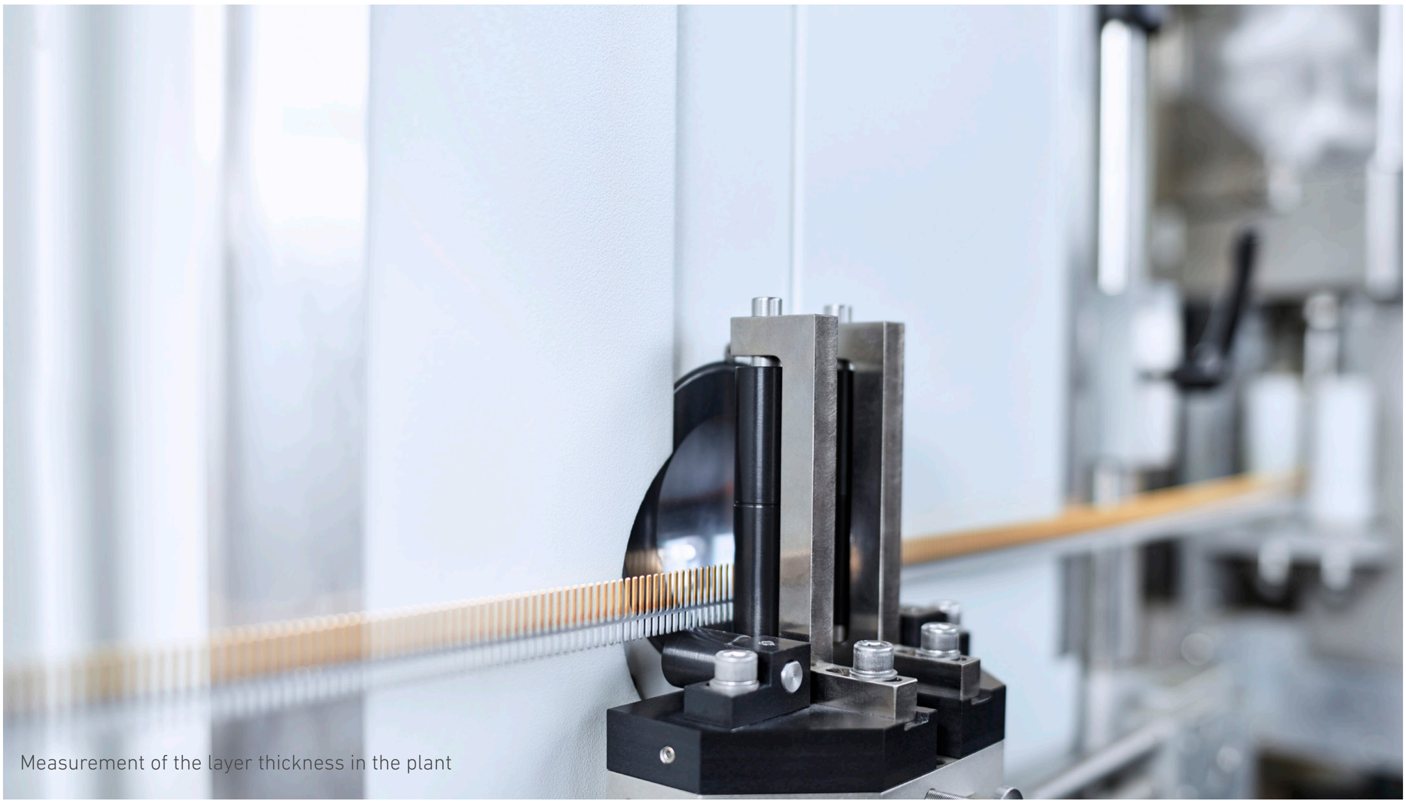

Measurement of the layer thickness in the plant

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Properties of Sn Coatings on Cu Alloys

Question: In recent months, we have received an increasing number of inquiries from customers on the subject of tinning copper alloys. This subject mainly concerns connectors and sensitive applications in the electronics sector. We are toying with the idea of building a plant for these requirements and intensively studying the theory to obtain a risk assessment and schedule appropriate coating tests. We found little about this in the literature available to us, so our question is how tin coatings' properties change on copper alloys.

Answer: Not all tin is the same. The properties and variation depend on many parameters. Major customers, therefore, specify the characteristics to be achieved and the method. In some cases, even the bath type, bath parameters, and the entire process are determined to ensure that all coaters achieve the same coating properties. This information is already available from other coating systems, such as zinc and zinc alloys.

The influencing parameters include coating process, process parameters, interlayers, base material and operating conditions. The influence of the intermetallic phases (see below) and their granular structure as a function of the type of interlayer and the base material are essential.

