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Visual aspects of hot-dip tin coatings

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Preamble

Besides galvanic tin plating, hot-dip tin plating is often used for coating strips of copper and copper alloys with pure tin and tin-silver. Such coated strips are often processed into electrical connectors by means of stamping and bending processes.

An essential advantage of hot-dip tinning is the process-related formation of a low-stress intermetallic phase between the base material (copper or copper alloy) and the pure tin on the surface. This intermetallic phase on one hand ensures excellent adhesion of the tin layer and on the other hand provides high safety against the formation of tin whiskers. This beneficial property "whisker safety" of hot-dip tin coatings is reflected in positive assessments and in recommendations for the use of this coating in the publications of the leading associations of the electronic industry, e.g. the ZVEI (German Central Association of the Electrical and Electronic Industry / "Deutscher Zentralverband Elektrotechnik und Elektronikindustrie") and the iNEMI (International Electronics Manufacturing Initiative).

Copper and copper alloy strips with hot-dip tin layers are standardized in DIN EN 13148. In chapter 6.5.2 „Appearance", the standard describes that the use of liquid tin and the high temperature during the tinning process lead to visible crystallization phenomena which, however, have no influence on the electrical contact properties of the coating.

The tin-plating effects and defects catalogue presented here represents the state of the art for optical phenomena on the surface of a hot-dip tin layer. It was developed in order to objectify the evaluation of hot-dip tinned surface qualities, to achieve a uniform correlation between optical appearance and function and in order to detect tinning defects.

This catalogue contains a uniform evaluation basis for the classification of tolerable tinning effects (good samples to marginal samples) and non-tolerable tinning defects (bad samples).

Instructions for sampling

Should sampling be agreed in a discussion case, the customer is asked to take the samples in accordance with the following instructions:

Samples should be taken from the beginning and end of each affected coil. Samples should not be taken from the outer material layer, as it cannot be ruled out that the material will be affected by handling effects. Therefore, 1–2 layers of material must be unwound for proper sampling.

Samples taken must be handled carefully and must only be touched with gloves to avoid damage and contamination of the surface. Damage caused by coil handling and defects on the outer material layers are not subject to evaluation

1. Visual tinning effects – Good samples

After hot-dip tinning, visual phenomena often appear on the surface which are not present in galvanic tinning, but which have no influence on properties such as contact resistance, roughness, corrosion protection and friction behaviour. These effects are defined as functional good samples.

The respective effect must lie within the layer thickness tolerance and cannot be measured by X-ray fluorescence analysis with a collimator diameter of 0.3 mm.

1.1 Tiger skin

Description of the effect

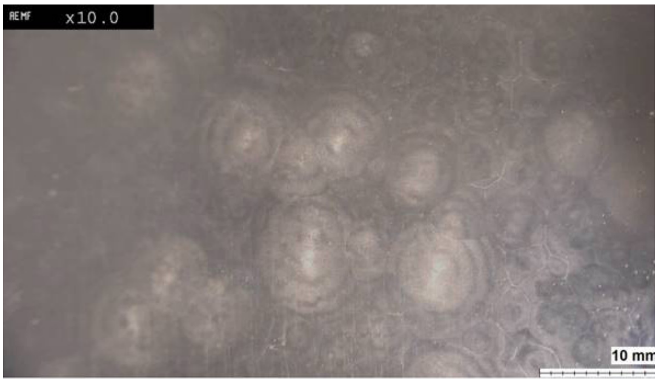
Slight stripes perpendicular to the blowing direction without topography differences compared to the rest of the strip surface.

B14; 0.315mm; 1–3µm tin layer thickness; SnPUR (blow-off direction vertical)

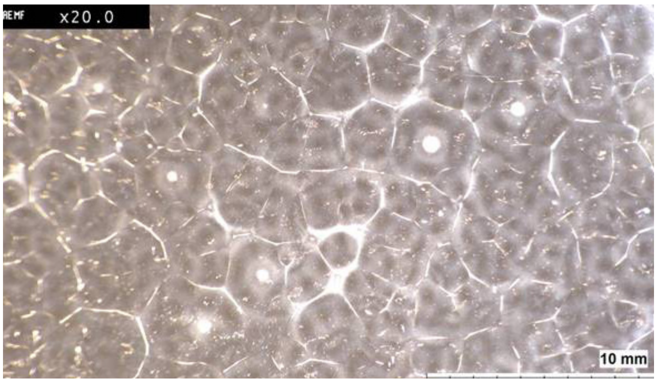
1.2 Honeycomb pattern + White spots

Description of the effect

Typical crystallization structure at layer thicknesses >3 μm with clearly visible nucleus and partly clearly visible grain boundaries. Preferred for brass and bronze.



Typical appearance of the white spots

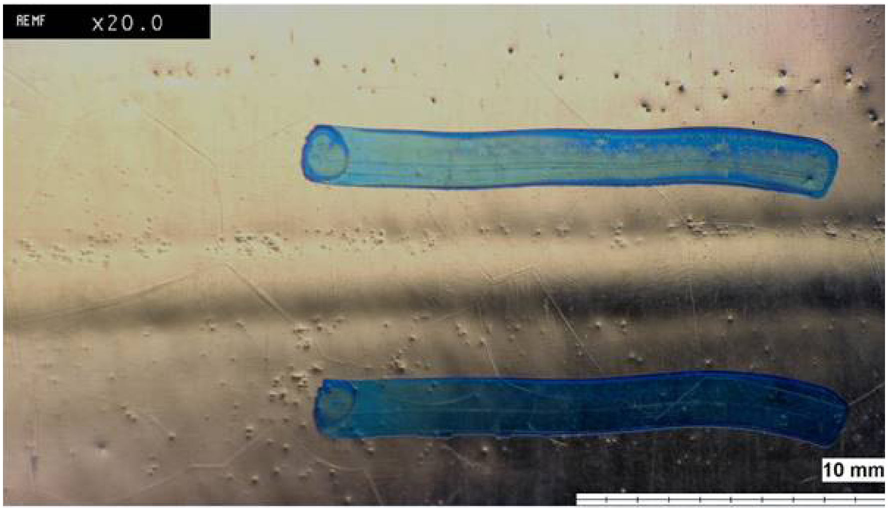


M30; 0.342mm; 3–5.5μm tin layer thickness; SnPUR

1.3 Blow-off stripes / Nozzle stripes

Description of the effect

Elongated elevation in tinning direction partly with micro wetting within the layer thickness tolerance (dewetting, pickle & grit are not relevant for this phenomenon).



