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Hot-dip tinned copper and copper alloy strip

HOT-DIP TINNED STRIP

WHY HOT-DIP TINNING?

Characteristic for hot-dip tinned coatings is the formation of intermetallic phases (IMP) between the base material and the tin layer, see Fig. 2. They consist of Cu_3Sn and Cu_6Sn_5. The intermetallic phase produced in this way ensures a very good bonding of the tin layer to the base material as well as a high degree of protection against whisker formation.

The free tin layer is located above the IMP. Tin is very ductile and encloses the contour of the contact partner during the insertion process. This results in a large contact surface and good electrical contact with low contact resistance.

The smaller the thickness of the free tin layer, the lower the insertion and withdrawal forces. Similarly, the greater the surface hardness, the lower the insertion and withdrawal forces and the better the wear behavior.

Tin also oxidizes over time, but tin oxide layers are relatively soft and are easily penetrated during insertion and removal processes, which has a positive effect on the electrical contact properties.

The free tin on the other side ensures good solderability.

PRODUCTION

Strip with a well-cleaned and activated surface are driven through the molten tin bath, see Fig. 1. After leaving the tin bath, the coating is still liquid and adheres to the strip. The liquid tin is blown by an air stream without contact, to achieve the desired thickness.

Subsequently, the strip is cooled down and the tin layer thickness is measured, with an in-line X-ray fluorescence, continuously and automatically, controlling the tin-layer thickness on both sides of the strip. The process is monitored using statistical methods.

After tinning, the strips are wound into coils, cut to the required width and delivered in the delivery form ordered by the customer.

