HUBER+SUHNER HIGH QUALITY SURFACE PLATINGS FOR RF COMPONENTS

HUBER+SUHNER is your specialist in regards of plating technology. We are your competent partner to develop and apply proper coating solutions according to your specifications. This catalogue will confine itself to the most important metallic plating used for the different components, as this metallic plating has to

- **add conductive material to supply sufficient current carrying capacity (good electrical and thermal conductivity)**
- **diminish or eliminate surface oxidation and provide protective coating over conductors and resist crackling/spalling**
- **provide good contact between conductors**
- **achieve a good solder or weld attachment surface**
- **obtain a better wear resistance (abrasion resistance and hardness)**
- **provide interconnections from one conductive layer to another**

SUCOPRO - THE GOLD PLATING FOR THE FUTURE

SUCOPRO is a thin gold plating with a nickel-phosphorus alloy (13 % phosphorus) underlayer. The gold layer - which is not subject to oxidation itself - protects the nickel-phosphorus underlayer against oxidation and thus allows for good wetting while soldering. It provides stable, low contact resistance and improved protection against oxidation and corrosion. Because it only contains a thin layer of gold, the solder joints will not become brittle.

The nickel-phosphorus layer provides very good corrosion resistance, high wear resistance and hardness, and a diffusion barrier against gold, copper, tin and zinc. Below 300°C the NiP is amorphous and non-magnetic. Between 300 and 500°C it changes its structure to microcrystalline and its hardness increases but no brittleness or weak adhesion occurs.

At low temperatures (-20°C) no changes of the soldering properties were detected.

The main advantages of SUCOPRO are:

- **Excellent wear resistance**
- **Non-magnetic**
- **Excellent corrosion resistance**
- **Excellent wettability / solderability**
- **Very high strength of soldered joints without embrittlement**
- **Low contact resistance**

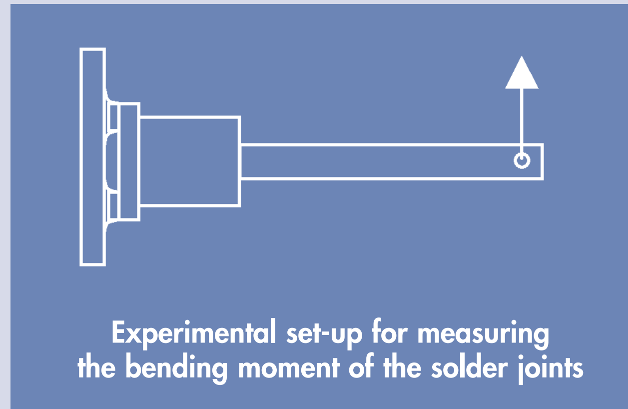
STRUCTURE OF THE SUCOPRO PLATING

Top Layer:	Gold 99.7%	min. 0.1 µm
Underlayer:	Nickel Phosphorus Alloy (P13%)	min. 2.0 µm
Underlayer:	Copper	min. 0.5 µm
Base Material:	Brass or other Materials	

