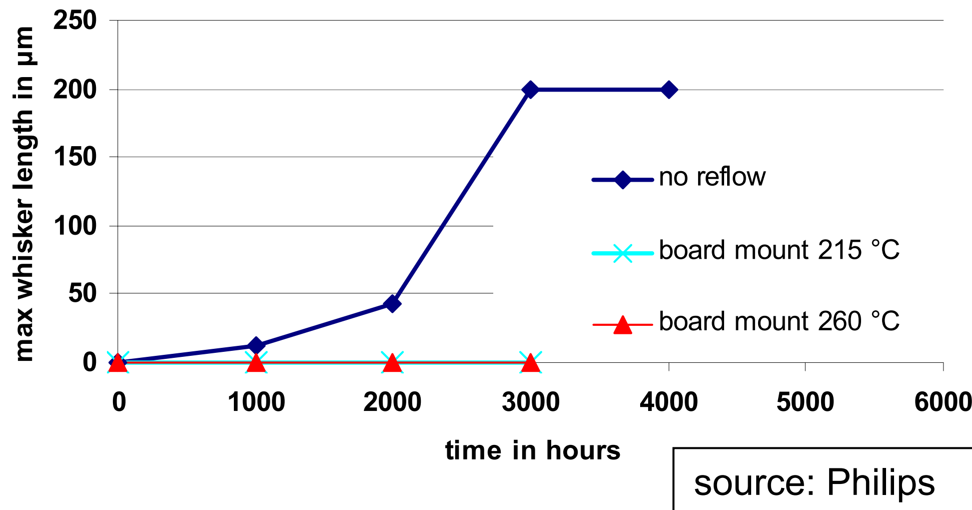
source: Philips

2 µm Ni underlayer

Influence of board assembly



source: Freescale



source: Philips

LQFP132

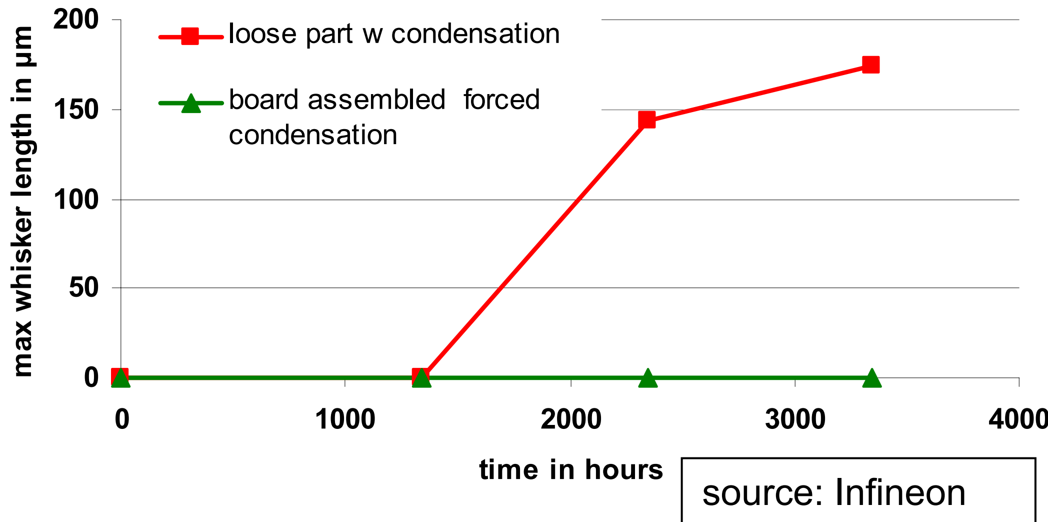
no full wetting of leads

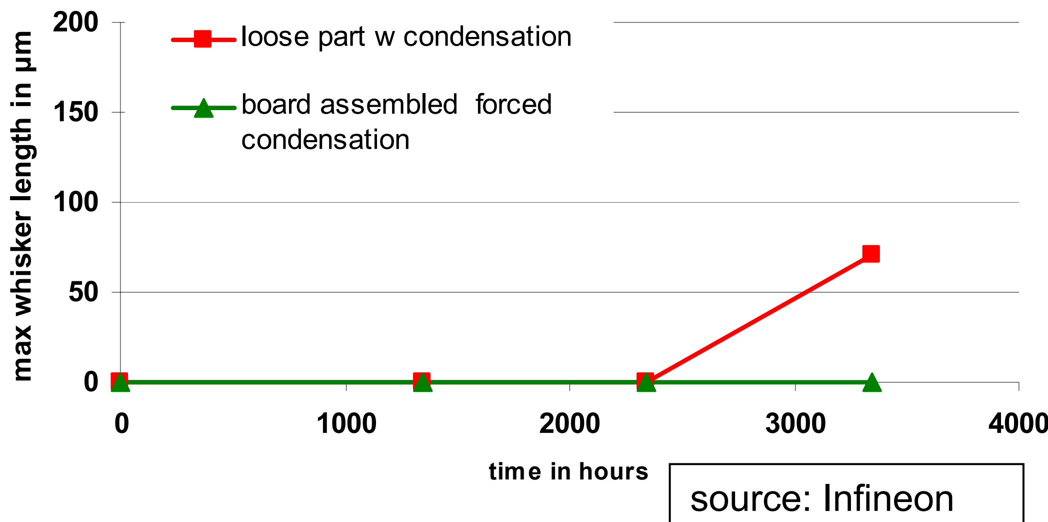
While whisker grow on loose parts, no whisker grow in board assembled state

