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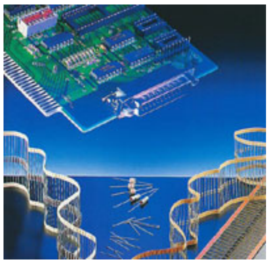

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THE HOT-DIP TINNING PROCESS FOR LEAD-FREE ELECTRICAL CONNECTIONS

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1. SUMMARY

A comparison between the electroplating and the hot-dip tinning process is given. Both processes are used to produce tin-coated lead-wires according to customer specifications.

Both, environmental reasons and technical reasons lead to a tendency for using hot-dipped tin-coatings more and more in Europe. Especially the concentric hot dip tinning process is presented.

Technical arguments concerning the hot-dip tinning process are listed

- Lead-content of tin-coatings
- Formation of whiskers
- Porosity and density of coating
- Coating - hardness
- Coating abrasion strength
- Solderability

comparisons to electroplated qualities are made.

With the hot-dip tinning process manufacturers of leaded passive electronic components have the chance to avoid lead-alloy at all. Customer feedback is given.

2. INTRODUCTION

The rapid technical progress becomes clearly visible within the electronics.

Hardly any branch of industry nowadays gets along without more or less intelligent electronic equipment.

Electronics and the related hardware and software often show significant advantages, although there are hidden disadvantages.

- Due to environmental reasons lead containing tinned lead-out connections are a weak point in this technology chain.

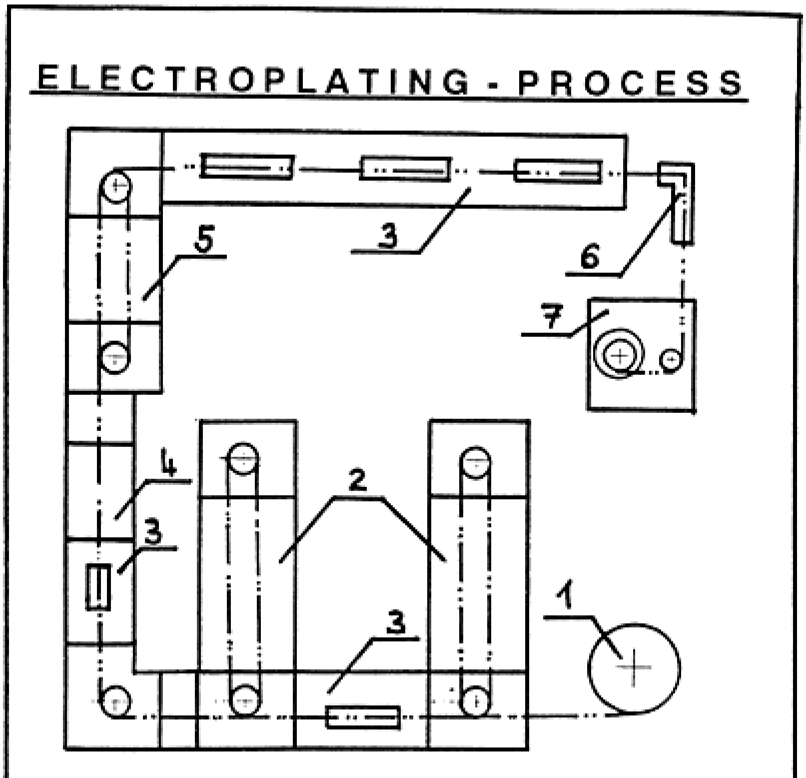
Disadvantages of lead-compounds are:

- Lead is toxic, as it damages the central nervous system and causes anemia, cancer etc.
- Lead can penetrate into the ground water, if electronics scrap is stored on disposal sites
- Lead requires an expensive recycling procedure

3. COATING METHODS

3.1 The Electroplating Process

The wire passes pre-treatment baths and cleaning baths, and is then coated in several added steps.



