Structure and Properties of ACD Ni-P/ Immersion Gold Finish for Lead-free Solder Joints

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Tin-based solder alloys are used in microelectronic packaging to interconnect components with the copper base material. Excessive growth and coarsening of the intermetallics, particularly those of copper and tin, can result in a severe degradation of the solder joint mechanical performance. To limit the intermetallics growth, a diffusion barrier is introduced between the solder alloy and copper. The need for diffusion barriers has recently become of major concern as a consequence of the perspective banning of lead-containing solder alloys. Tin-silver-copper and tin-silver-bismuth alloys are the candidate alternative to the commonly used eutectic tin-lead alloy.[1] Moreover, to maintain the joint reliability requirements, the electronic industry must try to develop new processes consistent with lead-free alloys improving the mechanical properties of such solders.

The Autocatalytic Chemical Deposition (ACD) Ni-P /immersion Au finish is commonly used, particularly for Ball Grid Array (BGA) packaging, to protect copper and assure long term storability without impact on the solderability.[2,3] The nickel layer provides a diffusion barrier to inhibit the growth of intermetallics. The outermost gold layer protects the base material from corrosion and oxidation, during thermal reflow and damage from handling. In recent years numerous failures in packaging were observed and attributed to the ACD Ni-P/immersion Au process. One of the causes is referred to as “black pad”, an attack on the nickel surface by displacement reaction in the gold bath.[4] Other authors found a relationship between joint reliability and recrystallization with change of composition in the amorphous matrix during solder reflow.[5] The growth of different intermetallics at the electroless nickel/solder interface was recently investigated.[6,7]

In this work, the ACD Ni-P/immersion Au process is carefully investigated. The ACD deposition from different Ni-P and immersion Au baths is studied. Surface finishes are characterized by X-Ray Photoelectron Spectroscopy (XPS) and Energy Dispersion Spectroscopy (EDS) before and after reflow. Content and distribution of phosphorus, carbon and oxygen, and the evolution with heat treatment (standard thermal reflow), within the surface finish layer are determined and related to the final mechanical behavior of the joint. The phosphorus peak is shifted towards the external surface, while oxygen peak towards the substrate. Carbon is concentrated in a small region of the deposit near the interface and its profile does not seem to be completely correlated with the oxygen profile, with a peak corresponding to phosphorus maximum. Carbon and oxygen contents depend on the ACD Ni-P deposition bath. Their presence, in a limited region, could be attributed to the displacement reaction of gold cyanide immersion process for carbon, and to possible phosphorus oxidation.

The behavior of the surface finishes in presence of tin is evaluated after different aging conditions (T = 250 °C for t = 1, 5, 10, 15 min). The interfacial reaction between the ACD finish and electrolytic tin layer is evaluated through EDS line profiles on the joint cross section. Microindentation, used to investigate the intermetallics layer, shows high hardness values. Diffusion of Ni-P and Ni-P/Au finish in presence of a tin layer electrodeposited onto the surface shows a very high value of phosphorus at the interface between Ni-P and Sn. This high value comes out after 1 minute at 250 °C and is higher when gold is present. The enrichment zone is extended and can be attributed to the formation of Ni_3Sn_4 towards the tin layer with precipitation of Ni_3P in the nickel depleted zone towards the substrate. Results by microindenter penetration curves show an increase of microhardness corresponding to the Ni_3P layer, thus suggesting a growing brittleness of the joints caused by the diffusion process.

As alternatives to Ni-P/Au, encouraging results are obtained in the case of the Au/Sn/Ni-P system with Sn either codeposited with Ni-P or as a layer on Ni-P or in between the Ni-P layer. In all cases a decrease of nickel diffusion and growth of intermetallics layer is observed, depending on the tin quantity added.

The mechanical behavior of joints between the lead-free solder alloys and nickel-phosphorus/immersion gold finish is characterized by shear resistance tests and compared to the standards of the traditional tin-lead alloy.

Tests were performed with different thermal cooling rate and oxidation degree (two blank reflows) of the surface finishes. The shear values for the Sn-Ag-Cu alloy are definitely not satisfying the specification: this is related to the wide standard deviation of the shear resistance value. Shear values are lower than those for the Sn-Pb alloy. The shear values for the Sn-Ag-Bi alloy are lower than those for Sn-Pb and similar to the Sn-Ag-Cu values; the standard deviation is better than for Sn-Pb and the solders does not fail the specification. There is no evidence of an influence either from oxidation or from thermal profile cooling rate.

Sn-Pb shear values greatly decrease after thermal aging TA (T = 150 °C for 15 days). Sn-Ag-Cu maintains its shear values after TA. Sn-Ag-Bi shear values decrease after TA for slow thermal profile, while for fast thermal profile they increase after TA.

ACD Ni-P/immersion Au finish show increased problems with the newly proposed lead-free solder alloys. Alternatives and modifications must be examined to overcome the difficulties.

References

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