LQFP128

no full wetting of leads

Influence of board assembly & base material





Test condition:

60 °C / 93 % RH, forced condensation

- **Significantly shorter incubation for whisker growth to start and higher growth rate for FeNi42 base material.**
- **no whisker growth in board assembled state**

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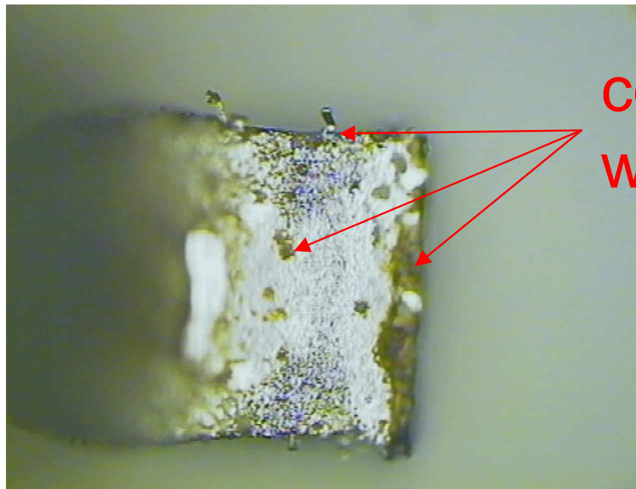
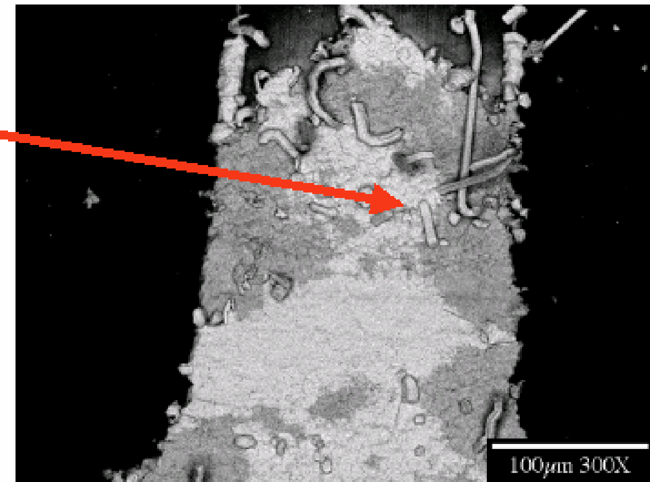
Correlation of corrosion to whisker formation

- **At least 6 companies or groups (Freescale, iNEMI, Infineon, Philips, Samsung, STMicroelectronics) report on evident correlation of whiskers with visible corrosion.**
- **Both corrosion and whisker are preferrably found close to dambar cut or lead tip (areas with exposed base material)**
- **Corrosion and whisker however are also found on well covered area**



