DEFINING industry... with The SMART Group and Nepcon UK

Intermetallics

Intermetallics are compounds that form when certain combinations of two or more metals are mixed together in certain proportions and react to produce a solid phase that is distinctively different from the constituent elements.

Much of the change in character is due to a difference in the chemical bonding that binds the atoms of the phase together. In pure elements and solid solutions, the atoms are bound together with metallic bonds. The chemical bonds binding the atoms together in intermetallic compounds are more covalent in nature. This can profoundly alter the character of the new phase in terms of crystal structure, chemical, mechanical and electrical properties.

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Most of the interest in intermetallic compounds in solder joints has focused on their affect on the mechanical properties and reliability of the joint as a whole. Intermetallic compound formation may also affect the wetting and solderability characteristics of some coating technologies and have an impact on rework and repair.

IMC elements

Many of the elements that associated with the soldering materials can combine to form intermetallic compounds. Most intermetallics that are commonly encountered in solder joints include tin as one of the components. Lead rarely forms intermetallics in solder joints but commonly encountered elements that may form intermetallic compounds with tin include copper, nickel, silver and gold.

The intermetallic-forming elements can come from the substrates and coatings being soldered. During the soldering operation, material from the solid substrates will dissolve and mix with the solder, allowing the formation of intermetallic compounds. This type of behaviour usually produces a layer of intermetallic compound (IMC) between the solder and the substrate.

Intermetallic formation in the bulk of some lead-free solder alloys, such as tin-silver, tin-copper and the ternary tin-silver copper is normal. The effect of the intermetallics is taken into account during the design and selection processes. If this type of intermetallic formation were inherently bad, these materials wouldn't be considered for use. It is thought that the presence of some intermetallic compounds may stabilise high temperature performance.

Intermetallic compound formation at the interface between the solder and substrate is an extremely important reaction. All common substrate materials should produce an IMC layer when soldered, with the notable exception of iron-nickel lead-frame materials. In cross-sectioned samples, the IMC layer should be clearly visible as a thin layer, a few microns thick, between the solder and substrate/coating using an optical microscope. The absence of this layer can be indicative of soldering problems and the joints should be treated as suspicious.

Problems

Too much intermetallic compound formation at the solder-substrate can be a problem, potentially resulting in production or reliability problems.

Although a required product of most successful soldering reactions, the IMC layers are usually only poorly wet by molten solder alloys. Too much intermetallic growth at the solid-liquid interface, usually as a result of too much thermal exposure during soldering, can result in dewetting. An existing IMC layer may reduce the time required for dewetting to occur.

Intermetallic compound layer growth can also result in brittle joints and poor reliability. If the IMC layer is allowed to become too thick, the soldered joints become brittle. The initial thickness can be controlled by substrate selection and process control but IMC growth can occur in the solid-state after joint formation, especially if exposed to elevated temperatures. Even when the growth rate is slow but joint embrittlement can occur given sufficient time.

Joint embrittlement can also occur if the "wrong" intermetallics are formed. The most common example is gold embrittlement. This usually occurs when soldering thick gold coatings or due to bath contamination. A certain amount can be tolerated but too much is definitely bad.

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