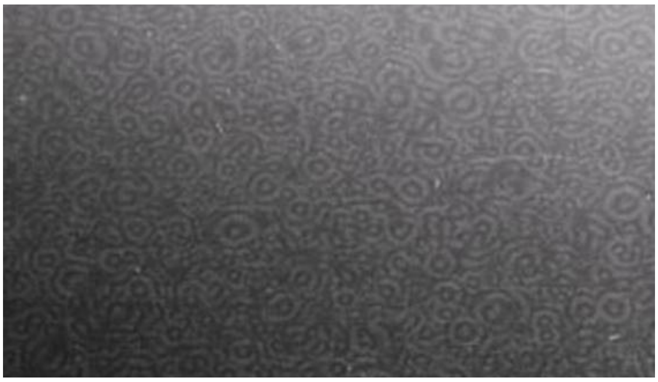
B16; 0.8mm; 4–8μm tin layer thickness; SnPUR

1.4 Leopard pattern

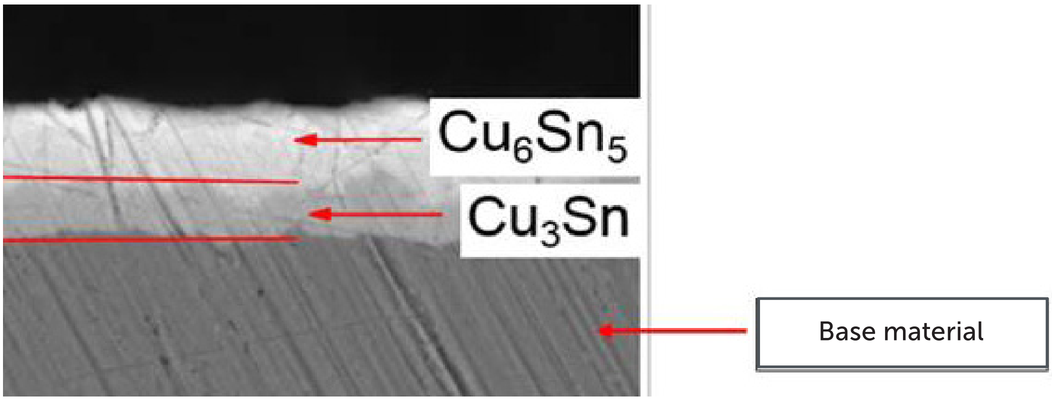
Description of the effect

Typical surface formation of the intermetallic phase after heat treatment (SnTEM).

K65; 0.32mm; 1–2µm tin layer thickness; SnTEM



SEM image of the surface of a SnTEM coating

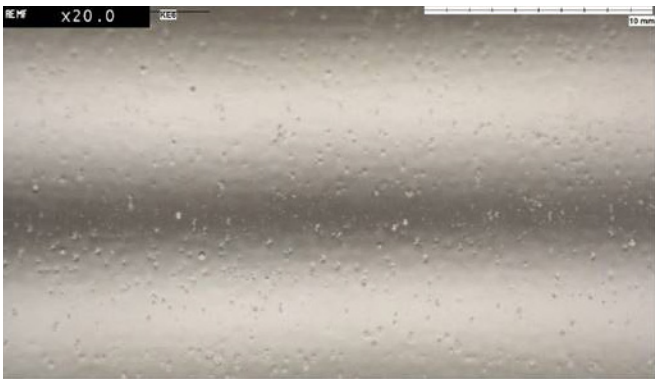


SEM image on a microsection through the tempered tin layer. The typical intermetallic phases can be seen

1.5 Micro dewetting / Pinholes < 0.5mm Ø

Description of the effect

This is a dewetting of the free tin that can be seen with the naked eye as a dot structure, whereby the IMP remains closed. The base material is therefore not visible. The tin layer thickness in the pinhole is $\geq$ 0.5µm (see also Chapter 4).



K73; 0.246mm; 1–3µm tin layer thickness; SnPUR

1.6 Honeycomb pattern / Tin grains / Net structure

Description of the effect

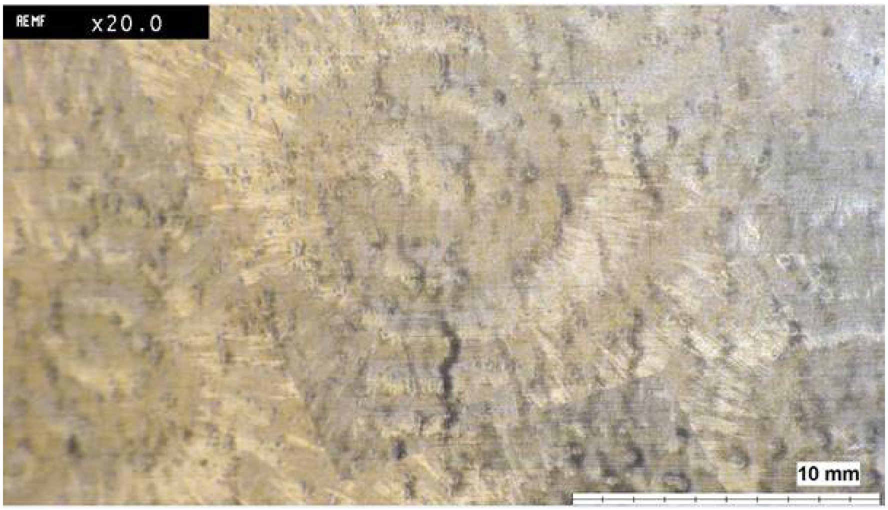
A pronounced grain structure of the solidified tin crystals is to be observed, preferably with higher strip thicknesses > 0.4 mm, whereby in contrast to 1.2, no white spots are visible.

M30; 0.8mm; 3–6µm tin layer thickness; SnPUR

1.7 Yellow discoloration

Description of the effect

This oxidation effect, slightly yellowish in appearance, occurs in conjunction with additional thermal treatment (SnTEM), both at 50% fully grown IMP (total layer thickness 2–4µm) and 100% fully grown IMP (total layer thickness 1–2µm).



K65; 0.32mm; 1–2µm tin layer thickness; SnTEM

1.8 Crystal structure

Description of the effect

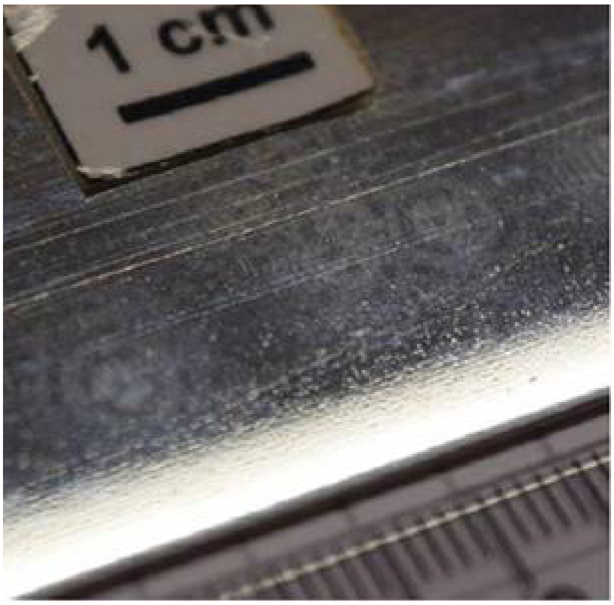
The typical solidification / crystallization structure of the low-alloy tin coating SnTOP is characterized by linear, less convex grain boundary curves compared to SnPUR. A nucleus is not recognizable.

