Is it really “Black Pad”?

By: Jason Gjesvold

Of paramount importance in electronics assembly is the solderability of materials, including the circuit board. Generally, solderability is affected by inherent material properties, cleanliness of surfaces, and surface ageing by environmental stresses.

Specifically relating to circuit boards, there are a variety of surface finishes currently in production designed to combat the degrading effects of the environment on solderability. They include hot air solder leveling (HASL), organic solderability preservative (OSP) over bare copper (Cu), and barrier metal over Cu processes. Board manufacturing processes incorporating a barrier metal over Cu use materials such as nickel (Ni) or tin (Sn) as a barrier to inhibit Cu oxide growth, and preserve the solderability of the surface. While both electroless and electrolytic Sn are used in many applications, failure modes such as Sn whisker growth preclude widespread adoption. The use of Ni as a barrier alleviates whisker growth concerns produced by utilizing Sn, however Ni exposed to the environment will oxidize readily. Therefore, application of a barrier over the Ni, such as gold (Au), must be added to the manufacturing process of the board. While Ni barrier metals offer very uniform composition, good corrosion resistance, and very flat surface finishes, an increased awareness of potential failure modes must be established before reliable manufacturing can begin.

“Electroless Nickel Immersion Gold” (ENIG) is a barrier metal process rapidly gaining prevalence in the board manufacturing industry. Unfortunately, the awareness of proper implementation is hindering the adoption of the technique. Several variations of Ni alloys, containing low-mid-high Phosphorus (P) content, have become the standard alloy configurations. As presently defined by most board manufacturers, low-mid-high P content Ni is 2-4%, 5-7%, and 8–10% respectively by weight.

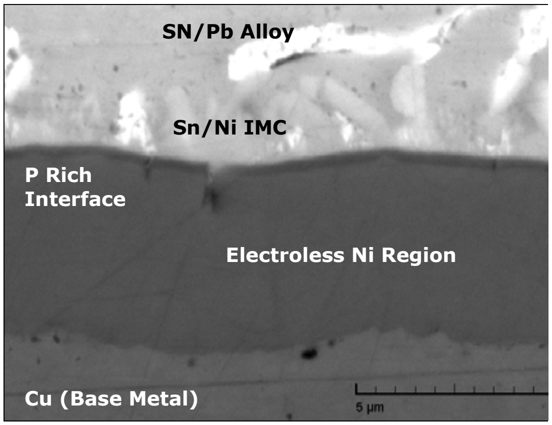

Image 1. Acceptable Sample

Phosphorus rich Ni alloys are often used for corrosion resistance during the highly acidic immersion gold (IG) process. However, a mutual problem between mid-high phosphor alloys (5-10% by weight) is the tendency to develop P rich areas at the connection interface between the solder and Ni after reflow. While the higher concentration of P serves to impede the Ni corrosion in the IG bath, this excess P will remain inactive while the formation of the Sn/Ni intermetallic occurs. This pooling of phosphorus below the intermetallic creates a mechanically weak area. Subsequent mechanical stress due to thermal expansion or mechanical forces then has a higher probability of fracturing the connection interface.

This mechanism has come to be known as “Black Pad” and much research is currently underway to understand this phenomenon. Also under development are analytical processes to accurately and noninvasively diagnose this phenomenon. Currently, all procedures for diagnosis are destructive to the sample being analyzed. Whether through Ni surface analysis after Au etch, or through cross section energy dispersive spectroscopy, characteristics of the failure mode must be developed. The sample seen in image 1 illustrates the small, but defined, P rich interface characteristic of an acceptable sample. In this example, the P rich interface thickness is measured as approximately 0.25 microns and not classified as excessive. In the case of boards exhibiting the failure mode, a much deeper P rich area, up to 2.5 microns is observed and very poor solderability and mechanical strength characteristics are exhibited.

Currently, visual inspection of scanning electron micrographs of Ni plating can yield compelling clues as to whether “Black Pad” exists in a sample. A characteristic described as “mud cracking” is prevalent in samples with high P concentrations at the surface of the Ni. Additionally, P concentrations that are not uniform as a function of depth in cross-sectioned samples suggest that this phenomenon is being exhibited. Interestingly, a high concentration of P in a Ni barrier layer will not always signify the “Black Pad” phenomenon. In recent failure analysis efforts in Soldering Technology International’s Analytical Lab, relatively high concentrations of P (11% by weight) were noted throughout the Ni barrier layer of a failed sample. While this level of P content certainly degrades the solderability of the Ni, it does not constitute “Black Pad”. It was simply a situation in which variables in the plating process deviated and the P content of the Ni changed. It is important to remember the process by which the Ni is applied. Changes in bath chemistry directly affect the concentrations of P to Ni, therefore, a process that is not properly maintained will not produce reliable hardware. As with all other aspects of electronics manufacturing, process control is mandatory. Additionally, cause and effect analysis must be conducted in order to understand process variation impacts on the end product. This information then needs to be shared with the rest of the industry, as is our goal at Soldering Technology International.

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