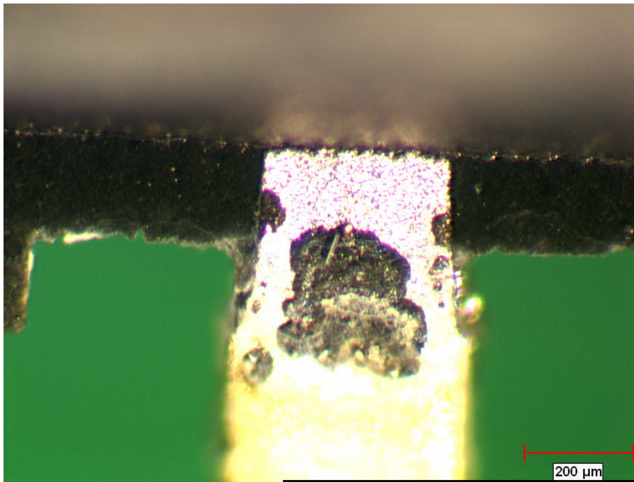
source: Infineon

corrosion & whisker

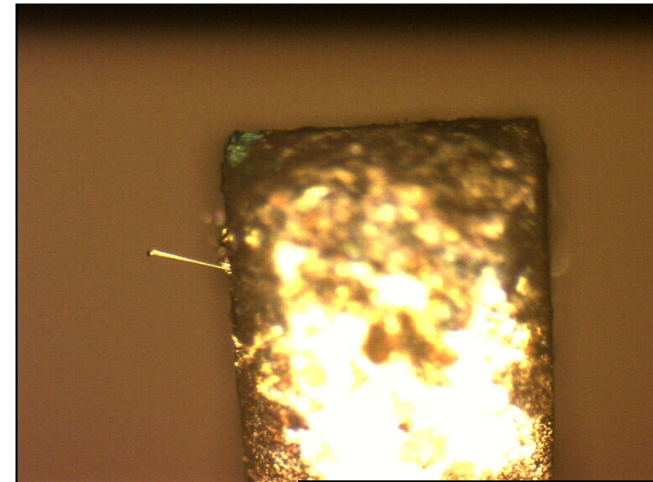


source: iNEMI

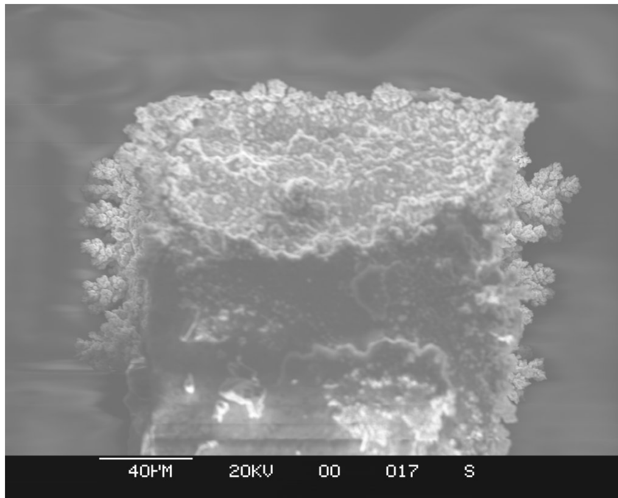
Correlation of corrosion to whisker formation



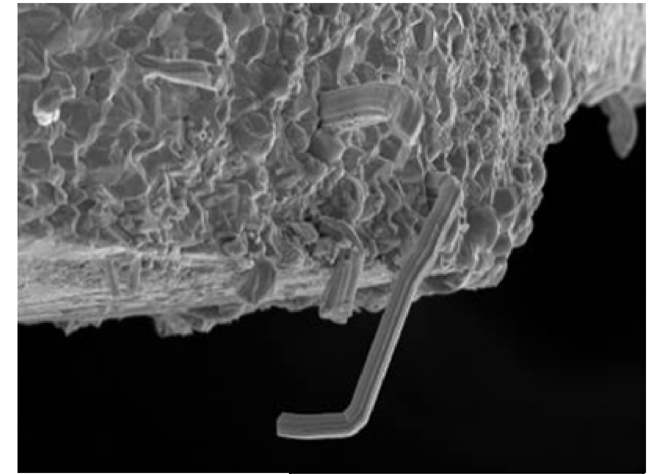
source: Philips



source: STMicro



source: STMicro



source: Freescale

Summary of findings

- Even by reduction of humidity to 85 % both corrosion and whisker growth observed (FSL, IFX)
- Condensation not necessary to result in corrosion
- Huge variation on same sample type in various test locations possible → control of test equipment almost impossible
- Most - but not restricted to - corrosion and whisker growth observed in areas close to exposed base material
- board assembled units do show almost no corrosion and whisker (also on non solder-wetted areas)

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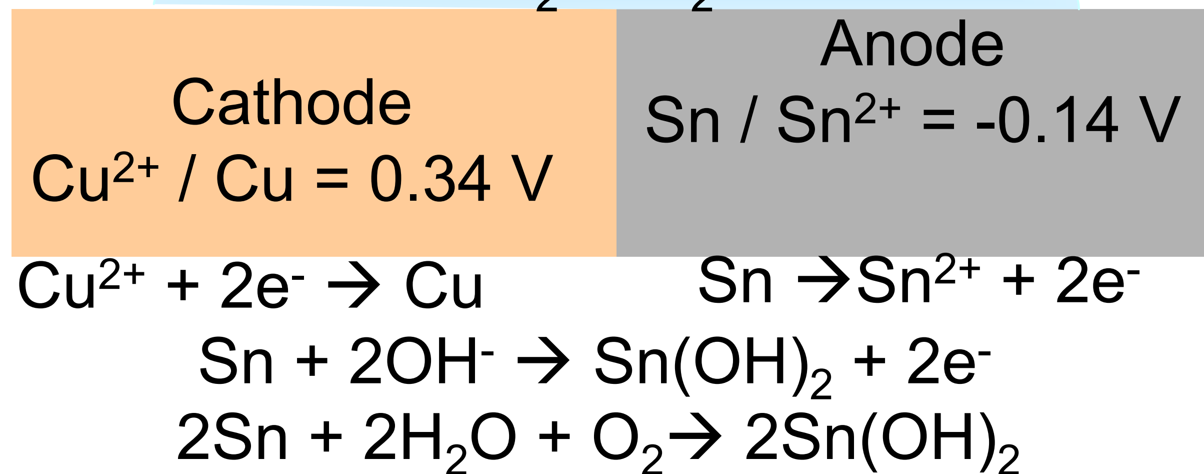
Theoretical approach