1 Wire spooler (entry side)	5 Electroplating
2 Pre - Treatment	6 Dryer
3 Rinse	7 Wire spooler (exit side)
4 Acip dip	

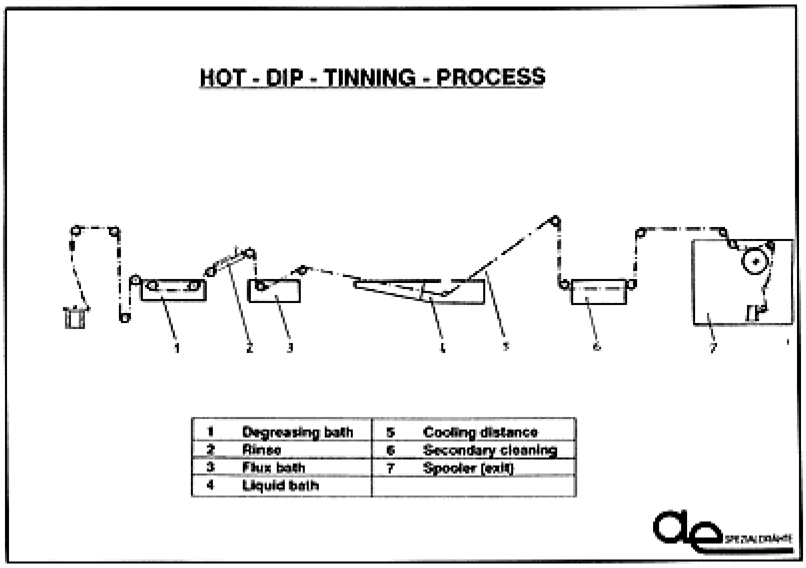
Fig. 1 shows the different steps.

3.2 The Concentric Hot-Dip Tinning Process

The hot-dip tinning process normally is known as an old fashioned process with possible disadvantages for special applications, if the coating is not concentric. Edelhoff developed the concentric hot-dip tinning process. This improved process is the base for the coming explanations.

The wire passes several cleaning baths and a specific bath with flux. Then the wire gets it`s surface-coating by being solder-dipped in tin/lead. After cooling and cleaning the coated wire is recoiled again. A special system provides a 100 % concentric tin-coating around the wire.

Fig. 2 shows the Hot-Dip Tinning Process



4. LEAD-FREE SURFACE COATING

Instead of tin/lead two new alloys have been propagated at the CARTS 1996 in Nice/France as possible future coatings:

- Tin-Bismuth-Alloys (Sn/Bi)

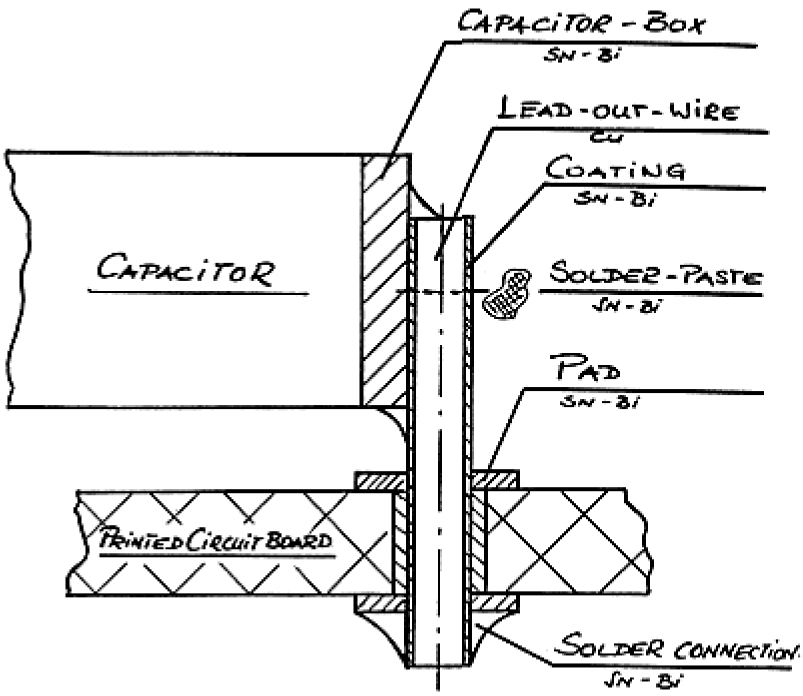
- Tin-Indium-Alloys (Sn/In)

Possible advantages from those new alloys will only come up, if all parts within an electronic printed circuit board will be based on those new alloys.

