Gold-Tin: The Unique Eutectic Solder Alloy

APPLICATION NOTE

Introduction

The eutectic gold-tin alloy is 80%Au/20%Sn with a eutectic of 280°C (556°F) and is reflowed in a pure nitrogen or forming gas* atmosphere, which forms the "flux," normally onto gold-based metallizations. The peak reflow temperature is usually 320-340°C in a bell-shaped profile, with a dwell time of 2-3 minutes at peak temperature and a total cycle time of 20-30 minutes, depending on the thermal load in the furnace/chamber. Figure 1 shows a "typical" gold-tin reflow cycle. The alloy provides excellent wetting characteristics, great joint strength, superior resistance to corrosion, and superior thermal conductivity, making it the material of choice in many applications
The thermal properties of the gold-tin alloy become more significant with the increasing miniaturization of line widths on silicon and increasing transistor count, according to Moore's Law,

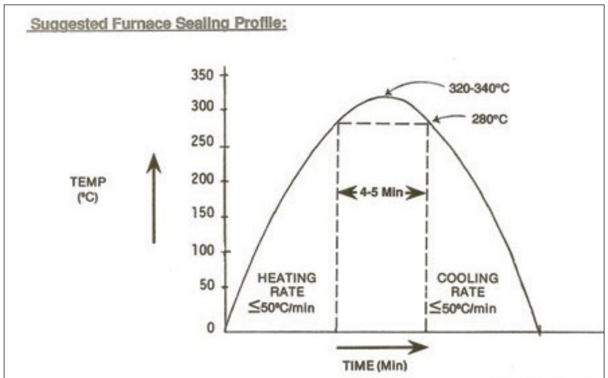

Figure 1. AuSn Reflow Profile

Attributes

- Excellent wettability
- High joint strength; tensile strength is 275 MPa (40,000 lbs./sq. inch)
- Yield strength 31.5 psi x 103
- Excellent resistance to corrosion
- High thermal conductivity 0.57 w/cm°C@85°C
- Temperature coefficient of expansion (TCE) matches many of the materials used in high-reliability applications, viz., silicon, GaAs, GaP
- InP, alumina ceramic, Kovar, Cu, CuW, and alloy 42 viz., 16ppm/°C@20°C
- High surface tension, zero wetting angle
- Fluxless soldering, the original flux-free reflow alloy
- Suitable for "step soldering" applications

Processing Considerations

Gold-tin is usually the alloy of choice when joining gold-bearing surfaces, such as gold plating (typical minimal thickness of 12.7 microns), sputtered Au films, Au, PtAu, and PdAu thick film metallizations. Because of the high surface tension and zero wetting angle, AuSn does not flow easily on a horizontal surface. Although it has excellent wettability, pressure is required to ensure good, void-free, reflow. In the case of lid-sealing applications to ceramic metallized and plated packages, a clip of a suitable pressure is used to ensure that a good fillet of solder is seen around the entire periphery of the lid.

In some cases, gold-tin can be used to solder plate nickel surfaces, which are notoriously difficult due to nickel oxide formation. With the forming gas* option, and a higher temperature approaching 400°C, the oxide can be reduced back to nickel metal and, due to the excellent wetting proper ties of gold-tin, a void-free joint can be formed.

When considering the gas to be used, nitrogen is acceptable in the majority of cases, but forming gas was historically used to ensure that any residual tin oxide in the gold-tin solder itself was reduced by the action of the hydrogen. In both cases, the supply of gas has to be from a high-purity monitored line and the oxygen content of the gas must remain below 20ppm. Thus, an oxygen monitor is highly desirable to ensure complete compliance to this level.

A typical gold-tin sealing profile for a furnace application is illustrated here. The important parameters, apart from the gas purity and flow rate, are the ramp up, time at peak temperature, and cooling rate. These can all be varied by furnace set-up and design, and the thermal soak of the items being processed. In general, the following should be typical:

- Ramp rate of 50°C per minute, with no dwell time, up to a peak temperature of 320°C
- A time above the eutectic temperature of 280°C for 2-3 minutes, with a bell shaped profile—no plateau at peak temperature
- A cooling rate of 50°C per minute or less to prevent any thermal stress on the component
- The thermocouple used to profile the furnace should be calibrated and always be attached to the component being reflowed, with the furnace belt loaded as it would be in production use. In this way, a true reflection of the temperature profile at the solder interface is recorded, rather than the gas flow temperature if the thermocouple is sitting up in the gas flow

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When used in a die-attach application, the preceeding rules apply. These rules can be modified to ensure complete gas coverage of the die-attach area. Appropriate pressure should be applied at the die interface to ensure good void-free spread of the solder, but with no agitation or ultrasonic assistance, as the eutectic is at a true 80/20.