MECHANICAL PROPERTIES

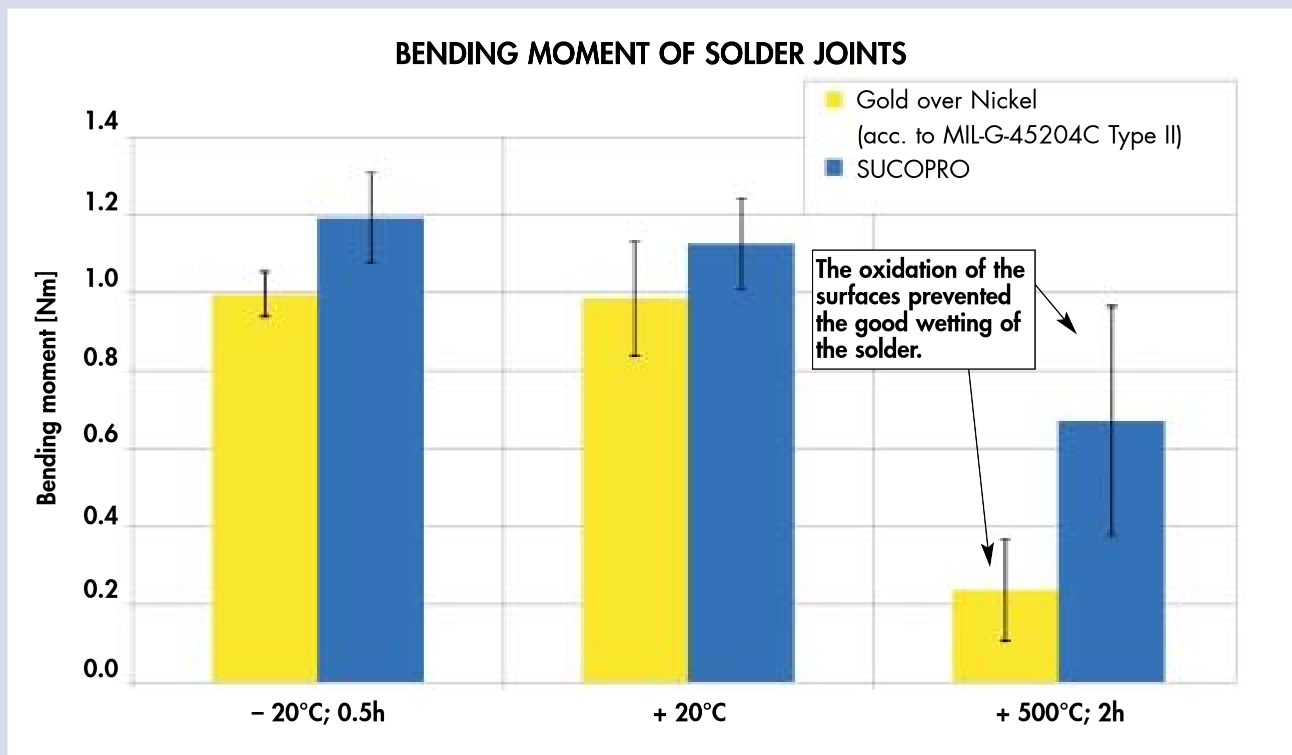
Mechanical strength of solder joints

The mechanical strength of the solder joints with SUCOPRO is generally 10-20% higher than that of a standard gold plating (top layer: gold 99.7%, min. 0.8 m / underlayers: nickel, min. 1.3 m; copper, approx. 0.5 m / base material: brass). This is due to the larger amount of gold in the standard gold plating. Gold and tin build intermetallic phases AuSn, $AuSn_2$ and $AuSn_4$. These phases are brittle and therefore the solder joint deteriorates as the amount of gold increases. No essential difference was detected at -20°C and +20°C. The bending moment of SUCOPRO aged at 500°C reached 50% and the standard gold plating 25% of the bending moment of the non-aged platings.



Experimental set-up for measuring the bending moment of the solder joints

All the effects were caused by the gold thickness and oxide layers. SUCOPRO achieved better results because of its thin gold plating and the very good corrosion resistance of the nickel-phosphorus alloy underlayer.



