The Effect of Solder Paste Volume on Passive Component Self-alignment

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Background

1. Surface mount technology (SMT) → Consistency of solder paste volume; Placement of passive component → Surface mount component self-alignment

2. The utilization of component self-alignment nature →
   - Increase the package rate;
   - Relative low cost;
   - High precision;
   - Avoid electrostatic damage;
   - No need specially designed copper pad;

Objective

3D model (Surface Evolver) →
- Predict the solder joint profile during reflow soldering process
- Investigate the effect of the solder paste volume on component self-alignment

Model Setup

1. Theoretical background: The gravitational energy and surface tension energy in the molten solder will be considered in the reflow soldering process to predict the solder joint profile and the self-alignment performance.

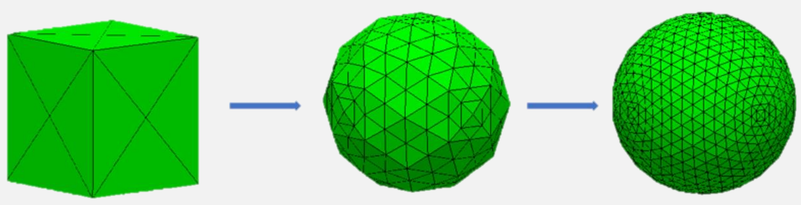


Fig. 1. The energy minimization of the liquid cube evolved by Surface Evolver

2. Material: Chip capacitor C1005, C0603, C0402, SAC 305 solder, copper pad with Nickle-gold surface finish.

Solder type	Surface tension (dyne/cm)	Density (g/cm³)	Contact angle
SAC 305	544.9	7.361	20^0

3. Restoring force and torque calculation

➢ The restoring force and restoring torque are determined by the change of surface tension energy and gravitational energy.

$$E = E_s + E_g, \qquad E_s = \int \gamma \, d_s, \qquad E_g = G * \rho * \iiint z \, dV$$

Based on the principle of virtual work, the restoring force can be calculated by finite differences 2*δq. In the same manner, the restoring torque can be calculated by a virtual angle 2*δθ.

$$Fs = -\frac{E(q+\delta q)-E(q-\delta q)}{2*\delta q}, \qquad T = -\frac{E(\theta+\delta\theta)-E(\theta-\delta\theta)}{2*\delta\theta}$$

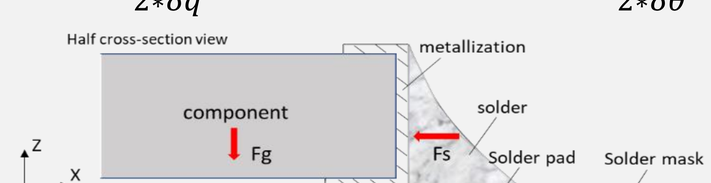


Fig. 2. Surface tension force and gravitational force schematic

Solder Joint Profile Prediction

➢ Based on the user-defined initial solder joint profile, after reflow soldering process, different solder joint profiles are presented with respect to different solder paste volumes.

➢ The concave and convex solder joint shape are determined by the molten solder contact angle, solder paste volume, copper pad size and component size.

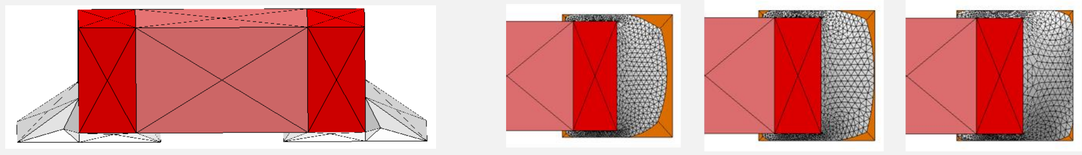


Fig. 3. User-defined solder joint initial profile

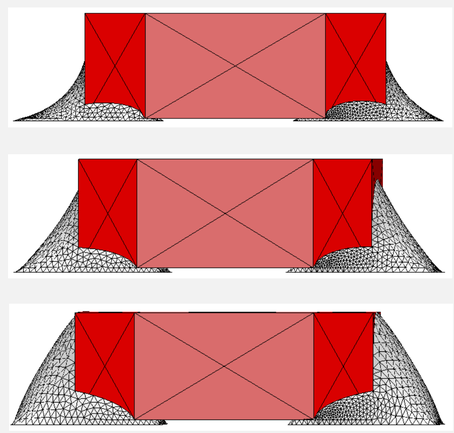


Fig. 4. Solder joint profile with different solder paste volumes

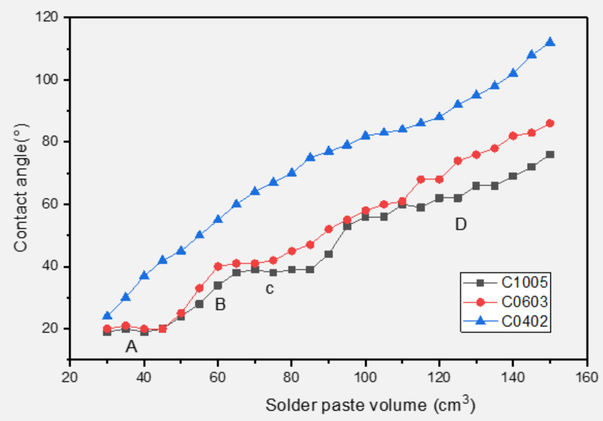


Fig. 5. Molten solder contact angle with different solder paste volumes

Component Self-alignment Performance

1. Shifting mode.

➢ Investigate the effect of solder paste volume inequality on component shifting self-alignment performance, Fig. 6.