Fig. 3 shows several connection-points on a PCB.

Solder connection at components

with tin - bismuth (Sn - Bi)



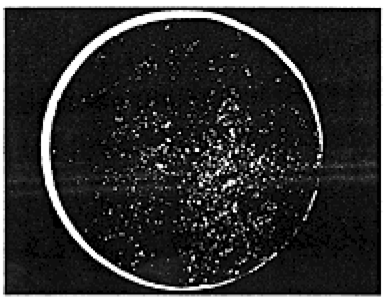
From our point of view this will be a long-lasting process, as all manufacturers have to be coordinated to use those new alloys. Edelhoff went another way and therefore concentrated on the known alloys, but implemented specific advantages within the production process of leaded wires.

- Using the concentric hot-dip tinning process, lead can be avoided in coated lead-out wires.

Advantages of hot-dip tinning compared with the electro-plating:

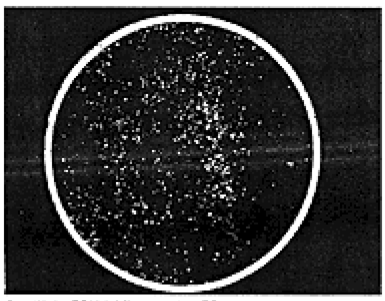
- Coating directly from the molten bath
- The formation of an instant inter-metallic bond ensures totally firm adhesion
- No whiskers in pure tin coating
- Solid, homogenous coating, free from contamination or chemical residues
- No outgassing under reheating
- Higher abrasion resistance

Edelhoff developed the concentric hot-dip tinning process - Fig. 4 shows a microsection - about ten years ago in cooperation with several European manufacturers of electronic components.



Schliffbild FDV / Microsection FDV

Standard hot-dip tinning process (excentric)



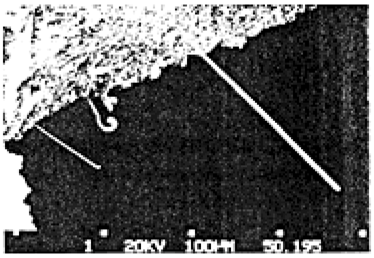
Schliffbild FOV / Microsection FOV

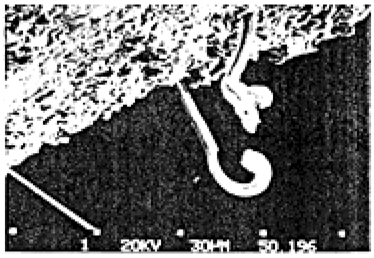
Concentric hot-dip tinning process

The following explanations show the advantages of the hot-dip tinning process against the electroplating process, especially, if pure tin coating is being used.

5. PREVENTION OF WHISKER-FORMATION

Fig. 5 and Fig. 6 show the phenomenon of whisker-formation





Whiskers are fine, capillary single crystals consisting of different materials, which may grow out of the metallic layer.

Among all metals tin has the strongest tendency to form whiskers. Whiskers have a diameter of 1 - 2 μm and can reach a length of about 3 mm. [1]

- Whiskers might cause the failure of components through short-circuits.

5.1 Whisker-Formation in Electroplated Coatings

Under certain circumstances electrolytically refined pure tin layers may tend to form whiskers. A lead content of at least 3 % may prevent the formation of whiskers, but has environmental impacts. [1]

- Lead is needed to avoid whisker-formation in electroplated coatings

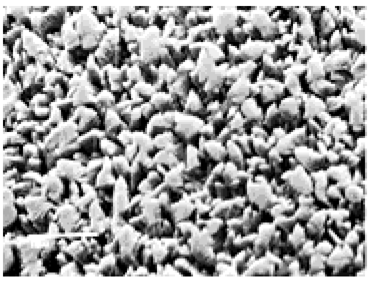
5.2 No Formation of Whiskers in Hot-Dip Tinnings

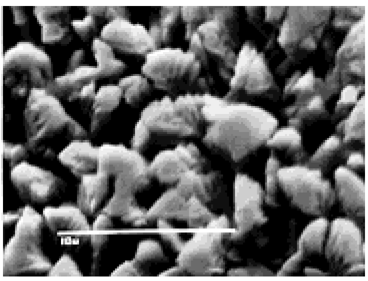
Hot-dip tinned coatings with pure tin are whisker-free. The solder-dip tinning does not allow any formation of whiskers.