Solder test

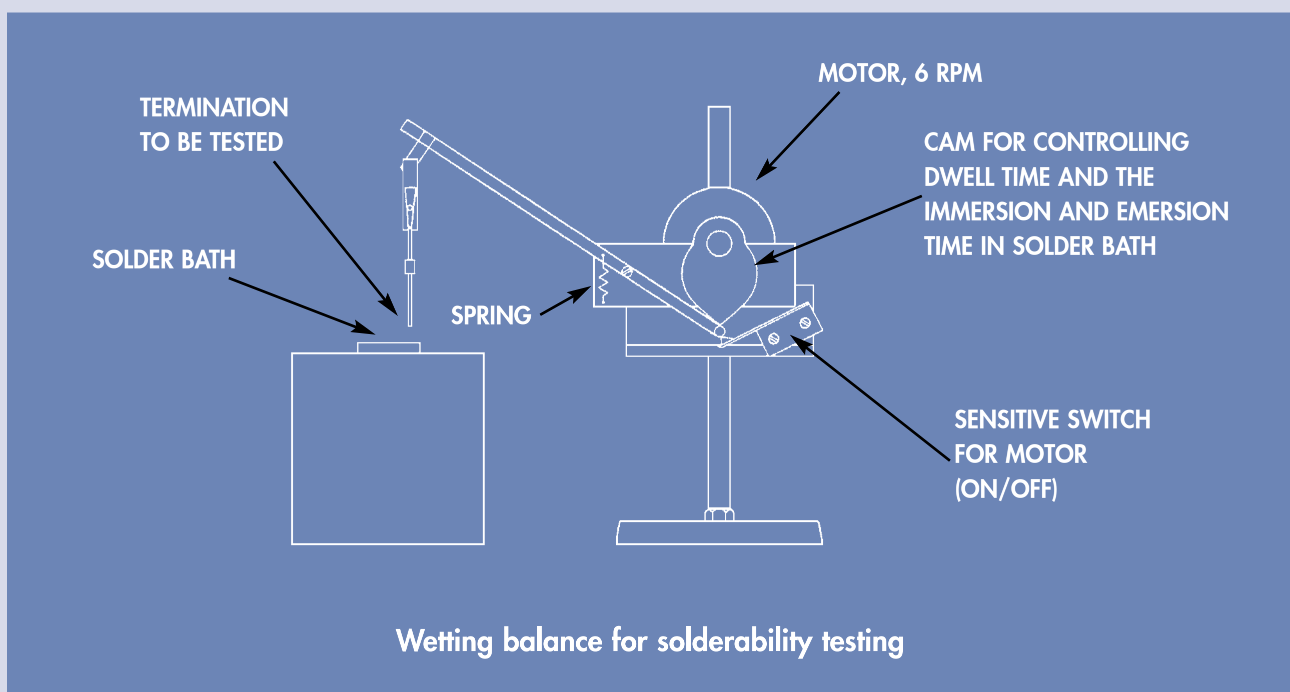
All solderability tests are done according to international standards by the wetting balance method. Depending on the shape of the sample, the following standards are applicable.

International standards of solderability tests	
Terminations of any shape	IEC 68-2-54 [1]
Terminations on surface mounted devices	IEC 68-2-69 [2]
Leads up to 1.27 mm in width and up to 0.64 mm in thickness	MIL-STD-883D, Method 2022.2 [3]
Leads and terminations longer than 0.5 mm	ANSI/IPC-S-805, Method B [4]

Wetting balance method

The specimen is suspended from a sensitive balance (typically a spring system) and immersed edge-wise to a set depth in a bath of molten solder at a controlled temperature. The resultant of the vertical forces of buoyancy and surface tension acting upon the immersed specimen is detected by a transducer and converted into a signal which is continuously recorded as a function of time on a high-speed chart recorder.

This method measures the wetting behaviour as a function of time.