➢ Compare the shifting self-alignment in x and y direction, Fig. 7.

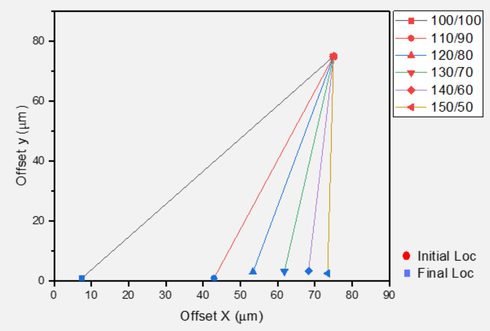


Fig. 6. Self-alignment under inequal solder paste volumes

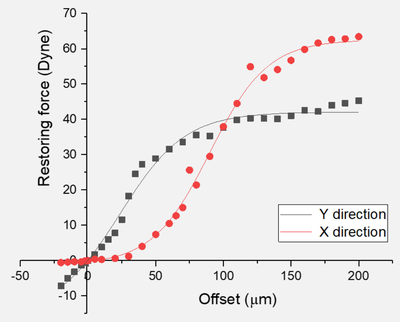
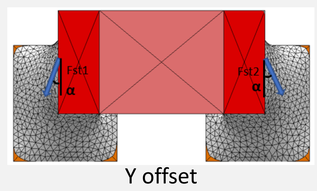
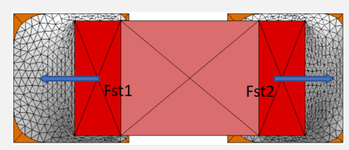
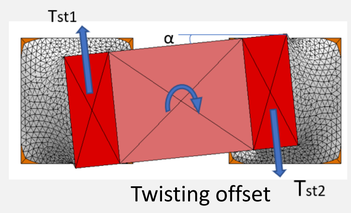


Fig. 7. Self-alignment under different initial misplacement

➢ The restoring force profile during the self-alignment is investigated. Moreover, the force diagram are analyzed to explain the force profile.







2. Twisting mode.

➢ The initial twisting angle is set as 10^0 and -10^0. Use inequal solder paste volumes to investigate the effect of solder paste volume inequality on twisting self-alignment (Fig. 8).

➢ Use equal but different total amount of solder paste volumes (Fig. 9).

➢ Increase the copper pad width by 1.25 times, to investigate the effect of copper pad size on the restoring torque (Fig. 10).

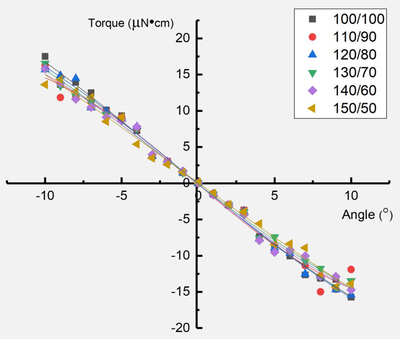


Fig. 8

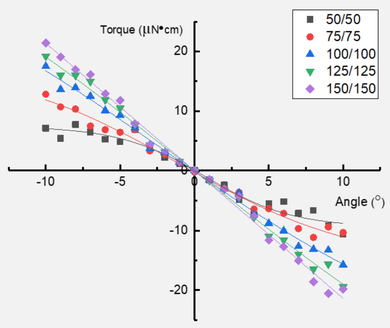


Fig. 9

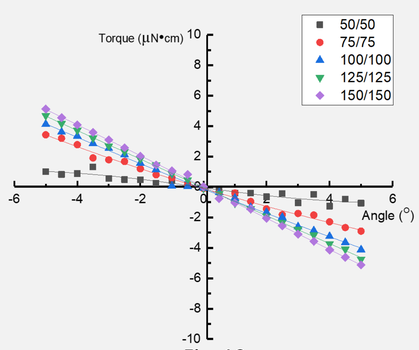


Fig. 10

Conclusion

➢ Based on the created 3D model, the solder joint profiles under different conditions can be predicted.

➢ In shifting mode, component with equal amount of solder paste will have the best self-alignment performance. The self-alignment performance in y direction is better than in x direction.

➢ In twisting mode, the solder paste volume does not have significant effect on component twisting self-alignment. While proper copper pad size can improve the component twisting self-alignment.