6. SURFACE CONDITIONS

6.1 The Electroplating Process

Fig. 7 and 8 show Scanning Electron Micrographs (SEM) of electroplated tin-coatings.





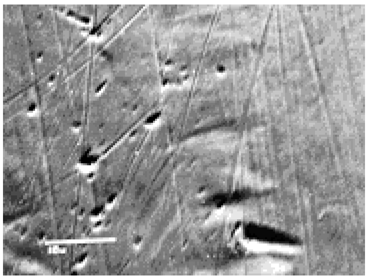
Electroplated tin- or tin/lead-alloys grow in a column crystalline structure (rod-shaped, stalk-shaped). There are cavities between the single crystals. The surface itself is porous.

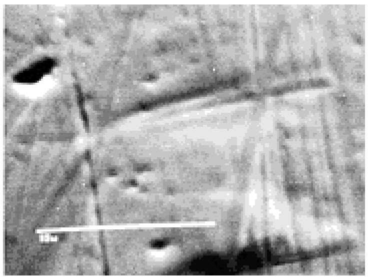
The porous surface can cause:

- outgassing of particles from the electroplating-bath during a further heat treatment
- penetration of external pollutants into the electroplated surface
- above mentioned changes in the surface conditions can cause problems in storage stability

6.2 The Hot-Dip Tinning Process

Fig. 9 and 10 show as a comparison to Fig. 7 and 8 Scanning Electron Micrographs (SEM) of hot-dipped tin coatings.





The tin coating is applied directly from the molten bath and has a dense and smooth surface with a homogeneous structure.

This non-porous surface structure has specific advantages:

- high resistance against the effects of pollutant-penetration
- high storage stability without loss of quality
- Due to specific surface conditions hot-dip tinned coatings have better characteristics

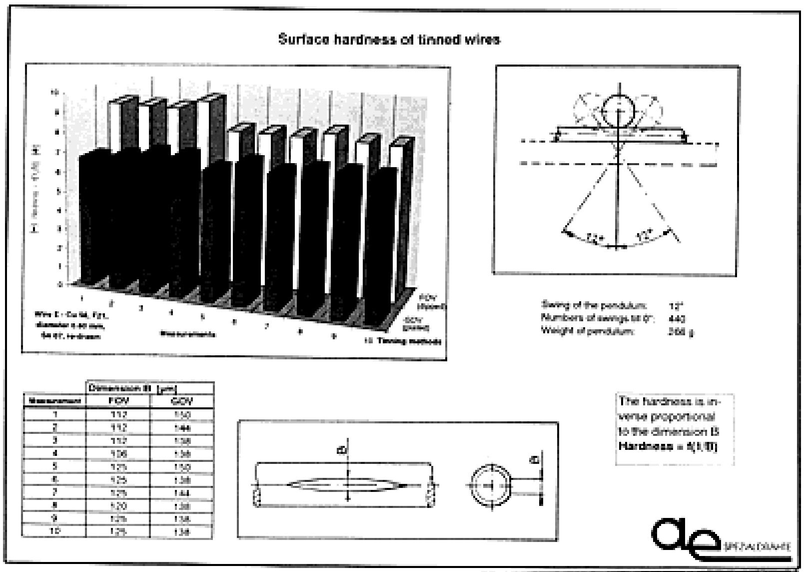
7. SURFACE HARDNESS

Tin/lead - alloys have a rather low hardness. With regard to the Vickers-hardness they are within a range of 8 to 10 HV15.