K81; 0.2mm; 1–3µm tin layer thickness; SnTOP

1.9 Scratches

Description of the effect

Slight scratches on the tin surface, already visible to the naked eye. The base material is also covered by the tin layer inside the scratch. The tin layer thickness inside the scratch is within the tolerance and the scratched surface also meets the specified roughness tolerance.



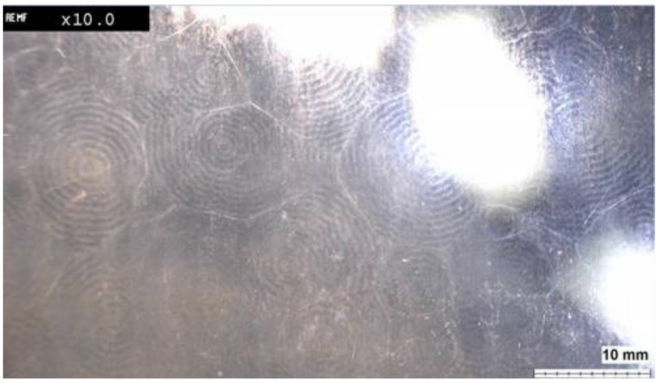
Optically visible scratches within tolerances

1.10 Coarse grain

Description of the effect

This is the typical appearance of the tin coating with thick tin plating (tin layer thickness > 4μm) as it is usual for soldering applications. Within the large-meshed, coarse-grained structure with clearly defined grain boundaries, substructures pointing to the centre of the grain or concentric circles can also be seen.

K55; 0.8mm; 10–18μm tin layer thickness; SnPUR



Thick tinning with typical circular structure

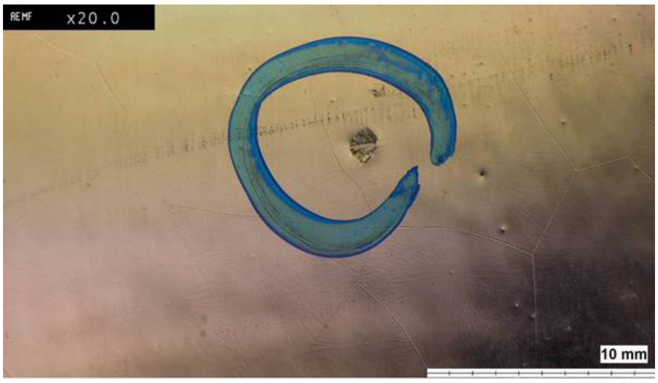
2. Tinning Effects – Marginal Samples

The tinning effects discussed in the following section also represent tolerable tinning inhomogeneities.
As with the samples treated in Chapter 1, no influence on functional properties such as contact resistance, roughness, corrosion protection and friction behaviour is to be expected. In contrast to the effects discussed in Chapter 1, these effects occur in greater severity and/or density.

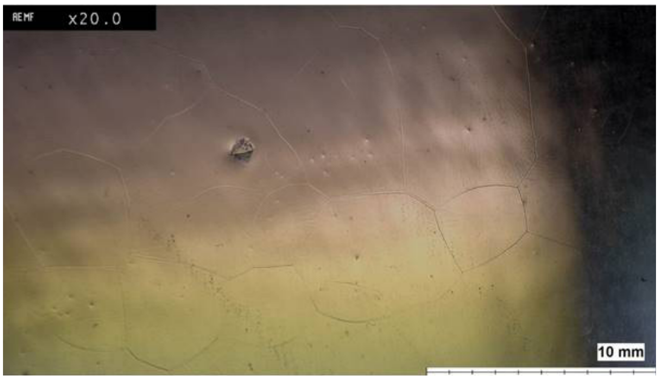
2.1 Footsteps

Description of the effect

Individually occurring micro dewetting in the range of 1–2mm. This occurs in particular with thick tin plating.
The tin layer thickness in the pinhole must be ≥ 0.5μm.



B16; 0.8mm; 4–8μm tin layer thickness; SnPUR

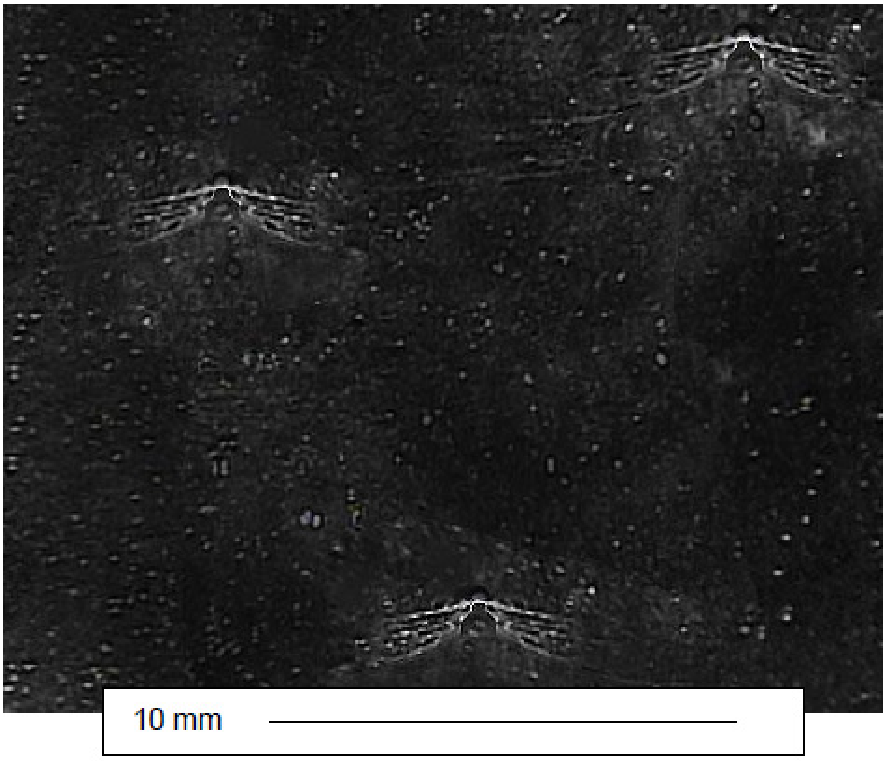


Individually occurring depression as a result of dewetting

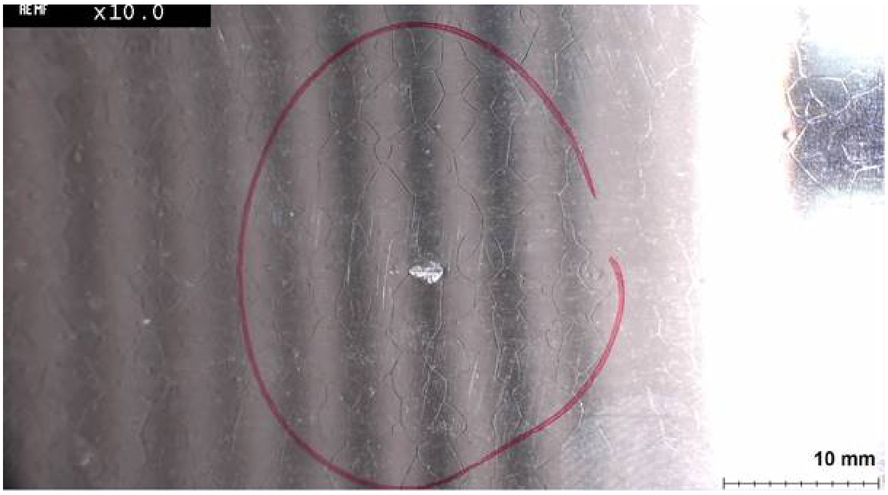
2.2 Crow's feet

Description of the effect

Arrow-shaped structures with tips pointing in the opposite direction to the blowing direction.



