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Reduction of solder contamination to probe tip by study of electromigration effect

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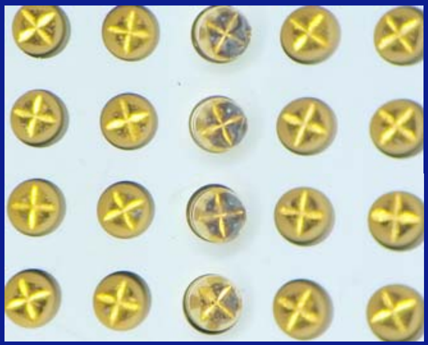
Contents

- Background introduction
- Electron migration introduction
- Mechanism force of Electromigration
- Simulation and calculation for atoms divergence
- Solder contamination test
- Result discussion
- Summarize

Pin Tip Contamination

- Devices tested at higher power (current) have worse solder transfer when compared with low current.
- High temperature testing increase solder transfer as well.
- Melt, Cold Welding, Intermetallic, Electromigration, etc……



Background

- Conductive metals under high current density, atoms will diffuse from the one to another. Voids and cracks are formed in the anode, and mounds, extrusions. And whiskers are formed in the anode. Void formation will lead to contact resistance increase, eventually leading to contact contamination or contact fail.
- With continuous improvement, the volume of interconnection solder joints is shrinking and the current density is increasing.
- The average current density of pin to solder is increasing over 2X10^4 A/cm2, migration failures becomes more severe.

Electromigration (EM) Fundamental

- Electromigration (EM) is a phenomenon of material transport caused by a gradual movement of ions in a conductor due to momentum transfer between conducting electrons and diffusing metal.
  - Current Density
  - Temperature Gradient
  - Mechanical Stress
  - Chemical Potential
  - Etc.

Mechanism force of Electromigration

- Electronic – Wind – Force
  - The Force of Momentum Exchange in Metal Atoms Collided by Electrons under Electric Field. The direction is the same as the electron.
  - Coulomb force is the direct force produced by electric field on metal atoms.

$$q_{EW} = \frac{c}{k_B T} e Z^* \mathrm{j} \rho D_0 \exp\left(\frac{-E_A}{k_B T}\right)$$

$c = C / C_0$, C-Atomic density, C_0-Initial atomic density without stress field ; k_B –Boltzmann constant ; T- Absolute temperature ; e –Electronic charge ; Z^* –Number of effective charges ; j-Current density vector ; ρ-Temperature-dependent resistivity ; D_0 –Self-diffusion Coefficient of Conductor Materials ; E_A-Activation Energy of Materials

Mechanism force of Electromigration

- Temperature gradient
  - There is a tendency for atoms to move from high temperature region to low temperature region.

$$q_{Th} = -\frac{c}{k_B T} Q^* \frac{\nabla T}{T} D_0 \exp\left(\frac{-E_A}{k_B T}\right)$$

- Stress gradient
  - Non-uniform stress distribution.

$$q_s = -\frac{c}{k_B T} \Omega \nabla \sigma_H D_0 \exp\left(\frac{-E_A}{k_B T}\right)$$

- Atomic density gradient
  - With the progress of electromigration, the atomic density gradient becomes larger and its effect is increasing. When the critical point is exceeded, the electromigration will be inhibited to some extent.

Q^*- Mohr heat flux, Ω- Atomic volume, σ_H- Hydrostatic Stress

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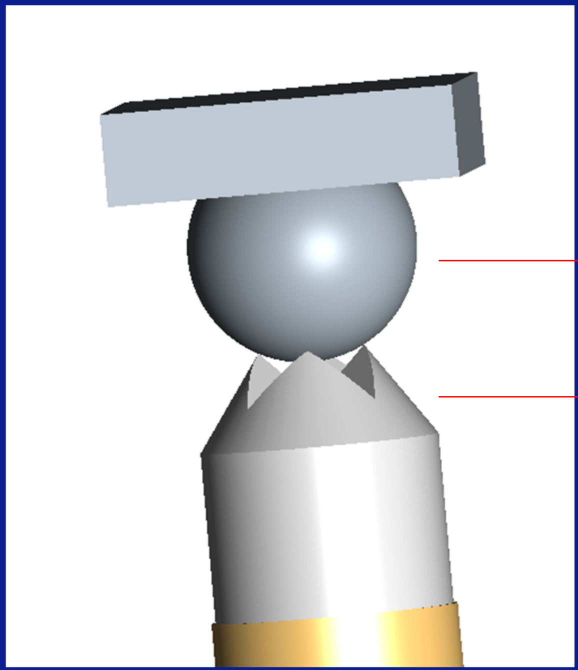
Model Setup