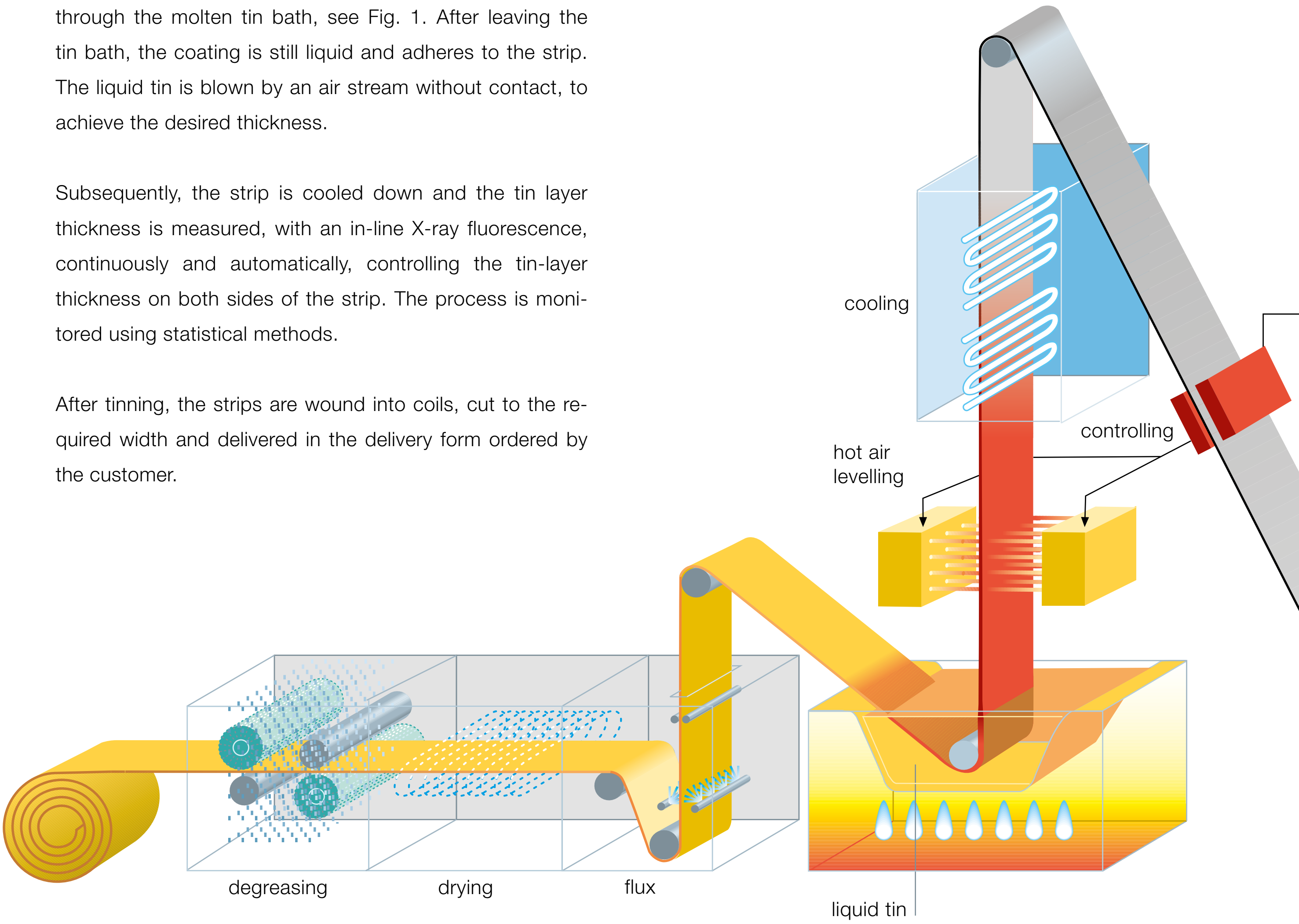


Fig. 2 shows the different types of hot-dip tin coatings which are:

- SnPUR® : Pure tin
- SnTEM® : Thermal tin 100 % intermetallic phase (IMP)
- SnTOP® : Tin-silver Sn + $SnAg_3$

SnPUR®: These hot-dip tin coatings have a low hardness and therefore are very ductile. SnPUR® coatings ensure a low contact resistance between the mating partners as wll as a good solderability.

SnTEM®: The tin layer is transformed by a subsequent heat treatment into a very hard and brittle CuSn intermetallic compound. The friction coefficient of this CuSn surface is significantly lower than that of tin. This advantage is used in multipole connectors in order to reduce the insertion and withdrawal forces, as well as increase wear resistance. The layer thicknesses range from 0.7 µm to 2 µm. The hardness of this coating limits the formability.

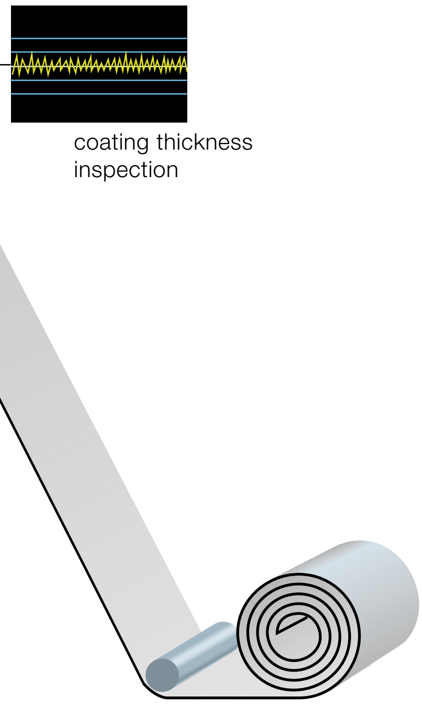


Fig. 1:

Schematic of hot-dip tinning process

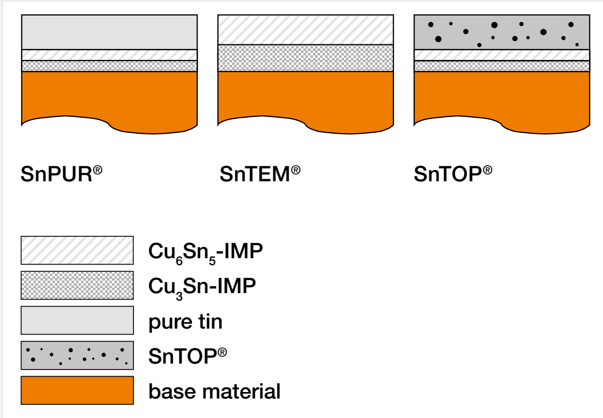


Fig. 2:

Structure of hot-dip tin layers on copper alloys

SnTOP®: The property profile of this layer is adjusted by adding a certain content of silver as well as by the coating layer thickness. The hypereutectic composition with 4 % silver leads to precipitation hardening of the coating, which has a positive effect on the coefficient of friction, abrasion resistance, friction corrosion resistance and voltage drop at the contact point. The composition allows the use of SnTOP® layers at temperatures up to 160 °C and guarantees good bending properties. For applications in the temperature range –40 °C – +160 °C, SnTOP® is an inexpensive alternative to silver-plated surfaces. In addition, good solderability is guaranteed.

Table 1 shows existing recommendations for maximum operating temperatures for the three layer systems, as well as recommended minimum contact forces, in order to maintain a good contact with low contact resistance.

Coating type	application temperature	contact force
SnPUR®	up to 130 °C	> 1 – 3 N
SnTEM®	up to 160 °C	> 0.8 – 2 N
SnTOP®	up to 160 °C	> 3 N

Table 1: Application recommendations

PROPERTIES

STANDARDIZED PROPERTIES

Copper and copper alloy strips with hot-dip tinning layers are standardized in DIN EN 13148. This standard describes the following characteristics:

- Nature of the coating: In order to avoid surface defects caused by transport (e. g. friction corrosion), the strip may have a lubricating film on the surface.
- Appearance of the coating: As a consequence of using liquid tin there are visible crystallisation phenomena which, however, have no influence on the contact properties of the coating.
- Solderability: The soldering properties are essentially dependent on the type of coating and the thickness of the free tin or tin-silver, see Table 2.
- Adhesion: The adhesion strength of the hot-dip tin coatings is very good, due to the intermetallic phase which is created during the process.

Layer thickness and tolerances	Application	Tinning type		
		SnPUR®	SnTOP®	SnTEM®
0.7–2 µm 1–2 µm	reduced insertion and withdrawal forces	+	++	+++
1–3 µm 2–4 µm	good corrosion resistance	+	++	–
2–5 µm 3–7 µm 5–10 µm	good solderability	++	++	–

Table 2: Suitability of coating thickness ranges for different applications (+++ excellent, ++ very good, + suitable, – not available)

PROCESSING PROPERTIES

- Solderability: see standardized properties.
- Formability: Hot-dip tinned strips are usually further worked into components by means of stamping and bending operations. The base material usually survives this cold work / plastic deformation without cracks. Depending on the severity of the forming process (bending, stretching,...) the following can occur in the tin layer:

  i) IMP and free tin are without cracks
  ii) the IMP breaks, but not the free tin. The free tin covers the IMP cracks.
  iii) both, IMP and free tin crack. The base material becomes visible at the bottom of the crack.
- The occurrences mentioned under ii) and iii) are considered to be acceptable if the cracks are not in the contact area.
- Shelf life: During longer storage periods, especially in cases of deviations from ideal storage conditions, the tin layer may age, by growth of the IMP and tin oxide formation on the tin surface. Both have a negative effect on solderability and electrical contact resistance. For detailed information, please refer to the brochure “Shelf life, visual appearance and solderability” of Wieland-Werke.