Typical characteristics of crow's feet



Typical characteristics of crow's feet

2.3 Crosscuts

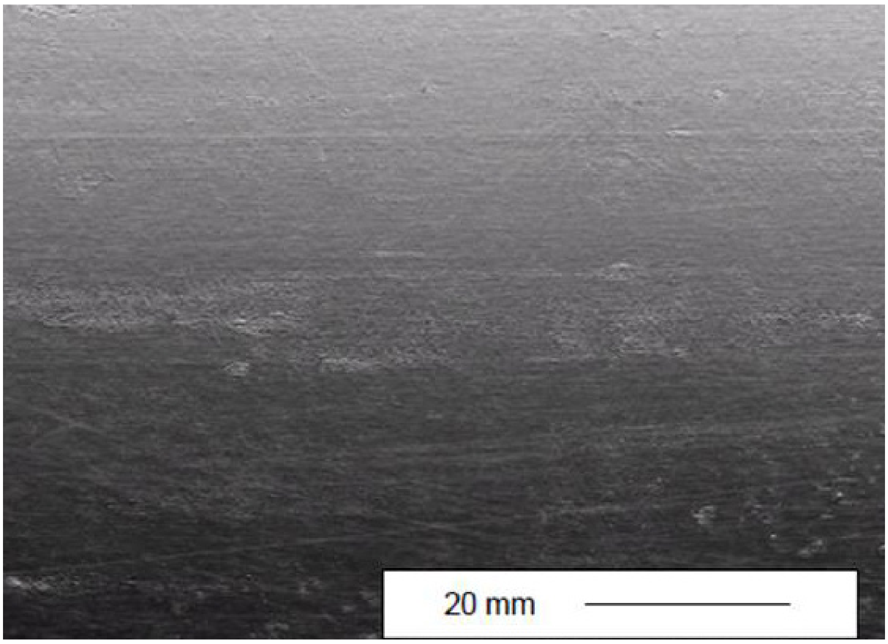
Description of the effect
The crosscuts in the edge areas are accumulations of micro dewettings occurring at a certain frequency transverse to the tinning direction.

Crosscuts

M30; 0.2mm; 1–2µm tin layer thickness; SnPUR with cross passages

2.4 Striped roughening

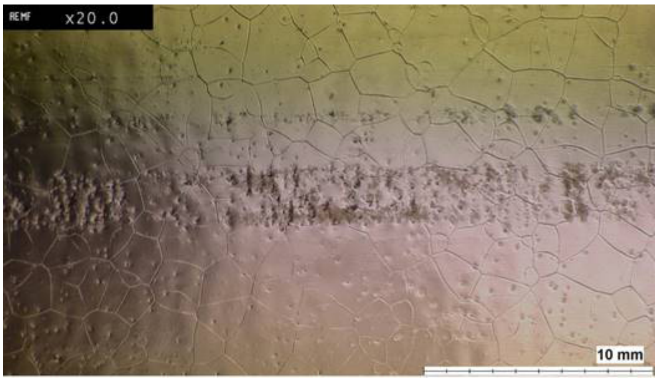
Description of the effect
This surface appearance means that the IMP has grown through at certain points and occurs particularly with thin tin plating (1–2µm).

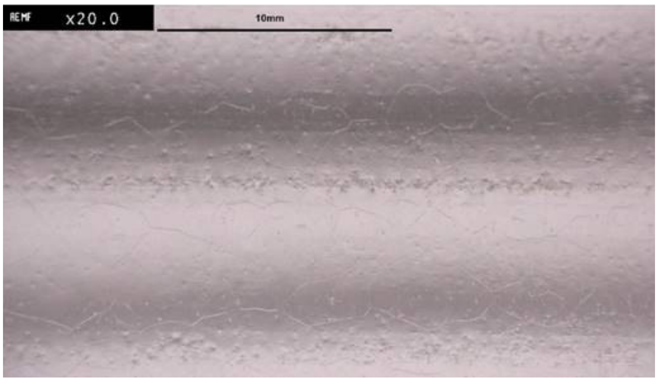


roughening due to punctually grown IMP

2.5 Dewetting stripes

Description of the effect
Linear agglomeration of micro dewettings in tinning direction.

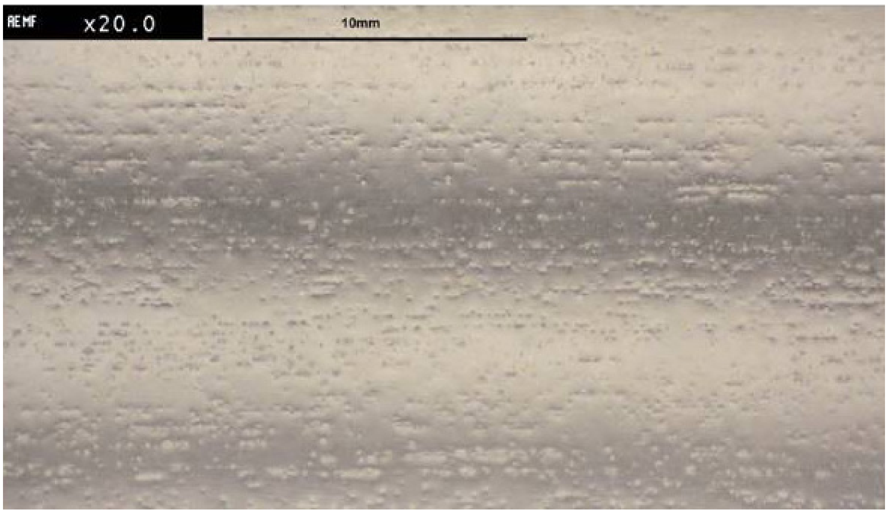




M38; 0.8mm; 2–4µm tin layer thickness; SnPUR

2.6 Dewetting on thick strip (d > 0.8mm)

Description of the effect
High density dot dewetting. These are permissible if the arithmetic mean of the layer thickness is within the tolerance and the tin layer thickness measured in the pinhole (collimator 0.3 mm) is $\geq$ 0.5µm.



1.2mm material thickness, 2–4µm layer thickness

2.7 Cooling strokes (“crescent moon”)

Description of the effect

Topographically not measurable, rarely occurring, punctual smoothing. Cooling strokes, which occur as single faults, are tolerable.

B14; 0.36mm; 3–6µm tin layer thickness; SnPUR

2.8 Solidification pattern "Ice flowers"

Description of the effect

Irregular solidification structure of the tin layer in nickel-containing alloys.