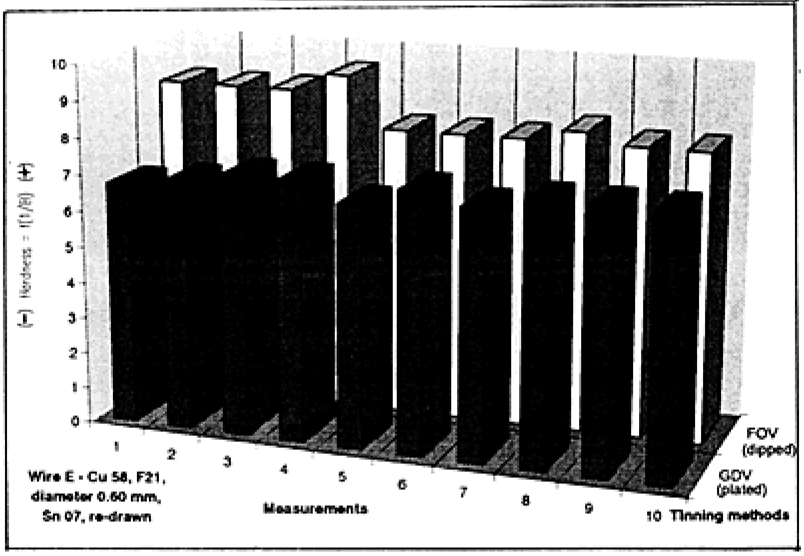
Tin/lead - alloys have it`s maximum hardness with a tin-content of 10%.

Mostly coating thicknesses of 2 to 10 µm are common. As reliable hardness indications and test methods for such coating-thickness have not been evaluated in a more detailed way, Edelhoff prepared comparative hardness-tests with electroplated and at hot-dip tinned lead-wires.

Fig. 11 and Fig. 12 show the testing equipment and the test procedure for 10 single measurements.



Measurement	Dimension B [µm] FOV	GDV
1	112	150
2	112	144
3	112	138
4	106	138
5	125	150
6	125	138
7	125	144
8	120	138
9	125	138
10	125	138



There are 2 wire samples laying under a swinging roll-pendulum. After about 440 pendulum movements the roll stops. The depth and the width of the pressed area on the wire can give a comparative indication for the hardness of the surface layer. All measurements only give an indication.

7.1 Hardness of Electroplated Coatings

440 pendulum movements on the tinned wire lead to a width "B" of about 138 µm to 150 µm.

7.2 Hardness of Hot-Dipped Tin-Coatings

440 pendulum movements on the hot-dip tinned wire leads to a width "B" of about 106 µm to 125 µm.

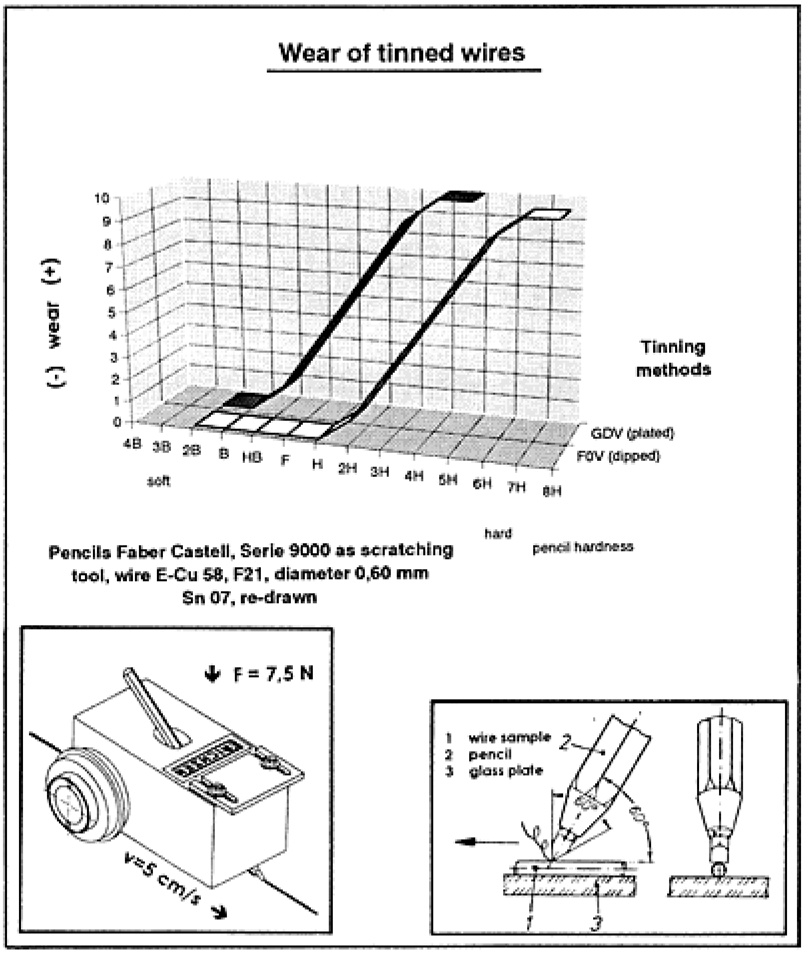
- The hardness of a hot-dipped pure tin coating tends to be higher than those of electroplated coatings.

