Corrosion Study on BGA Assemblies.

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Outline

- Context of study
- State of the art
- Experimental procedure
- Results
- Discussion
- Conclusions and perspectives

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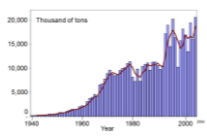
Context of study

- Corrosion: a major failure cause in microelectronic
- Effect of humidity in electronic assemblies: studied
- Corrosion of materials due to the salt water environment studied but a few studies for the electronic assembly.
- Winter roads, near the seaside… so the salt water environment causes galvanic corrosion.

Context of study

- Salt water environment: automotive, aerospace,…

Example of a real corroded electronic module in a AW139 helicopter Modular Avionics Units



Usage of rock salt for de-icing in the U.S. in thousands of tons:
corrosion risk for automotive electronic

Context of study

- Ultimate goal:
  - use the simulations in order to assess the reliability of the electronic assemblies submitted to salt water environment
- Goal of this study:
  - understand the corrosion mechanisms

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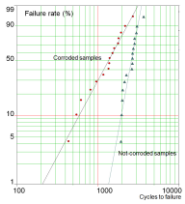
State of the art

- Passivation layer SnO:
  - SnAgCu solder *a priori* less sensitive than SnPb solder.
  - Use in assembly could change the degradation

T. K. Lee, T. R. Bieler, C. U. Kim & H. Ma, "Chemical and Environmental Attack. In Fundamentals of Lead-Free Solder Interconnect Technology", 2015.

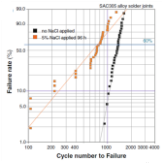
- PBGA assembled with SAC 405 submitted to cycling bending tests , after soldering and after salt spray test

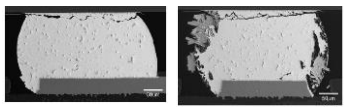
F. Song and S. W. Ricky Lee
"Corrosion of Sn-Ag-Cu Lead-free Solders and the corresponding effects on board Level Solder Joint Reliability", ECTC proceedings, 2006



State of the art

- Thermal cycling tests on WLCSP assemblies after 96h pretreatment by 5% NaCl salt spray at 35°C
  - corroded samples more fragile and fail earlier.
  - various failure mechanism
  - localized corrosion at a critical location in the solder joint





SAC solder joint after failure without pre-aging and with pre-aging

B. Liu, T.K. Lee, K.C.Liu, "Impact of 5% NaCl Salt Spray Pretreatment on the Long-Term Reliability of Wafer-Level Packages with Sn-Pb and Sn-Ag-Cu Solder Interconnects", Journal of Electronic Materials, Vol.40, No10, 2011

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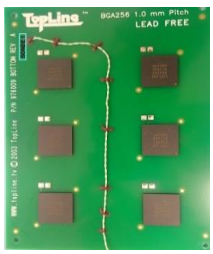
Experimental procedure

- Assembly specimen
  - Daisy-chained BGA
  - FR4 with ENIG finish
  - Sn3Ag0.5Cu solder paste



- Electrical resistance monitoring: a daisy chain pattern is built-in on the test boards and the packages.

Experimental procedure

- Salt spray test: Ascott CC450iP chamber
  - T = 35°C
  - 5% NaCl solution
  - Neutral pH
  - Rate 0.5 to 2.5ml/80cm²/hour
  - Exposure time: 24h, 48h, 72h and 96h

Experimental procedure

- Other goal: evolution of corroded samples during the storage in air
- Cleaning after test
  - washing in deionized water and drying with a stream of clean, compressed air.
  - gentle rinse with DI water at room temperature and baking at 50°C for 24 hours.

Experimental procedure

- Weight of specimen
- Electrical measurements
- Optical observations

- SEM equipped with EDX (energy-dispersive x-ray) analyses

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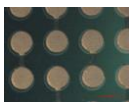
Results

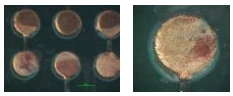
- No electrical failure detected in BGA assemblies
- No change of assembly weight
- Cleaning techniques
  - no evolution of the corroded samples after the end of the salt spray exposure
  - no difference observed between the 2 methods of cleaning