N17; 0.3mm; 2–4µm tin layer thickness; SnPUR

3. Tinning defects – Bad samples

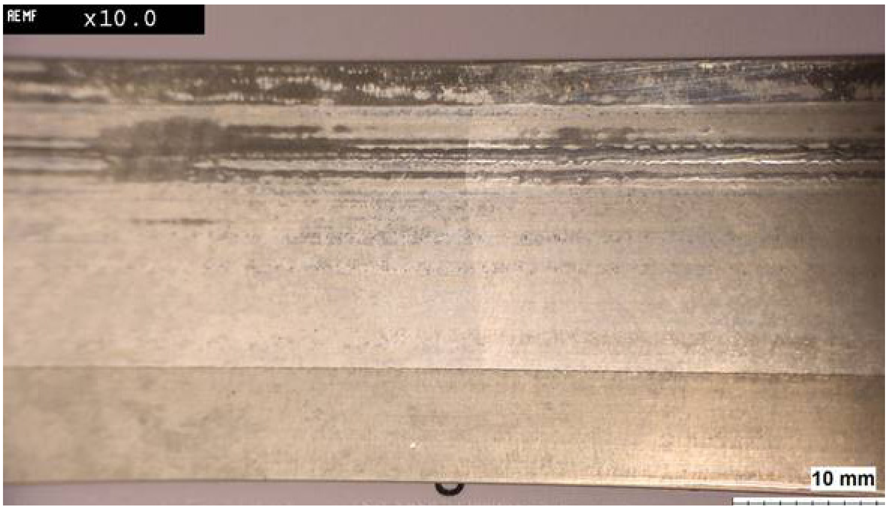
The tinning effects described in the following are classified as intolerable tinning errors which must be avoided. When they occur, a negative influence on properties such as contact resistance, roughness, corrosion protection, friction behaviour and solderability must be expected.

(See also acceptance/rejection criteria in the final remarks)

3.1 a Tin streaks

Description of the defect

Local layer thickness increase for thin tin plating (1–2μm).

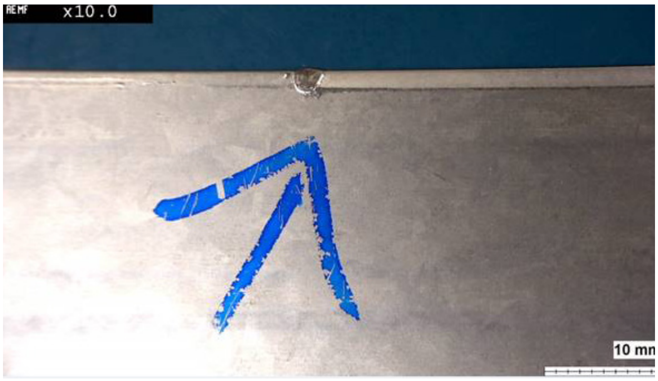


Tin streaks in the edge area

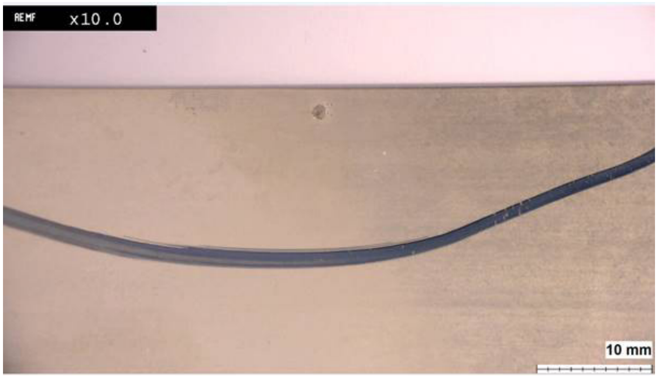
3.1 b Tin lumps

Description of the defect

Solidified tin particle (size 2–10mm) which occurs in the edge area.



Tin lump at the edge of the strip



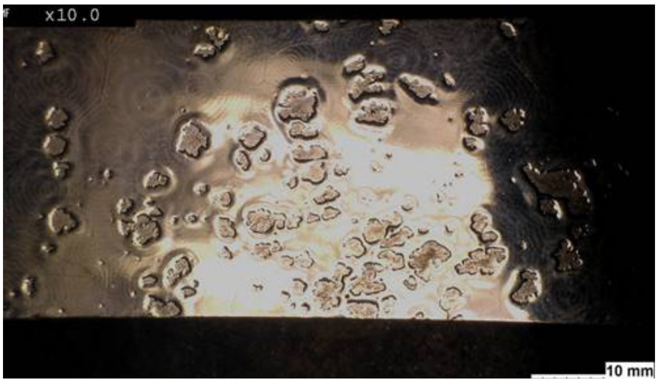
Tin lump at the edge of the strip

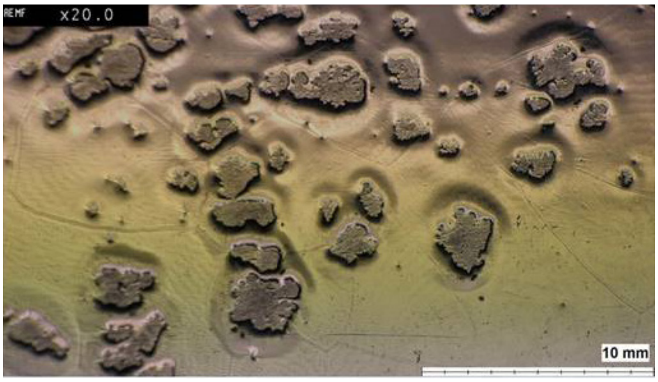
Tin lump at the edge of the strip

3.2 Local dewetting

Description of the defect

Dewetting with diameters of several millimeters, irregular arrangement and exposed intermetallic phase.





K62; 0.3mm; 4–8μm tin layer thickness, SnPUR

3.3 Scratches

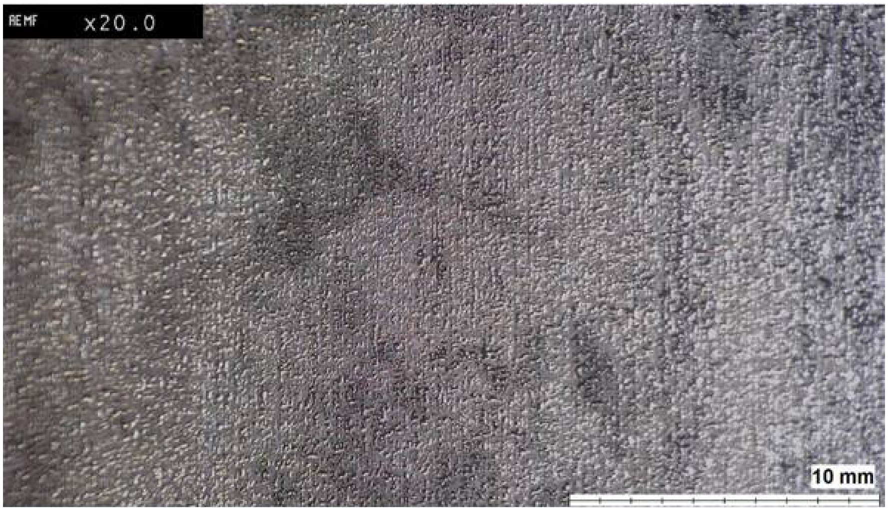
Description of the defect

Linear, mechanical surface damage. The layer thickness in the scratch and/or the roughness in the scratched area are outside the specified tolerance range.