FUNCTIONAL PROPERTIES

- Low contact resistance due to optimal embedding of the mating partner into the free tin.
- Excellent resistance to whisker formation, as IMP is formed at high temperatures during hot-dip tinning, resulting in a low internal stress layer.
- Good corrosion resistance due to the stable natural tin oxide layer and absence of pores.
- Low insertion forces are achieved by using the SnTOP® tin-silver coating. In contrast to pure silver, SnTOP® has no tendency to cold weld. Fig. 3 shows the corresponding property in the macro wear test.
- Good wear resistance is achieved by using the SnTEM® coating, with high surface hardness, see Fig. 4.

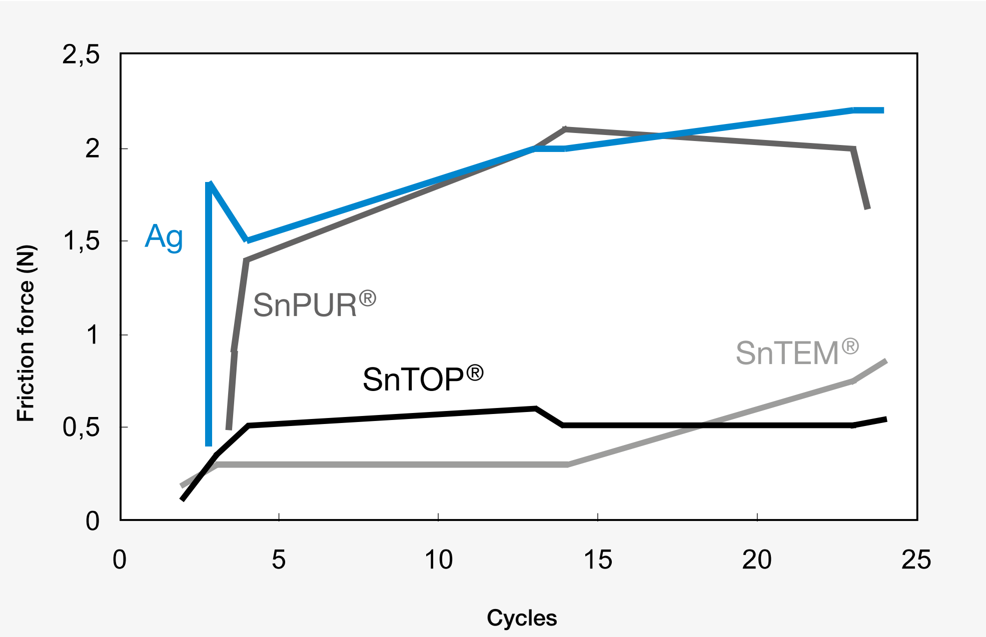


Fig. 3: Macro wear test, friction forces in dependence of number of cycles. Measured in laboratory experiments with the rider-on-flat method, mating partners with same coating, amplitude 3 mm, no lubrication.