Results

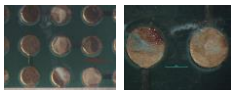
- Copper pads



72h

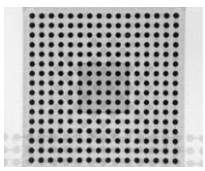


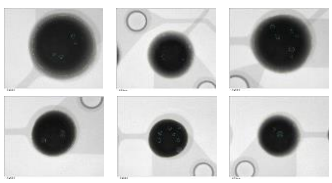
96h



Results

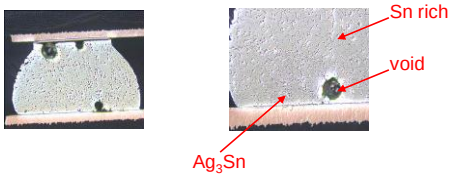
- BGA assemblies: X-ray inspection before test
  - Voids
  - Problem between pad size and solder ball diameter





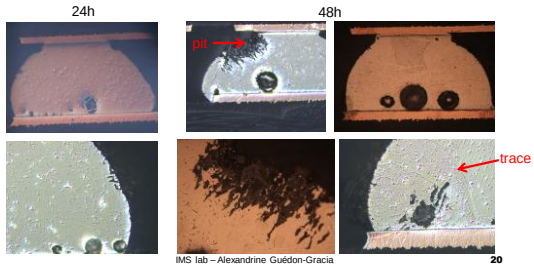
Results

- BGA assemblies:
  cross-section of solder ball before the test



Results

- BGA assemblies:
  cross-section of solder ball during the salt spray test



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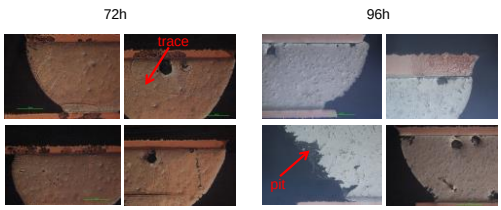
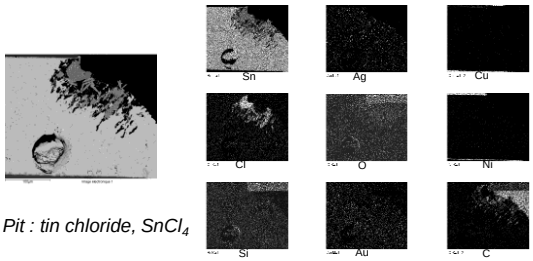


Results

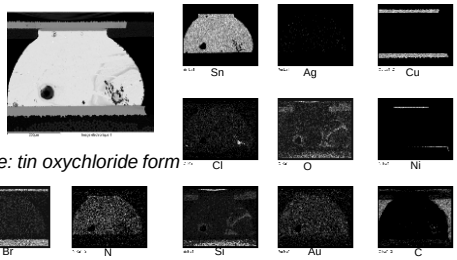
- BGA assemblies:
  element mapping for cross-section around a pit at 48h



➔ *Pit : tin chloride, $SnCl_4$*

Results

- BGA assemblies:
  element mapping near the traces at 48h



➔ *trace: tin oxychloride form*

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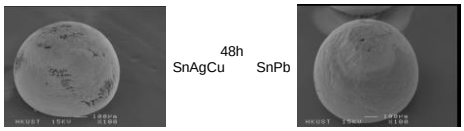
Discussion

- Passivation layer on solder alloy but corrosion in solder joint
- Corrosion in lead-free solder joints after 48h in salt spray test and after 96h in lead-tin joints *(Song and Lee)*



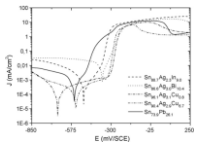
Discussion

- Even if %Sn in SnAgCu > %Sn in SnPb, corrosion on SnAgCu solder ball > corrosion on SnPb solder ball
- Presence of Ag_3Sn
  ⇒acceleration of the tin corrosion during the salt spray test
- The galvanic corrosion forms a brittle Ag_3Sn structure at the corroded regions.

Discussion

- Corrosion products present at the surface of SnAgCu alloy constituted by tin oxychloride
- Increase in %Cu from 0.8 to 6.7 (%at)

⇒ improvement of the corrosion resistance of SnAg solder alloys



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Conclusions and perspectives

Lead-free BGA assemblies after 96h in salt spray environment:

- no significant change of assembly weight
- the corrosion of the copper pads lead to the disappearance of some pads
- no electrical failure detected in BGA assemblies
- presence of pits and traces
- corrosion products constituted by tin chloride and tin oxychloride.
- presence of silicon around the corroded area (polishing process?)

Conclusions and perspectives

Further investigations on the lead-free solder balls in salt environment

- understand the corrosion phenomena of the lead-free solder alloy.

Ultimate goal: the modelling of these phenomena.