Tinned scratch

3.4 Large area dewetting

Description of the defect
Dewetting spread evenly over the width of the strip with small, punctual residues of free tin.



Large area dewetting

3.5 Tin splashes

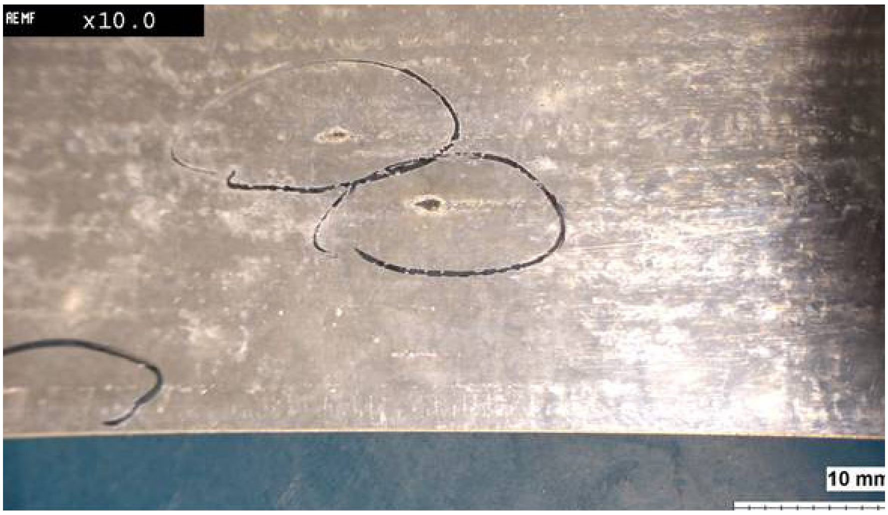
Description of the defect
Elevation of the tin layer for SnTEM, which shines clearly due to its very low roughness.

Tin splash

3.6 Slag inclusions

Description of the defect

Clearly visible slag particles which were drawn out of the tin tray by the melt-pool flow and embedded in the solidified tin surface.

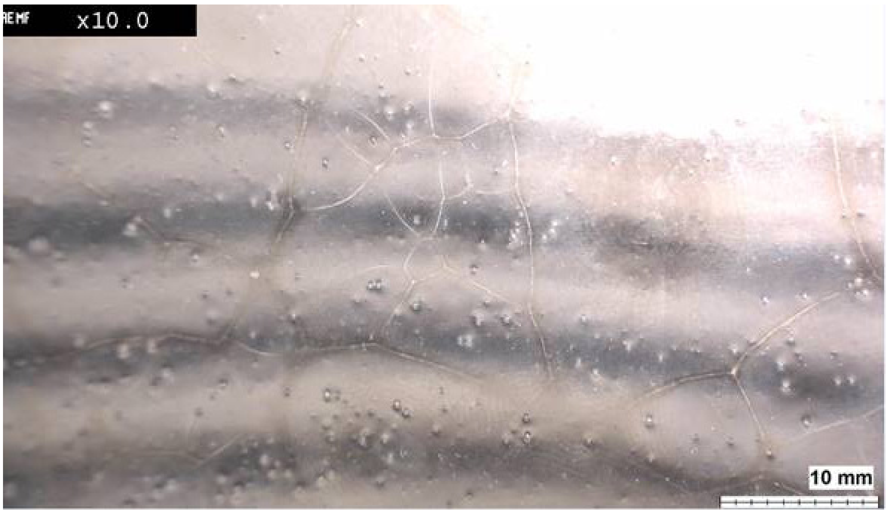


Slag inclusions

3.7 Pimples / Semolina

Description of the defect

Light, punctual elevations of the tin layer with a diameter of up to 2mm.



Pimples / Semolina

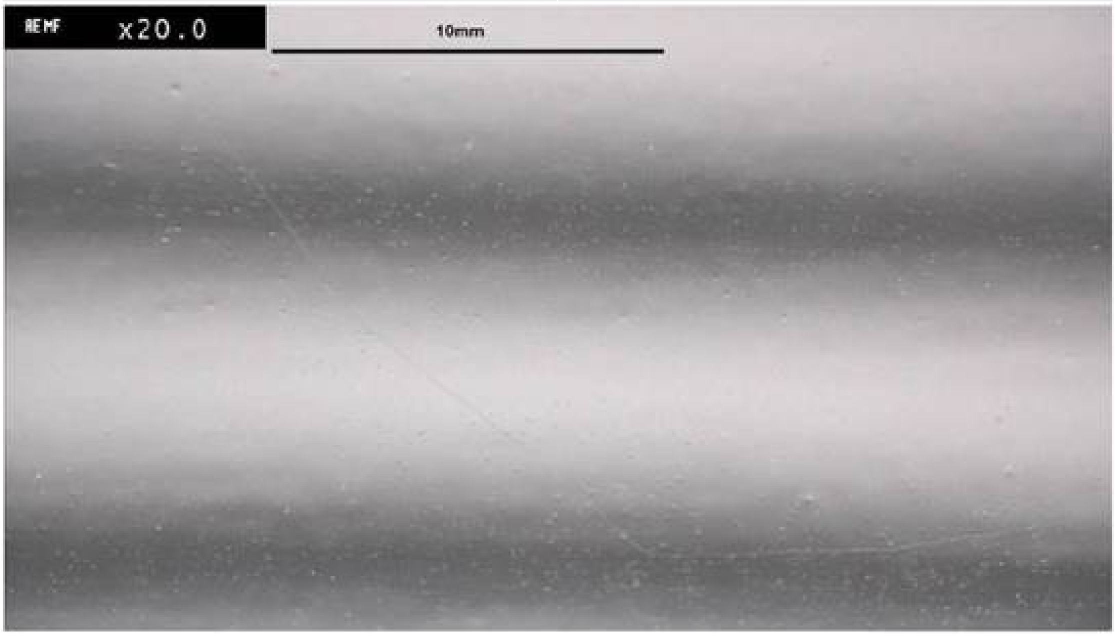
4. Special regulation pinholes / footsteps

Valid for: CuNiSi, bronzes CuSn4–8, CuFe2P, Cu and CuSn0.15, brass

Strip thickness 0.1 – 0.4mm	
Tin layer thickness 0.8 – 4µm	
≤ Pinhole Ø mm / Footsteps comparative diameter, (length + width) / 2	criteria
≤ 0.1 mm	Permissible
> 0.1 / ≤ 0.5 mm	Permissible, if tin layer thickness measured in pinhole, collimator diameter 0.3mm, ≥ 0.5µm
> 0.5/ < 1.0 mm	Permissible for single occurrence (no clusters), tin layer thickness measured in pinhole, collimator diameter 0.3mm, ≥ 0.5µm
≥ 1.0 mm	not permissible, if tin layer thickness outside tolerance, diameter 0.3mm collimator, measured in pinhole
≥ 1.0 mm	Permissible, if tin layer thickness within tolerance, diameter 0.3mm collimator, measured in pinhole