8. ABRASION STRENGTH

According to the test methods for enameled wires Edelhoff made comparative tests for getting indications for abrasion strengths using

- electroplated wires with Sn 100 % - coating
- hot-dip tinned wires with Sn 100 % - coating

Fig. 13 show more details about the test-method.



Therefore pencils with different degrees of hardness are fastened in a specific device, which runs over the wire-surface. Increasing the degree of pencil-hardness results from a certain point to a peeling of the tin coating (Scratch hardness testing).

8.1. Abrasion Strength of Electroplated Coatings

Using the rather soft pencil hardness "B" the device already peeled the tin coating.

8.2. Abrasion Strength of Hot-Dipped Tin-Coating

Using the rather soft pencil hardness "B" the device did not peel the tin coating at all. Peeling started by using the harder pencil with hardness "H".

- The abrasion strength of a hot-dipped pure tin-coating is higher than the abrasion strength of comparable electroplated coatings.

9. SOLDERABILITY

Edelhoff made comparative solderability tests with

- electroplated wires with Sn 100 % - coating
- hot-dip tinned wires with Sn 100 % - coating

9.1. Test Methods

9.1.1. Meniscus test according to DIN IEC 68

- Within a temperature-range between 190° C and 233° C both coatings had nearly the same test results.

9.1.2. Globule test according to DIN IEC 68

Test measures:

- Wire diameter 0,50 mm, globule weight 75 mg

- Wetting time at electroplating process: 0,32 s

- Wetting time at hot-dip tinning process: 0,26 s

- Hot-dipped pure tin-coating has a lower wetting time compared to electroplated coating.

9.1.3. Wetting test according to Edelhoff standard

The significant factor in the Edelhoff method is the wetting ability of 2 twisted wires. Edelhoff compared in various test both above mentioned coatings.

- Hot-dipped pure tin-coating tends to have advantages against electroplated coatings also in this test.

A possible reason for this phenomenon might arise from the more homogeneous structure and smaller surface of hot-dipped tin-coatings compared to electroplated coatings.

10. CONCLUSION

The concentric "FOV" hot-dip tinning with pure tin:

- is Edelhoff's special process which ensures concentric tin-coating directly out of the molten bath
- forms a solid, homogenous coating, free from contamination of chemical pollutants after soldification
- shows higher abrasion resistance than electroplated layers
- shows a higher hardness than an electroplated layer

- causes no outgassing under reheating
- is non-porous
- is resistant against harmful substances
- can be stored for many years without lack of quality
- forms an instant inter-metallic bond between core material and layer (Cu_3Sn + Cu_6Sn_5), which substitutes the barrier layer neccessary at electroplating processes at a large extent
- shows no whisker-formation even with 100% tin
- is environmentally beneficial - without lead
- melts easier when heated (in subsequent treatment) than electroplated layers (smaller surface)
- the combination "FOV" + homogenous molten coating can not be beaten by an electroplated wire

In Europe both, electroplated coatings and hot-dipped tin-coatings on lead-wires are common.

Due to increasing environmental regulations some customers put their focus on a decreasing lead-content of tin-coatings. Especially for high-quality products specific producers use lead-wires with concentric hot-dipped tin-coating.

Producers like Beyschlag /Philips, Germany, use pure hot-dipped tin-coatings without lead since many years.

Literature:

[1] Dr Jordan, Manfred: Die galvanische Abscheidung von Zinn und Zinnlegierungen