A completely new and innovative approach to providing solderability preservation for printed circuit boards has arrived based on a synthetic conductive polymer that provides a purely organic surface finish. As well as being environmentally-friendly and producing an ultra-thin uniform surface coating, the performance of this surface finish technology has proved to be superior to conventional organic solderability preservatives (OSPs) and almost as good as that of Ag, Ni/Au or Sn surface finishes.

Organic metal - physical and chemical background

A metal is characterised by the mobility of the electrons. Metallic electrons are “free” in an elongated “metallic band”, which consists of a binding electron energy band overlapped by the non-binding band. This characteristic is not limited to inorganic metals, but can also be realised with organic compounds and polymers. Nanometals - metal particles of a diameter in the range of a few nanometers or thin films in the same thickness range - also show thermally activated tunneling of the electrons. In this respect, Ormecon’s Organic Nanometal is both a metal and a nanomaterial. All earlier attempts to provide a commercially viable material, however, resulted in compounds that were unstable, insoluble and unmoldable – and therefore totally useless.

Starting in the late 1970s with basic and applied oriented research, over the years Ormecon has succeeded in designing a polymeric composition that is highly stable, and which can be produced economically and processed. However, as insolubility and unmoldability are the principal properties connected with the metallic property, processing cannot be performed by dissolution or molding techniques, but rather by newly developed dispersion technologies.

Organic Nanometal has a unique set of properties. To begin with it is a metal, placed between Silver and Copper in the galvanic series. It is therefore nobler than Copper, Iron and all other non-noble metals, but less noble than Silver and the noble metals. The Nanometal can be reproducibly reduced and oxidised – it can act as a catalyst in other words – whilst the raw powder is moderately conductive (5 S/cm). Recent research results have raised the possibility of achieving conductivity values 100 times higher than this, although it is thought that, in reality, even higher values can be achieved. Some dispersions are higher in conductivity than the raw material whilst dilute dispersions are transparent green, as are pure thin layers or coatings of the Nanometal. The conductivity can also be tuned, if necessary, over a range of 10 orders of magnitude.

Figure 1 - Current density - potential curves of Copper uncoated/coated with the organic metal

Figure 2a (left) - Copper plate etched in 10% sulphuric acid and then rinsed in water. When drying, oxidation and corrosion occurs within seconds

Figure 2b (right) - Here the Copper was dipped in the aqueous dispersion of the organic metal after etching and washing with no change to its surface colour

New Organic Metal Finish
For PCBs Outperforms OSP

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The passivation of Copper

The characteristics of Organic Nanometal allow for a completely new process, resulting in a new surface finish for printed circuit boards. The organic metal passivates Copper. Figure 1 shows the potential shift induced by the organic metal. The potential shift ranges at about 800mV and allows the Copper to oxidise at an equally higher potential, i.e. under much harsher conditions.

Figure 2 shows how even a wafer-thin organic metal coating on Copper, deposited from aqueous dispersions, minimises the oxidation of Copper. A Copper plate etched in 10% sulphuric acid is rinsed with clean water: when drying in open air, it oxidises and corrodes within seconds (Figure 2a). If, on the other hand, Copper is being dipped in the aqueous dispersion of the organic metal after etching and washing, and is even rinsed again afterwards, one would think there is no coating, as nothing can be seen. However, it is clear after a few seconds, and even more so as time passes, that the Copper surface does not change its colour.

The coating cannot be seen as it is only about 80nm thick. Such fine nanostructures can only be detected with tunnelling microscopy (STM) or x-ray photoelectron spectroscopy (XPS). Figure 3 is an XPS spectrum that shows the induced chemical change of Copper in the presence of the organic metal.

Upon exposure to air the green form of organic metal is transformed to the blue non-conductive form within 20 seconds. Cu(I) oxide formation is observed at the same time. Upon prolonged exposure of the sample to air, Cu(II) oxide is also formed (see Figure 3). This is different on a sample without polyaniline where only Cu(I) oxide is detected after the same amount of time.

This is proven by the aging of Copper pre-treated with the OM dispersion in comparison with sulphuric acid-etched plates. Colour changes are observed with annealing time from various violet and bluish tones into silver and bright golden. This is due to interference of light between the surface and the thin oxide layers. Varying oxide layer thickness causes different colours.

The copper oxide thickness was measured by sequential electrochemical reduction. The electric current applied is directly proportional to the oxide mass, provided the reduction current and the depleted area remain constant. A relationship between colour and oxide layer thickness was found. The change of oxide layer thickness for CuO and Cu2O is shown in Figure 4. The growth of copper oxides on surfaces etched with acids is proportional to the time expected for the oxidation of metals in the gas phase.

The pre-treated organic metal surface behaves differently to uncoated Copper. The formation of CuO is proportional to √t while Cu2O decreases exponentially to a minimum of 0.6 nm.

Figure 3 - Cu2p3/2 photoemission spectra of Copper foils with and without organic metal after prolonged exposure to air.

Figure 4 - Formation of copper oxide layers depending on aging time
Tin deposition on organic metal passivated Copper

Ormecon had already successfully taken advantage of the benefits of the organic metal in its CSN Classic and CSN FF Immersion Tin processes, as well as in the whisker-reduced CSN FF-W and CSN FPC-WR (special whisker-free Immersion Tin process for FPCs). The deposition of Tin on this modified, ennobled and passivated surface is catalysed by the organic metal.

However, developing a solderability preservation finish that only consisted of the Organic Nanometal, with no conventional metal finish, remained a challenge. Earlier attempts resulted in perfect oxidation prevention but not in solderability. Solderability preservation is more than just oxidation prevention - it also requires the surface to have a proper surface tension for wettability by the solder.

It took several years of continuous work to finally provide a surface finish formulation and an equivalent process by which the Copper surface can be protected and solderable even after multiple reflow, and under Lead-free soldering conditions. The performance of the new surface finish is superior to the most recent OSP formulations.

The new surface finish

Organic Metal Nanofinish (OMN) produces an ultra-thin (between 50 and 100nm), uniform and planar surface coating, using an environmentally friendly product technology. The product creates a clear layer and has very limited ionic contamination (see independent test data). It also supports fine-pitch device assembly.

No formic or acetic acid is used, and so there are no odours or other harmful emissions that can pose a health risk or cause irritation. The process is very easy and offers a broad process window.

Applications

OMN is applied via dip/immersion (or spray) coating on the pre-treated (purified and etched) printed circuit board. The product is supplied in the form of aqueous dispersion. The coating proceeds via complexation and adsorption.

So far in the product development process, only vertical application techniques have been tested. However, there is no indication that horizontal application techniques could not be used.

Product description and process control

The key OMN process bath is made from OMN 7100, an aqueous organic metal dispersion that contains about 0.1% of the organic metal. The 7100 dispersion has to be regularly monitored for organic metal concentration. Since the material is green, the bath can easily be checked by optical inspection (with the help of standard dispersions) or with UV-Vis spectroscopy. pH should also be monitored.

Evaluation results

The results of the evaluation tests (on solderability, wetting angle, pull strength and ionic contamination) can be viewed in Tables 1-4.