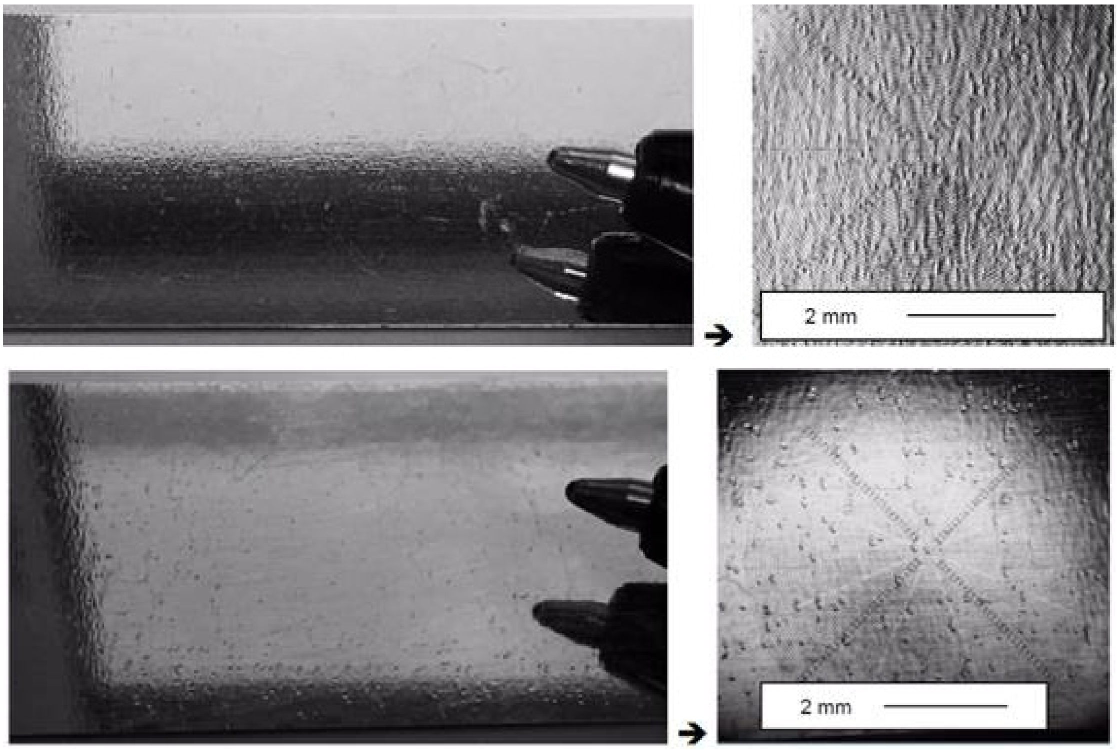
Examples from the individual categories:

Pinhole Ø ≤ 0.1 mm	Permissible

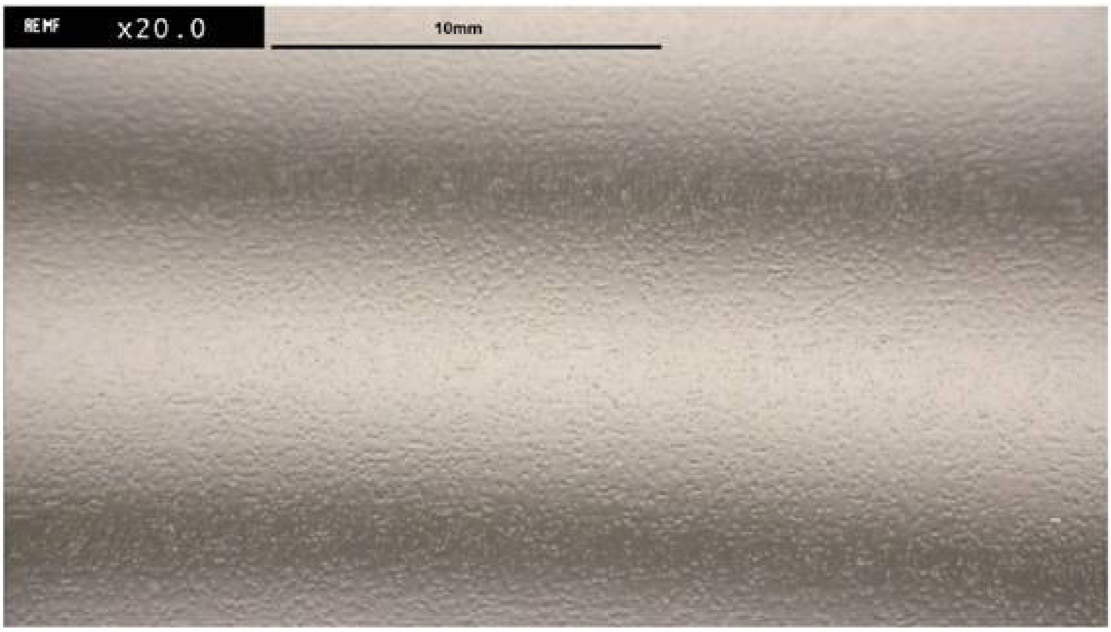


CuNiSi, C19010; 0.32mm material thickness, 3–6µm Sn

Pinhole Ø > 0.1 / ≤ 0.5 mm	Permissible, if tin layer thickness measured in pinhole, collimator diameter 0.3mm, ≥ 0.5µm