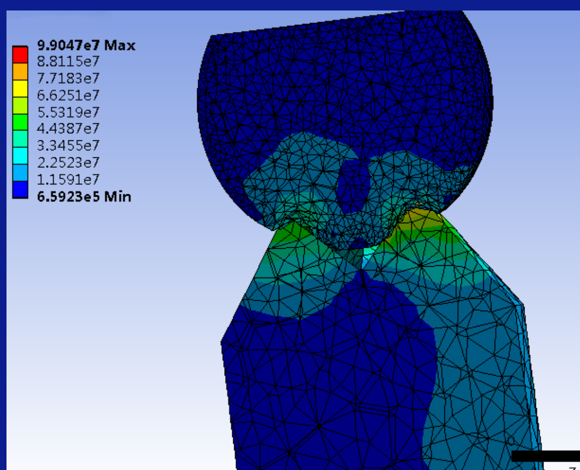


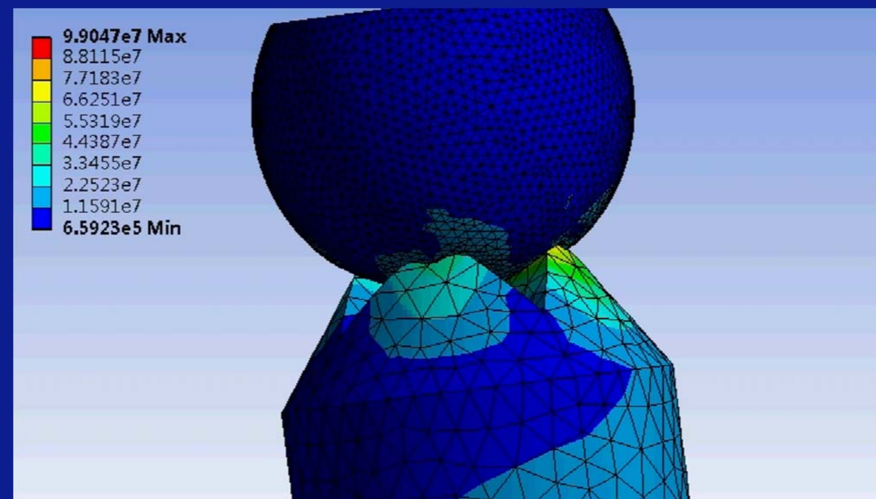
Solder Bump SAC305

Reduce-Crown-Pd Alloy

Mechanical Solder Penetration

- Contact Surface
- Mechanical Stress Gradient
- Penetration Depth (30gf~20um)



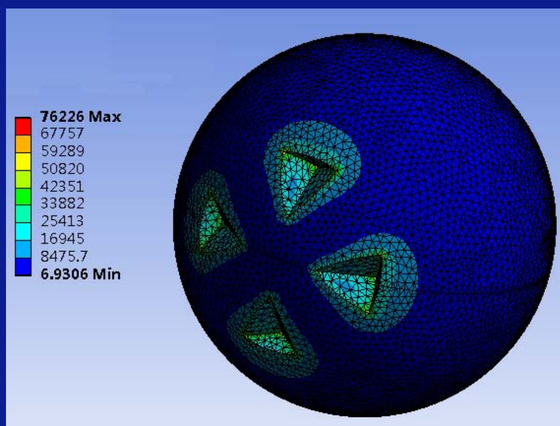


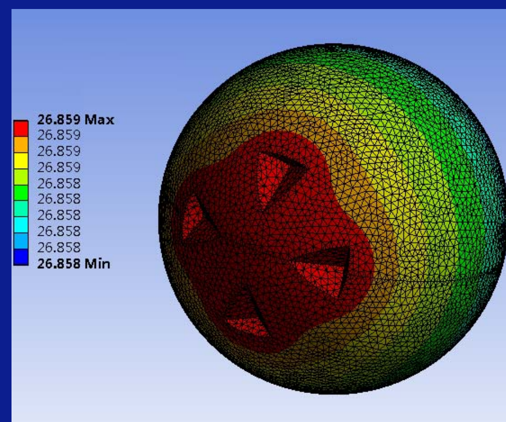
- Stress Average: 5.5E07Pa
- Mechanical stress migration divergence