IMP and Whisker

Due to diffusion, an intermetallic phase (IMP) forms between tin and copper. An IMP is a homogeneous chemical compound of two or more metals. In contrast to an alloy, it exhibits lattice structures that differ from those of the constituent metals. There is a mixed bond in its lattice consisting of a metallic bond portion and lower atomic or ionic bond portions. The IMP is formed either as a migration phase or convection phase. A Cu_6Sn_5 with a lower copper content and a Cu_3Sn phase with a higher copper content is established in this process. This process already occurs at room temperature. In 1.5 years, an IMP of approx. 1 µm is formed. This process generates internal stresses, which promote or cause the formation of whiskers.

Whiskers are fibrous tin single crystals that grow out of the layer due to the stresses mentioned above. They can

With the Fischerscope X-Ray 4000 series, the coating thickness is measured in real-time in a continuous line directly after coating

reach a length of several millimeters and are a cause of faults in electronics, for example, due to short circuits [6].

It is also crucial that the IMP is formed evenly. The more uneven, the higher the internal stresses. Above approx. 135 °C, it occurs more uniformly and much faster since diffusion does not only occur at the grain boundaries. Tinned coils are sometimes stored in the furnace for several hours to achieve this.

Another method for avoiding whiskers is the reflow process. After coating, the matte tin layers are melted in the plant (> 230 °C). Within approx. one second, the IMP is completely formed, and a uniformly bright tin layer is also obtained without the incorporation of organics (see below).

Intermetallic compounds are often hard (excellent hardness, brittleness, strength) and chemically resistant (corrosion resistance). They usually have a high melting point, and their electrical resistivity is usually orders of magnitude higher than that of pure transition metals. The substrate also has a significant influence on the uniform formation of the IMP. It affects whether it is pure copper or an alloy, precipitation alloy or not, which alloying constituents are present in which concentrations up to beta phases, for example, in CuZn alloys. The last one can even promote whisker formation on silver-plated surfaces.

IMP is particularly desirable for connectors. It provides higher hardness and makes the plug contacts more robust against abrasion. Since the IMP is not solderable, there must be enough free tin for soldering applications after the IMP is formed.

Avoidance of Internal Tensions

Many parameters influence the internal stresses of a tin layer. The largest share is due to the incorporation of carbon by organics. There are tin electrolytes specially adapted to this. Still, impurities, for example, from impure anodes, current density, and other parameters that affect the crystal structure, can also negatively influence the layer properties. It is vital to ensure the optimum condition permanently, which is why a high level of effort is required for bath and system maintenance.

Interlayers

In recent years, different layer combinations have been introduced to achieve other properties. In soldering applications and applications without reflow, IMPs are often undesirable. In such cases, a nickel layer of 0.5 – 2.0 µm is deposited as a diffusion barrier. The nickel-tin system is characterized by 3 intermetallic compounds: Ni_3Sn, Ni_3Sn_2 and Ni_3Sn_4. This IMP is very thin and limited to the nanometer range. There are combinations where an IMP is desired, but not between the substrate and the tin layer. In such cases, a nickel layer is deposited, followed by copper plating and tin plating. By now, silver is also used as an interlayer. Multilayer coating systems based on Ni/Ag/Sn offer advantages over pure tin and silver, such as reduced friction coefficients. The wear-resistant layer structure enables a higher number of contact durabilities and reduced insertion and withdrawal forces.

Coating Tests

The testing of tin coatings in the field mentioned above of application is varied and complex. The optical tests range from sighting with the unaided eye to microscopic images and micrographs. The surface's homogeneity is checked and determined whether nodules are already present on the surface using a microscope. These are often already a sign of initial whisker formation.

Cross-sections are comparatively time-consuming and costly and are rarely used in contract electroplating shops. However, IMP can be checked and the coating

Coulometric measuring method

thickness distribution documented.

Depending on the coating system and substrate, coating thickness and IMP can be determined by a combination of X-ray fluorescence (XRF) measurement and coulometric method. First, the whole tin is determined by the XRF measurement. Since the layer thicknesses are comparatively small, the XRF measurement enters to below the IMP. Thus, the total tin content is determined. The free tin is determined using the coulometric method at the points measured by XRF. The thickness of the IMP can then be calculated very accurately.

The X-ray fluorescence process also allows copper alloys to be reliably inspected. This method provides additional security for incoming goods inspection and helps identify the material if the marking of the coils is lost due to transport or other circumstances.

Modern strip electroplating lines are often equipped with an XRF system for inline measurement in real-time. The technology allows measurement at several points, even on both sides, to check the coating thickness distribution. This control enables shorter response times and higher, more stable coating quality.

Flexural behaviour, adhesion, and solderability can also be determined; the tests can vary widely and are sometimes tied to customer standards.

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