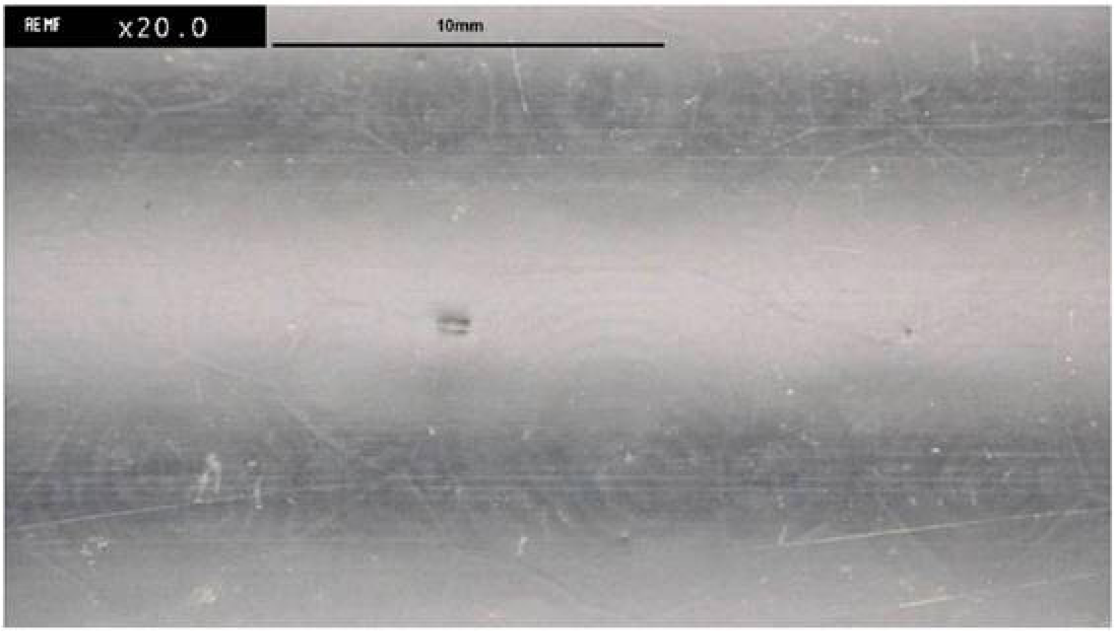


CuNiSi, 1–2µm Sn



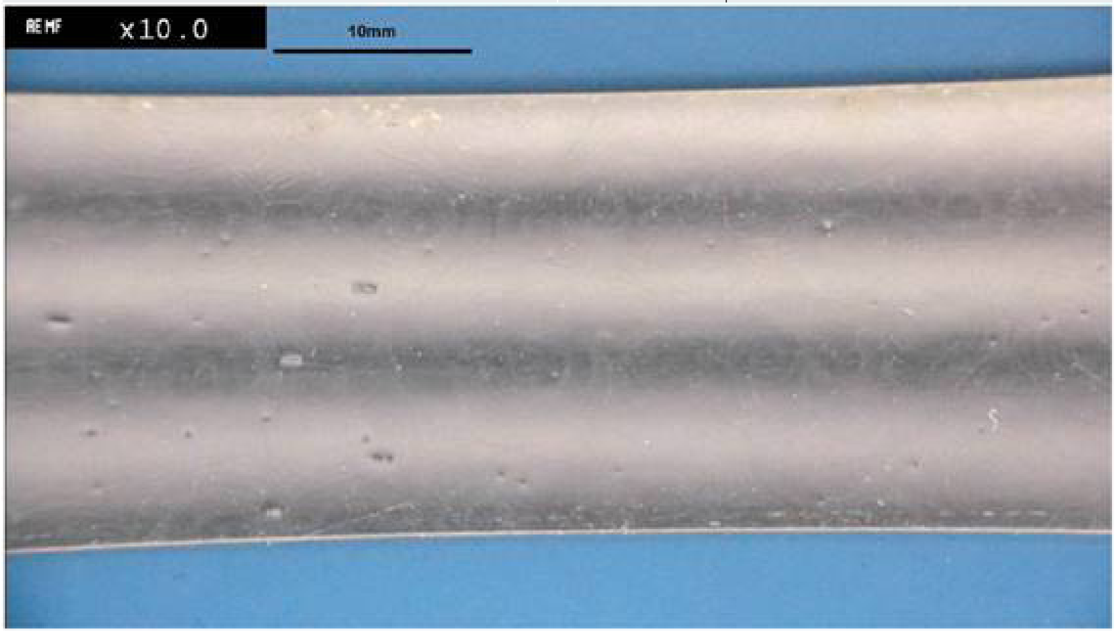
CuNiSi, C19010, 0.2mm material thickness, 1–2µm Sn

Pinhole Ø > 0.5 / < 1.0 mm	Permissible for single occurrence (no clusters), tin layer thickness measured in pinhole, collimator DIA 0.3 mm, ≥ 0.5 µm within the tolerance



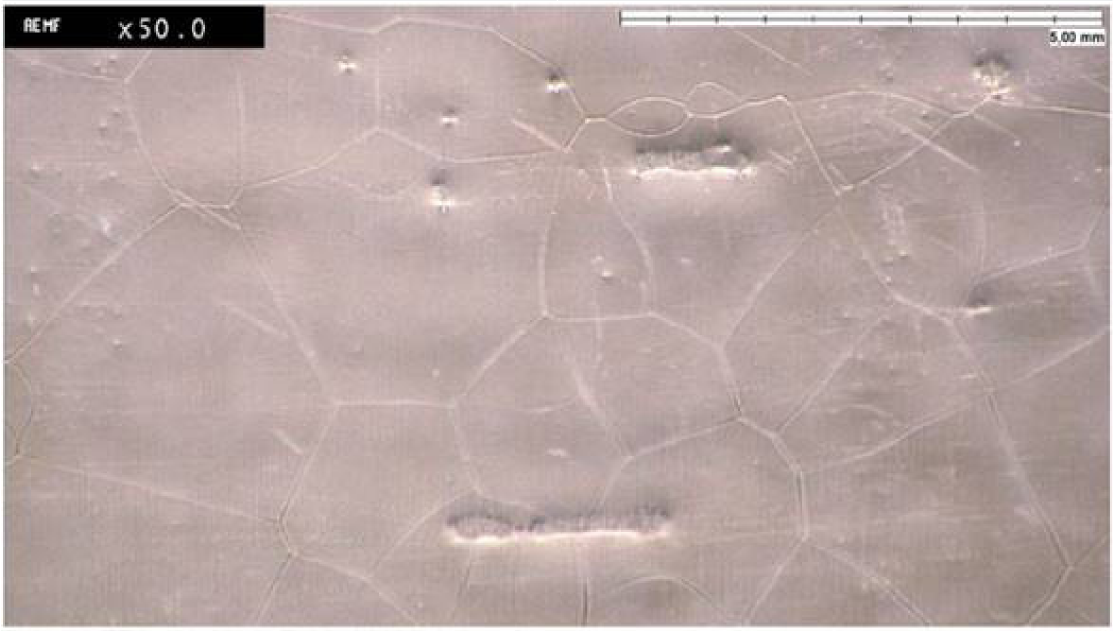
C18060, 4–8µm Sn, footsteps

Pinhole Ø ≥ 1.0 mm	permissible, if tin layer thickness within tolerance, diameter 0.3 mm collimator, measured in pinhole



C18060, 0,3mm material thickness, Sn, Sn layer thickness within tolerance

Pinhole Ø ≥ 1.0 mm	not permissible, if tin layer thickness outside tolerance, diameter 0.3 mm collimator, measured in pinhole



CuZn30, C2600, 2–4µm Sn

Final remarks

Acceptance / rejection criteria

The thickness (= the arithmetic mean value) of the coating must lie within the specified dimensions, but individual measured values may deviate from the specifications for the dimensions up to max. 10%, related to the tolerance limit up to a strip thickness of ≤ 0,8mm; for thicker strips the arithmetic mean value must lie within the tolerance limits. Prerequisite: 10 measurements per strip side randomly distributed over the strip width.

Tinning effects or tinning defects as described in chapter 1–4 are dealt with separately. Here, measured individual phenomena may deviate up to max. 20 % (related to the tolerance limit). Prerequisite: no negative impairments in the further stamping process (abrasion, flaking, ...).

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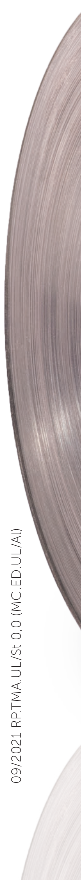

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