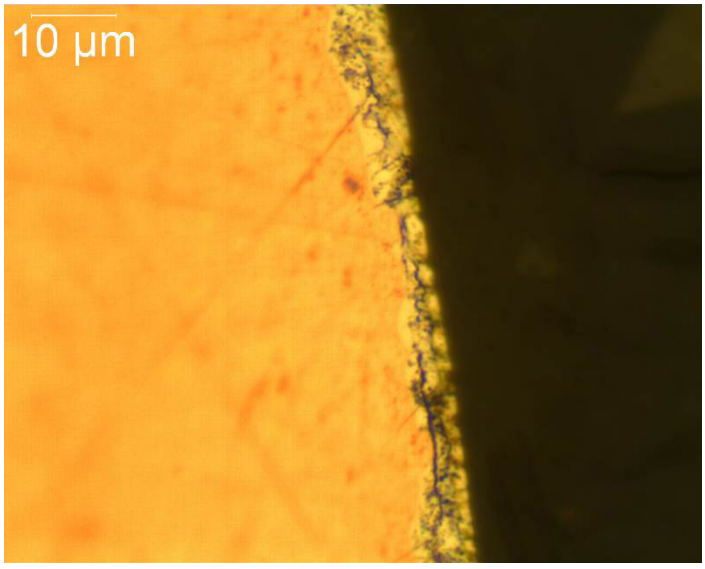
THE METALLURGY OF HEAT–INDUCED "SOLDERING"

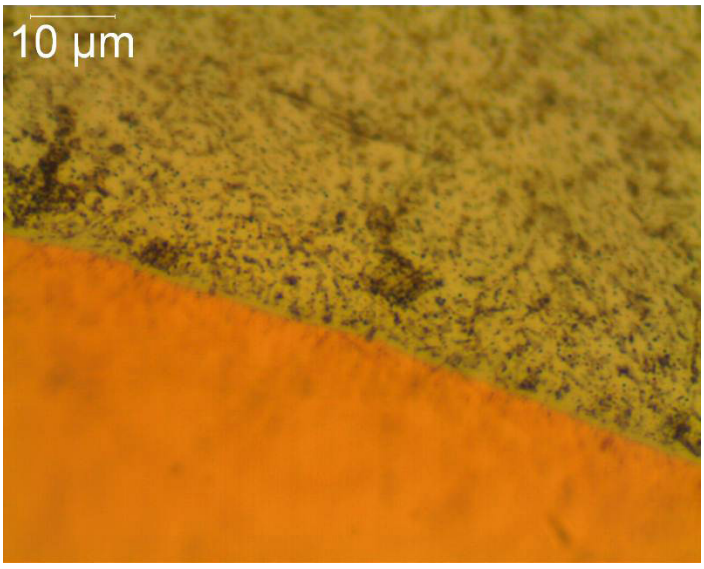
A solder connection meets the cosmetic reliability requirements of A-610 and J-STD-001. But is it, in fact, reliable? The answer is: not necessarily. **An "acceptable" connection made with a soldering iron may not actually be reliable.** Indeed, it may not even be soldered. At the elevated temperatures of soldering irons (roughly 700°F/370°C or more), solder will stick to metal oxides and create the erroneous impression of wetting.

We prove this in two steps. First, insert a copper wire without flux into a solder pot at 450°F/232°C. Since the wire has not been deoxidized, there is no solder coverage. Next, insert an identical copper wire, again without flux, into solder at a typical soldering iron temperature — 680°F/360°C. Although the wire has not been deoxidized, solder completely covers the wire and it meets the visual acceptance requirements of J-STD-002. But the wire only *appears* soldered; it is not *actually* soldered. At the higher temperature, the solder simply sticks to the oxides and *there is no intermetallic bond*.

The image on the left below is a cross–section of a wire after insertion without flux in 680°F/360°C solder; there is no intermetallic bond. On the right is a cross–section of a truly soldered wire (a flux capable of removing the oxides was applied before insertion into solder at 450°F/232°C). Note the thin line of intermetallic where the solder meets the copper.