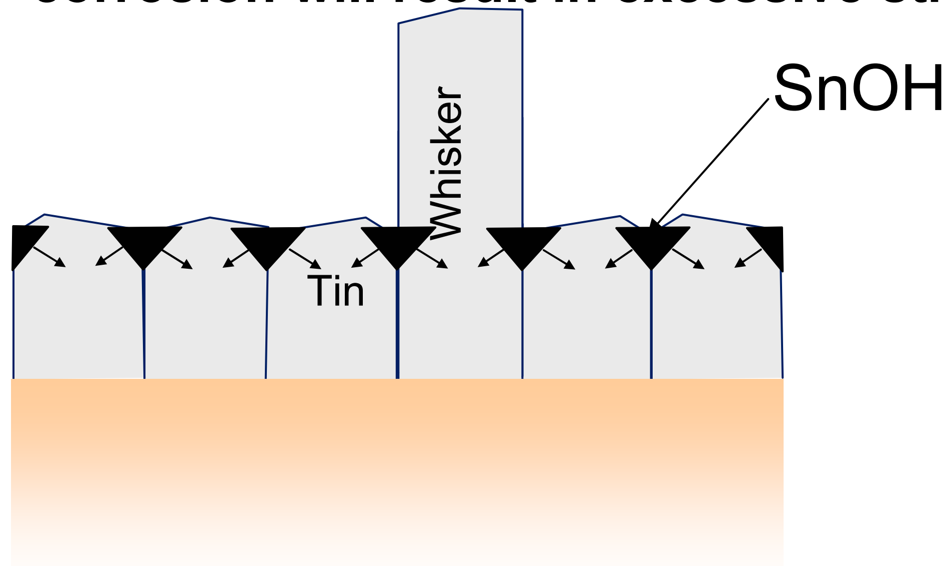
- **Corrosion may happen due to water condensation in association with exposed base material forming a galvanic couple (exposed base material)**
- **Also local defects within the tin may cause localised different nobility forming such a galvanic couple**
- **Monolayers of water w/o condensation may support the corrosive effect**

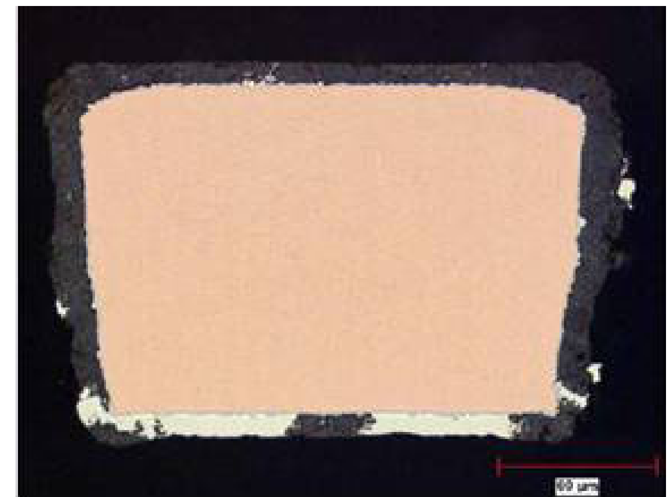


Theoretical approach

The formation of SnO or SnO_2 by reaction of tin with the atmosphere results in a localised volume increase by 29% or 47% (dependent on crystal structure / data source) or 32% respectively. A similar volume increase can be assumed by the formation of SnOH, or derivates

It may be assumed that the diffusion of OH- ions will be faster in the grain boundaries resulting in compressive stress within the tin layer as driving force for whisker formation. Excessive corrosion will result in excessive stress.





source: Philips

Conclusion

- **Besides intermetallic formation (moderate temperatures) and mismatch of cte associated with thermal cycling, high temperature/ high humidity conditions result in an additional mechanism for stress formation within a tin plating layer.**
- **This mechanism is associated to the volume increase by the corrosion of the tin**
- **Conclusively the whisker formation in high temperature / high humidity conditions is independent from diffusion barriers (regular intermetallic by post bake, Ni, Ag) at the base material / tin finish interface.**
- **However, whisker formation is strongly reduced or suppressed by soldering for board assembly.**
- **The high temperature / high humidity test is a corrosion test rather than a whisker test and shall be applied to components in their field use conditions only**