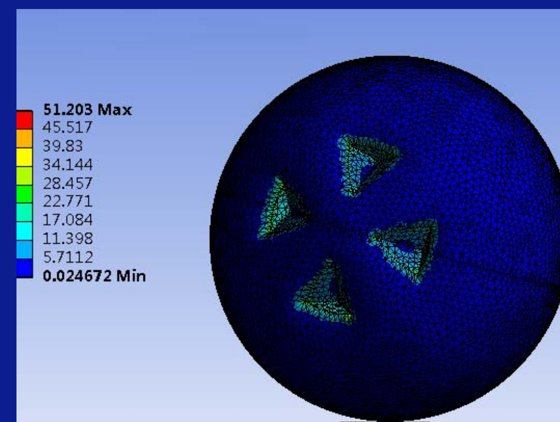
  div(Qms)=4.5E-07 atoms/m^3.s

Electron Migration Divergence

- Current 200mA- Electric – Thermal - Stress







Current Density

Max: 7.63E07 A/m^2

Min: 8.5E06 A/m^2

Temperature

Max: 26.9C^0

Min: 26.85C^0

Stress

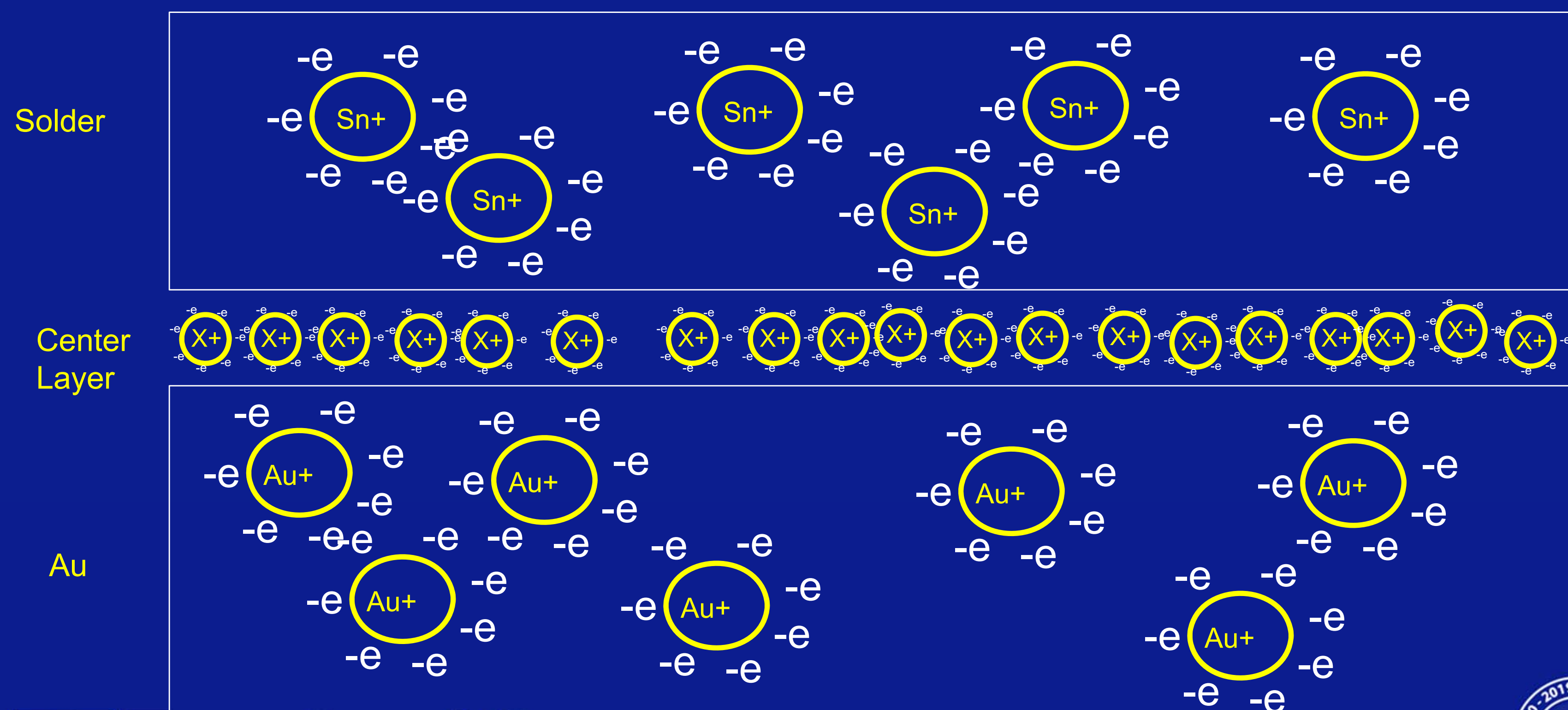
Max: 5.12E07Pa

Min: 5.71E06Pa

Electron Migration Divergence Discussion

Current	200mA	500mA	800mA	1000mA
Current Density	5.08E+07	1.06E+08	1.70E+08	2.10E+08
Tempearture	25.2	43	74	104
Thermal Stress	1.53E+07	1.78E+08	2.44E+08	3.81E+08
Mechanical Stress	5.50E+07	5.50E+07	5.50E+07	5.50E+07
	Atom Divergence			
divQew	7.4891E-08	1.56269E-07	2.50619E-07	3.09589E-07
divQt	1.14E-08	3.9422E-08	2.53133E-07	1.14069E-06
divQts	1.24734E-07	1.45115E-06	1.98922E-06	3.10612E-06
diVQms	4.4839E-07	4.4839E-07	4.4839E-07	4.4839E-07
Total	6.59401E-07	2.09523E-06	2.94136E-06	5.00478E-06