Dipped in 680°F/360°C Solder Without Flux

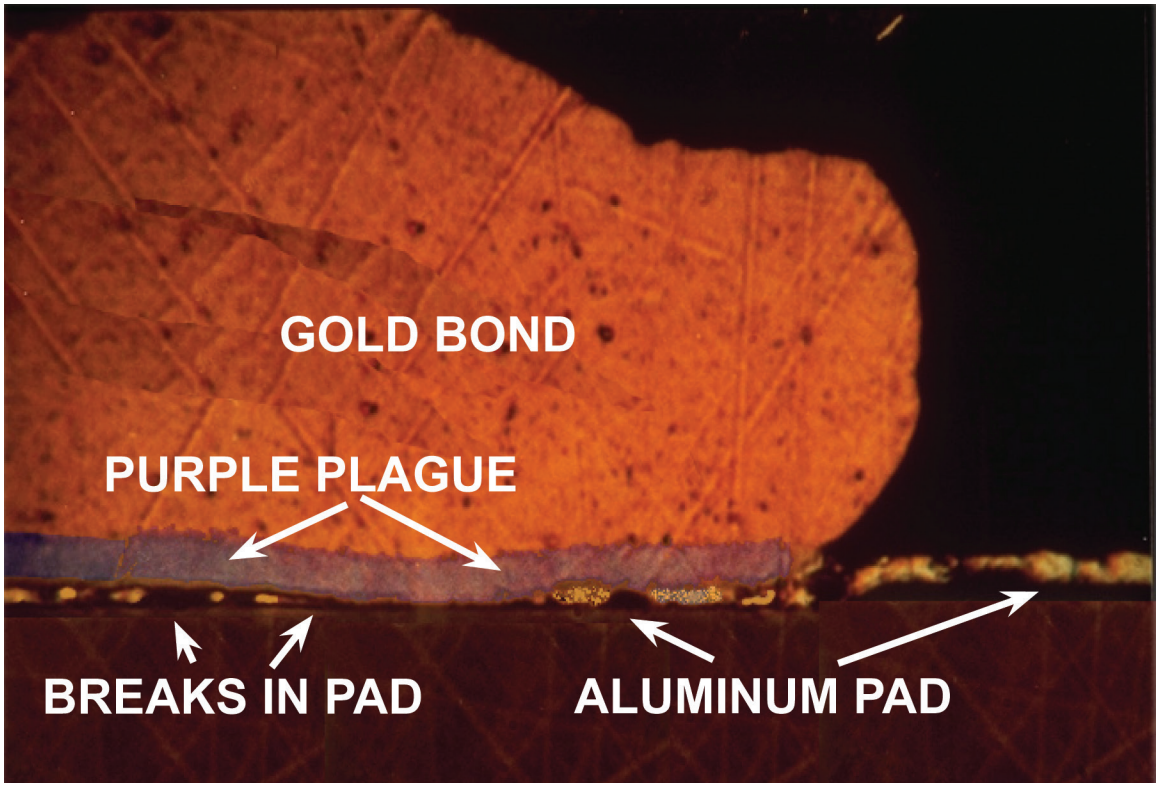


Properly Soldered at 450°F/232°C With Flux

The (Un)Reliability Consequences

The lack of intermetallic bond means vibration or repeated heating and cooling could cause the solder to break off. But that is only one reliability problem. Additionally, oxides (and, possibly, contamination) between the solder and the component creates electrical resistance in the solder connection. Depending on the sensitivity of the circuit, this resistance can cause failure.

But, worst of all, the component is subjected to extreme heat, generally for several seconds, to force visually acceptable solder coverage. This causes greatly accelerated growth of the intermetallic ("purple plague") where gold lead wires of I.C.s are bonded to aluminum pads on the chip die. The thicker intermetallic increases electrical resistance that affects performance of the device and this alone can cause failure. In addition, however, cavities known as Kirkendall voids develop under and at the edges of the bond (shown in the photograph below), resulting in intermittent or permanent breaks in the circuit.



Summing Up

More and more component surfaces consist of metals other tin/lead or tin. These new surfaces do not melt and may not be solderable with acceptable electronics fluxes. As a result, wetting defects have become very common. Poorly educated operators believe that they can make those wetting defects reliable by touching up. But touchup/rework only covers up the defect while making the component more likely to fail.

When a soldering iron has been used either in making the original connection or in touchup/rework, acceptable appearance does not prove reliability.

Overheating because of improper soldering iron use causes most component failures.