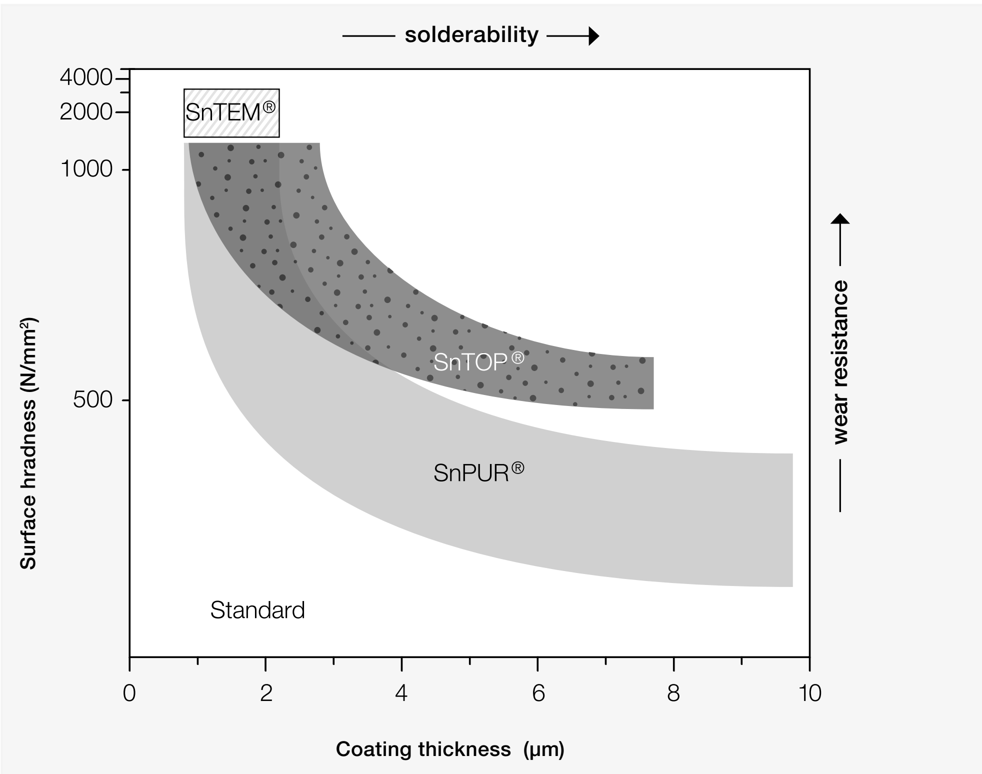


Fig. 4: Universal hardness HU in dependence of layer type and layer thickness.

DIMENSIONS AND EDGE DESIGNS

DIMENSIONS

Hot-dip tinned coatings can be applied to strip thicknesses from 0.1 to 2.0 mm and strip widths up to almost 400 mm. Detailed information is given in Fig. 5. Strip thicknesses of > 1.6 mm are considered to be "difficult for hot-dip tinning" for certain base materials. For this reason, the feasibility must be confirmed before placing the order.

EDGE DESIGNS

Standard design: strip edges are uncoated.
Special design: tinned strip edges, dimensions available on request.