This is not the case with, for example, the 98%Au/2%Si alloy used in silicon die-attach, as the true eutectic is at 3.1%Si. In this case, thermosonic power is required to scrub the die to diffuse the Si from the chip into the solder so that it reflows when that alloy percentage is reached. The scrubbing action here also ensures that the eutectic appears around the periphery of the die, visibly ensuring that the eutectic composition has been reached.

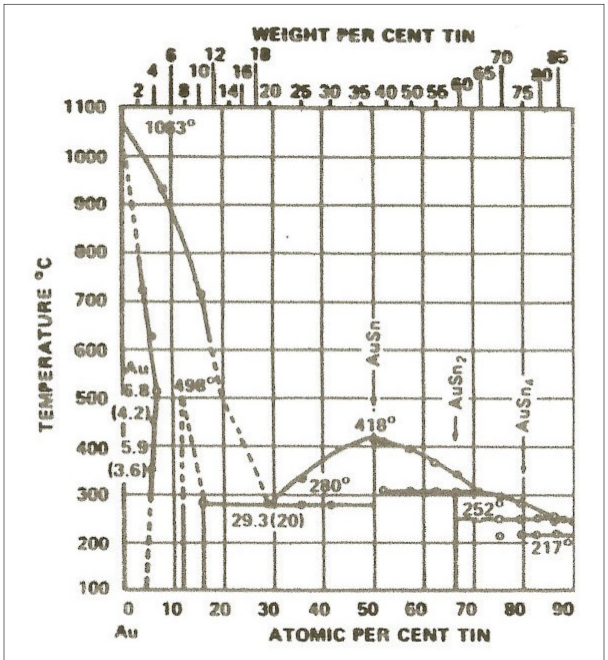

Figure 2. AuSn Phase Diagram

*Forming gas composition is commonly 95% nitrogen and 5% hydrogen; increasing the hydrogen content increases the reduction process.

Design Considerations

As gold-tin solder has a zero wetting angle, it requires pressure to reflow. The dimensions of a solder preform or frame have to be carefully considered to ensure a good void-free visible fillet, but without excess solder-forming solder balls as the fillet is formed. These solder balls can be visually undesirable, in the case of lid sealing, or functionally disastrous if these solderballs fall into the cavity. This is especially true for any unpassivated die, as with SAW devices.

The general rule is that the gold-tin preform should be 90-95% of the area of the die or metallization, always ensuring, in the case of lid sealing, that the preform frame is smaller on the OD by 250 microns and at least 125 microns larger on the ID dimension.

In addition, AuSn solder has a little quirk that is obvious from scrutiny of the phase diagram, but is not a commonly-known attribute of this eutectic material (Figure 2). When AuSn is joining two gold-bearing or plated surfaces, the gold diffuses into the alloy at the melting temperature, so that the time above the eutectic temperature and the peak temperature are controlled, as detailed above. However, as diffusion occurs and the gold content of the solder increases, the phase line for gold is at an angle of 75° (very steep). At 18% tin, the reflow temperature is 350°C and at 16% tin, it is at 400°C. Thus, subsequent processing of AuSn solder or any other alloys in a "step solder" process is acceptable between 300°C and 350°C.

This can be used to our advantage, but in attempting to remove Kovar lids soldered to ceramic packages, it must be remembered that the solder will only reflow again at this higher temperature. In defect investigations, it is far easier to remove a lid using a scalpel inserted at the corner of the lid and to apply pressure at a corner, which enables the lid to be removed without the temperature cycle.

Conclusions

AuSn solder is an excellent material with superior attributes and is the solder of choice, with no obvious alternatives, in many applications. The cost considerations have to be weighed carefully, but in many applications the attributes of excellent wettability and ease of use overcome the cost of material. In fact, yields using AuSn solder are usually above 99.5%, making the cost of ownership and the goal of zero defects more easily achievable.

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