Contamination Prevention



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Solder Contact Test

- Select same spring pin design with different top plunger surface finishes.
  - Gold plating
  - H3C- 330Pd Alloy
  - Nano Coating- 330Pd Mirror Finishes
  - C3 Coating- 330C
- Pump current 3A/2.5s and evaluate the solder contamination

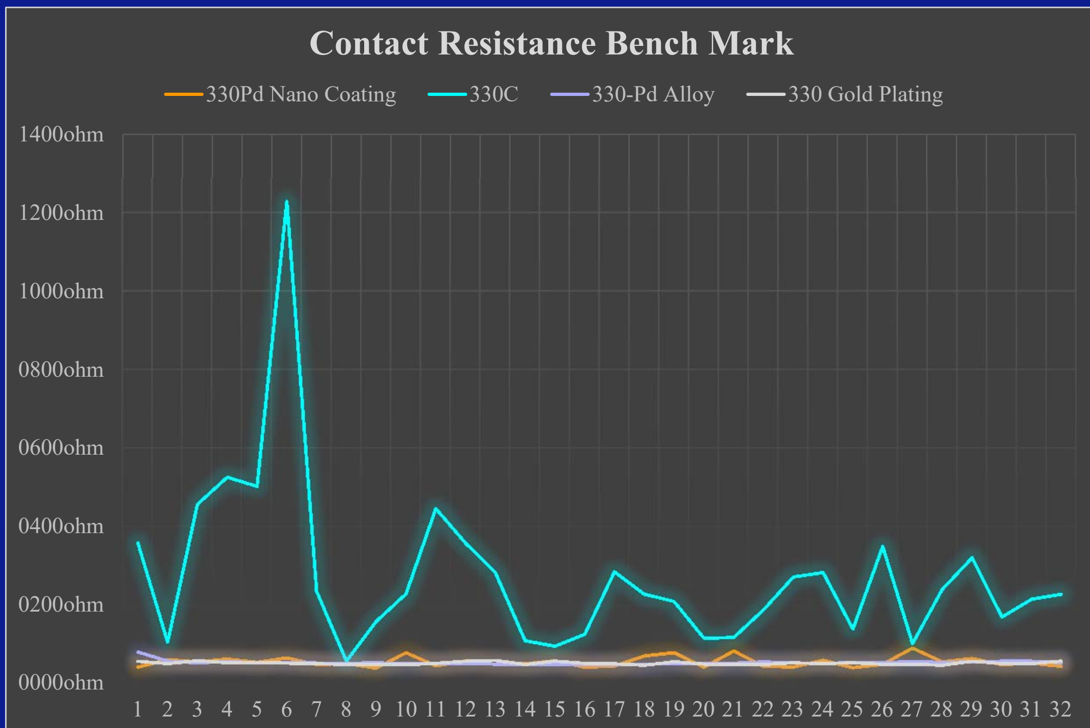
330Pd Alloy Mirror Finish

330Pd Nano Coating Non Mirror Finish

330C DLC Finishes

330 Gold Plating

Contact Resistance Bench Mark - Fresh Pin



330Pd Nano Coating	330C	330-Pd Alloy	330 Gold Plating
55.2	272.9	53.2	51.9

1. DLC coating contact resistance have very wide range.
2. Nano coating and Pd alloy tip have very similar result.
3. Gold plating pin has the lowers contact resistance.

Tip Contamination Bench Mark

- Test Conditions
  - 2.5 s each insertions
  - Current 3A
  - Total 500 insertions

1. 330Pd Alloy mirror finishes > Gold Plating > Nano Coated probe which is similar to DLC finished
2. DLC pin burned after continue with more touch down experiment.

330Pd Alloy Mirror Finish | 330Pd Nano Coating Non Mirror Finish | 330C DLC Finishes | 330 Gold Plating

Before

After

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Summary

- Discussed basic of electron migration
- Introduce an method to quantity the transfer rate of atoms base on mechanical stress and current.
- Evaluate different coating technologies effect of anti-contamination.