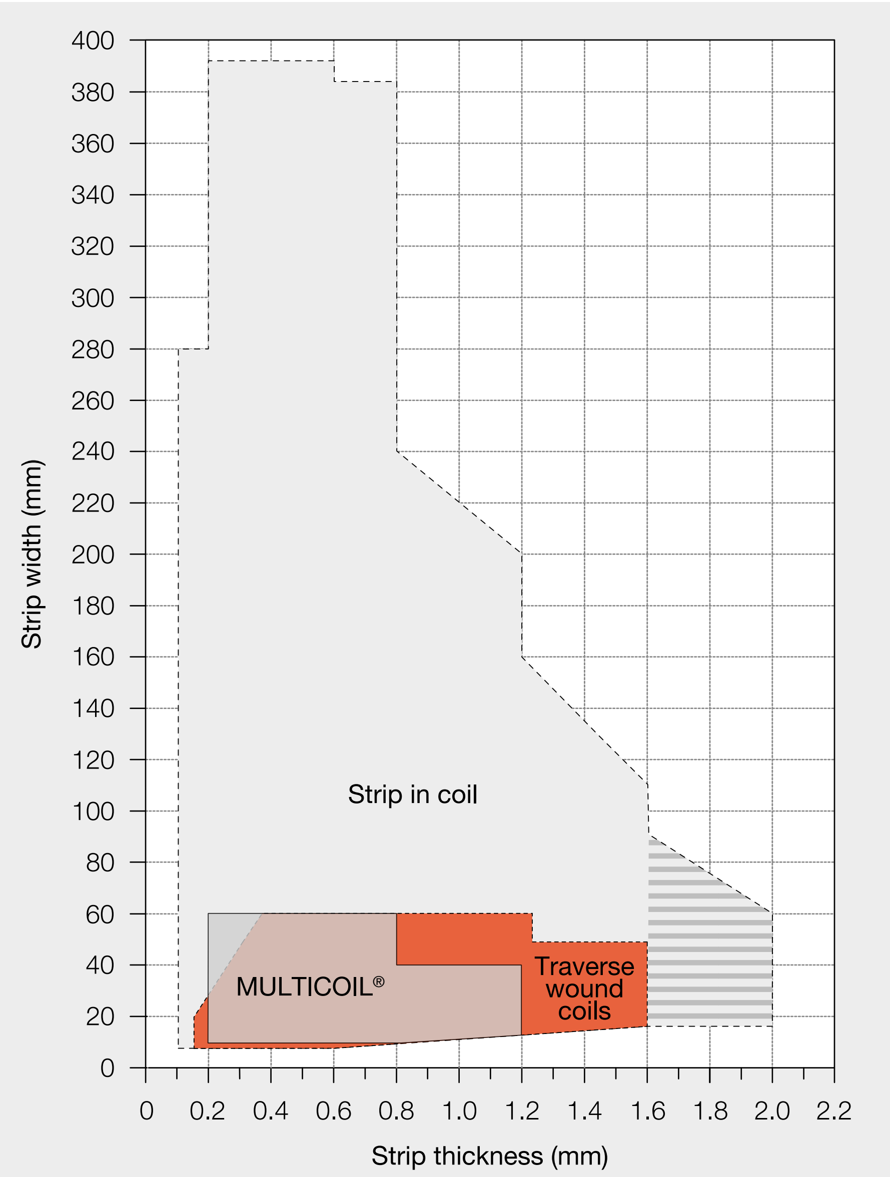
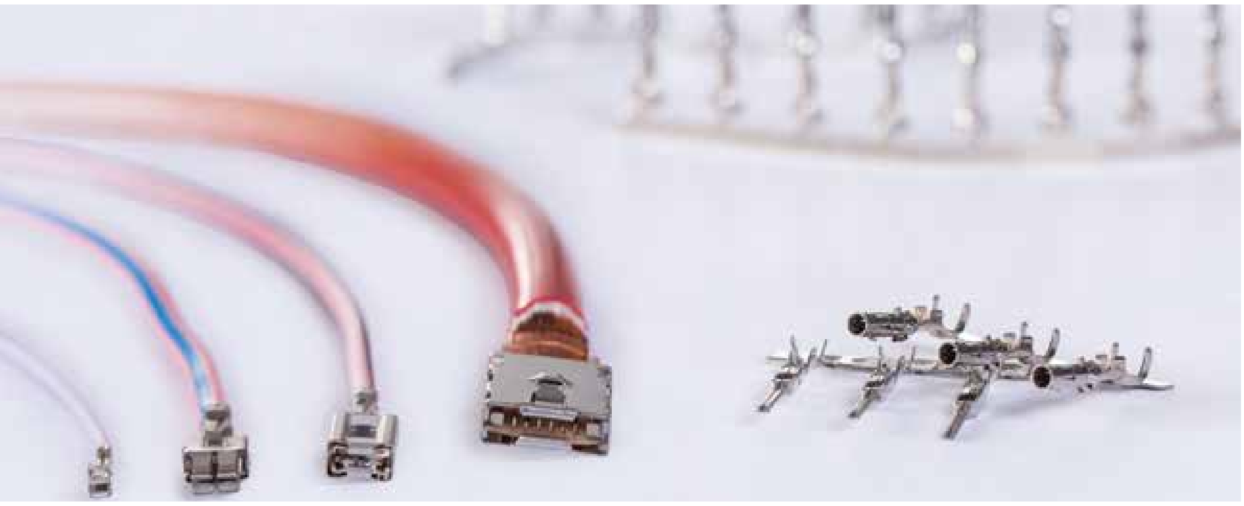


Fig. 5:

Ranges of available dimensions for hot-dip tinned strip. For some base materials there may be restrictions.

APPLICATIONS



Hot-dip tinned strips are used for the production of a wide range of products such as connectors, cable lugs, contact parts, earthing clamps, solder tags, shieldings against electromagnetic waves, conductors in automotive power distribution boards and battery terminals.

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