microJoining Solutions – microTips™

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Reflow Soldering – High Current Connections

Introduction

Electro-mechanical assemblies such as terrestrial solar cell panels and thermoelectric generators typically use tin or solder-plated copper connecting straps to connect the current generating devices. Copper connecting straps provide low electrical resistance and thus minimize the energy losses. In high temperature applications, brazing materials replace the tin or solder as the joining material. Heat to reflow the tin, solder, or brazing alloys can be generated by multiple heating methods which include: induction, flame, oven, resistance, and thermode. This microTip is limited to inductive, resistance and thermode heating methods.

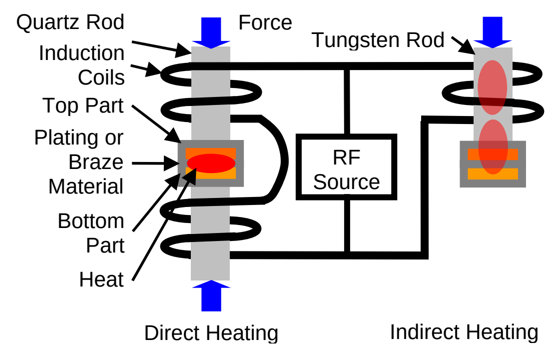

Figure-1, Induction Heating

Induction Heating

Induction heating uses an electromagnetic field (EMF) to generate “eddy currents” in metals capable of conducting electric currents. Magnetic metals such as nickel generate additional heat due to a hysteresis effect when the magnetic field changes directions. The heating effect is very selective and depends on:

- Electrical resistivity of the materials
- Magnetic coil diameter
- Proximity of the magnetic coil to the parts
- Coil current magnitude and time
- Coil current frequency

Induction heating works best with parts that are pre-plated with tin or solder or with use a fixed volume of high temperature brazing material placed between the parts. Hold the parts together with sufficient force using quartz or ceramic rods to ensure good heat transfer and prevent the parts from moving during solidification. Heating time depends on the mass of the parts, but is typically 1-sec or longer.

Heating can be direct or indirect. See Figure-1. Direct heating involves placing the parts within one current loop directly heats the all parts. Indirect heating is used when access is limited to just one part surface. Indirect heating involves surrounding a tungsten rod with multiple current loops. The heat induced in the tungsten rod flows into the metal parts. Over time, the tungsten rod will build up tin or solder plating on the contact surface and must be cleaned using #600 silicon-carbide paper.

Resistance Heating

Resistance heating uses the electrical resistance of copper connecting strap, substrate metal, and tungsten electrodes to generate the necessary heat to reflow the tin or solder plating on both metals. Passing a constant current through the connecting strap and substrate metal generates the necessary reflow heat. The heating time depends on the mass and electrical resistivity of the parts, but is typically 25 to 200-msec. See Figure-2. The heating effect is very selective, occurring only between the two electrode tips. The gap can range from 1 to about 100-mm and still produce even melting.

It may be necessary to place flux between the connecting strap and substrate metal to remove oxides and facilitate even heat flow. In some cases, the mechanical motion of the collapsing tin, solder, or brazing alloy is sufficient to displace the oxides. Over time, the tungsten electrode tips will build up tin or solder plating on the contact surface and must be cleaned using #600 silicon-carbide paper.

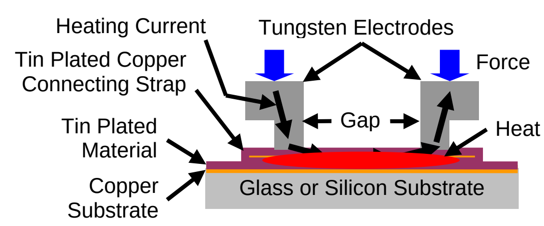

Figure-2, Resistance Heating

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Thermode Heating

Thermode heating, also called "hot bar" heating, utilizes a heater element made from Inconel, molybdenum, Nichrome, stainless steel, or tungsten. Passing an electrical current through the bar generates heat, which is conducted into the parts.

There are two main types of thermode configurations, fold-up and bar. The fold-up design shown in Figure-3 is used to heat voltage sensitive parts. The heating element is usually very thin, 0.5-mm or less and is attached to copper bus bars using E-Beam or laser welding. The heating current flows in a direction perpendicular to the thermode length so the voltage drop across the thermode length is zero. There is a small voltage drop across the thermode depth, which depends on the depth dimension and heating current.

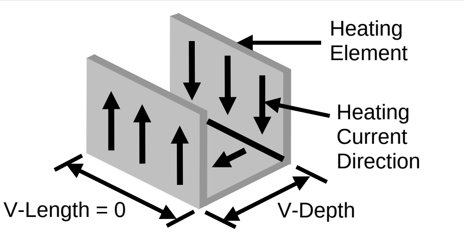

Figure-3, Fold-up Thermode

The bar design shown in Figure-4 is less costly to make compared to a fold-up thermode. A bar thermode should have a geometry that produces a constant temperature profile across the entire bar length *when in contact with the parts*. Because the heating current flows in the direction of the bar length, there can be a substantial voltage drop across the bar length, so bar thermodes should not be used with voltage sensitive parts. Bar thermode performance also suffers from shunting the heating current to the copper connecting straps. Finally, depending on the bar length, the center of the bar may warp during pulsed heating and lose thermal contact with the parts. The heating element is usually attached to copper bus bars using mechanical fasteners such as screws.

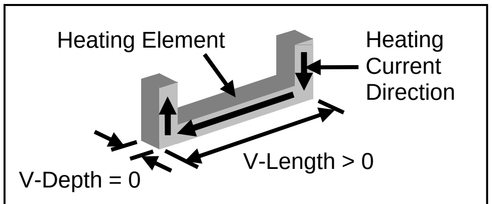

Figure-4, Bar Thermode

Both thermode configurations can be pulsed or constant temperature heated. A Type K thermocouple welded to a location closest to the contact face provides temperature feedback and some resistance to chemical attack by flux fumes.

All thermodes are subject to mechanical impregnation and alloying with the tin, solder, or brazing alloy. This process is not even across the thermode contact surface and will eventually result in "cold spots" where the tin, solder, or braze material does not reflow. The use of a polyimide layer between the thermode contact surface and the parts prevents the alloying effect and heating current shunting, but also slows heat transfer into the parts by a factor of 5 to 10 times. The polyimide film must be periodically advanced to a new portion due to mechanical abrasion and particle build up.

Cleaning is required when the reflow soldering process no longer produces a uniform melting pattern. Use #600 silicon-carbide paper or a ceramic block. Ultrasonic cleaning will not remove impregnated tin, solder, or brazing alloys from the thermode surface.

Pulsed heated thermode life depends on the maximum operating temperature, the temperature differential between the peak and release temperatures, thermode alloy, thermode geometry, and the degree of flux attack. Failures occur due to micro-cracking, tin and solder alloying, flux attack, and oxidation flaking caused by repeated heating and forced air cooling. Constant temperature thermode life is usually much longer than pulsed heat thermodes because there is less expansion and contraction.

Summary – Pulsed Heating Methods

Heating Method	Heat Source	Heat/Cool Time (sec)	Estimated Life (cycles)
Induction	Internal	1 to 5	>100K
Resistance	Internal	0.05 to 0.2	>100K
Thermode, Bar	External	1 to 5	>100K
Thermode, Fold-up	External	1 to 5	<20K

Other microTip References:

Resistance Brazing Basics

Selective Reflow Soldering – Quality Assurance Issues, Solder Thickness and Flux Control