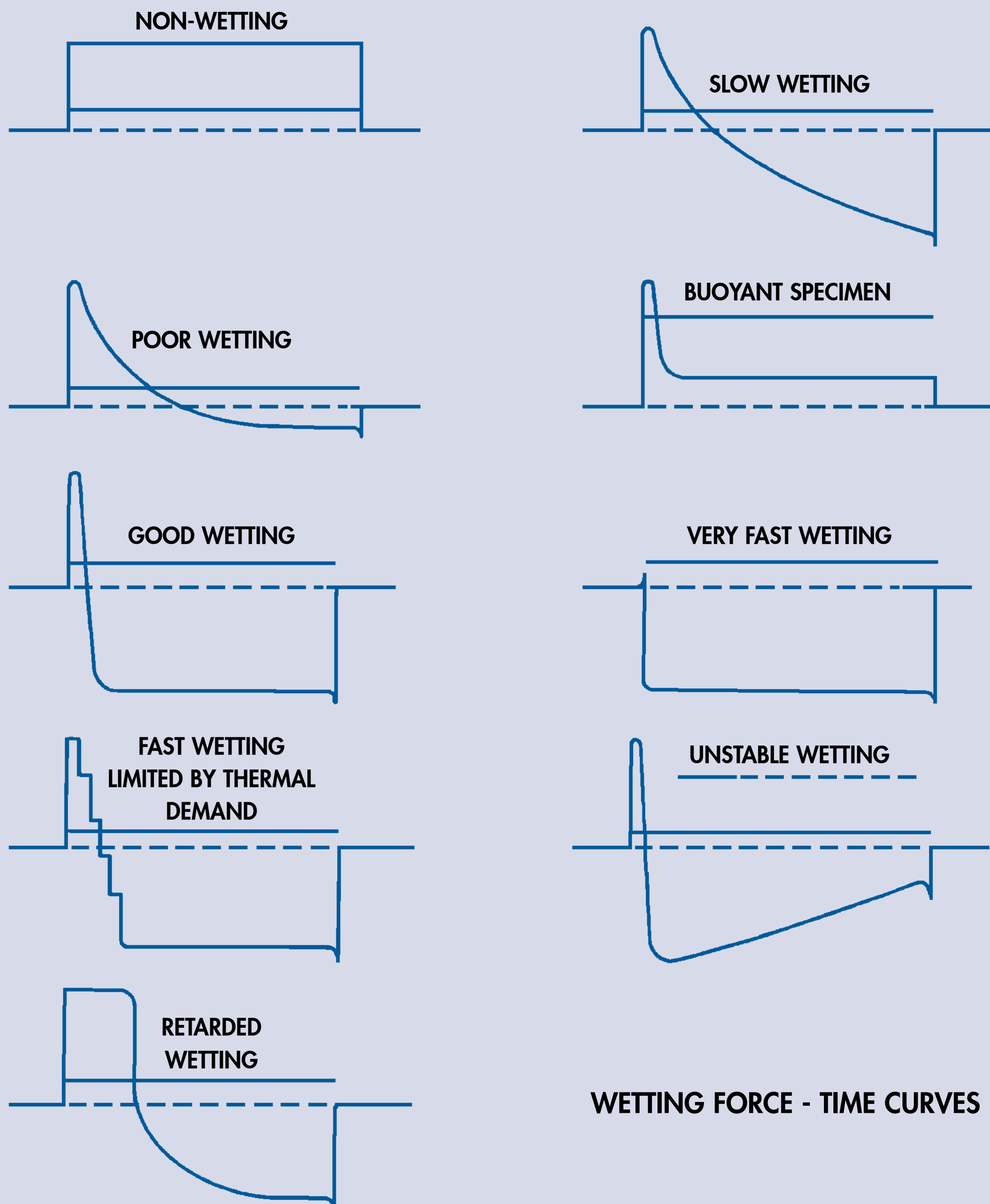


Wetting balance for solderability testing

68-2-54 ©IEC 1985

In these examples, the part of the curve representing forces acting upward on the specimen, i.e. non-wetting state, is shown as positive, the curve representing forces acting downward, i.e. wetting, is shown as negative.

The dotted line represents the condition at the start of the test cycle, having cancelled the weight of the specimen. The full horizontal line shows the buoyancy offset, where the wetting force is zero.
The buoyancy of the specimen can be calculated as the product of immersed volume and the density of the molten solder which it displaces. At the specified test temperature of 235°C the rounded-off value of 8 g/cm^3 should be used for the density of molten solder with 60% tin and 40% lead.



Wetting angle

The wetting angle can be calculated by using the measured forces and the geometrical parameters of the samples[5].

$$\cos\theta = \frac{F + pv}{\gamma_{LV} P}$$

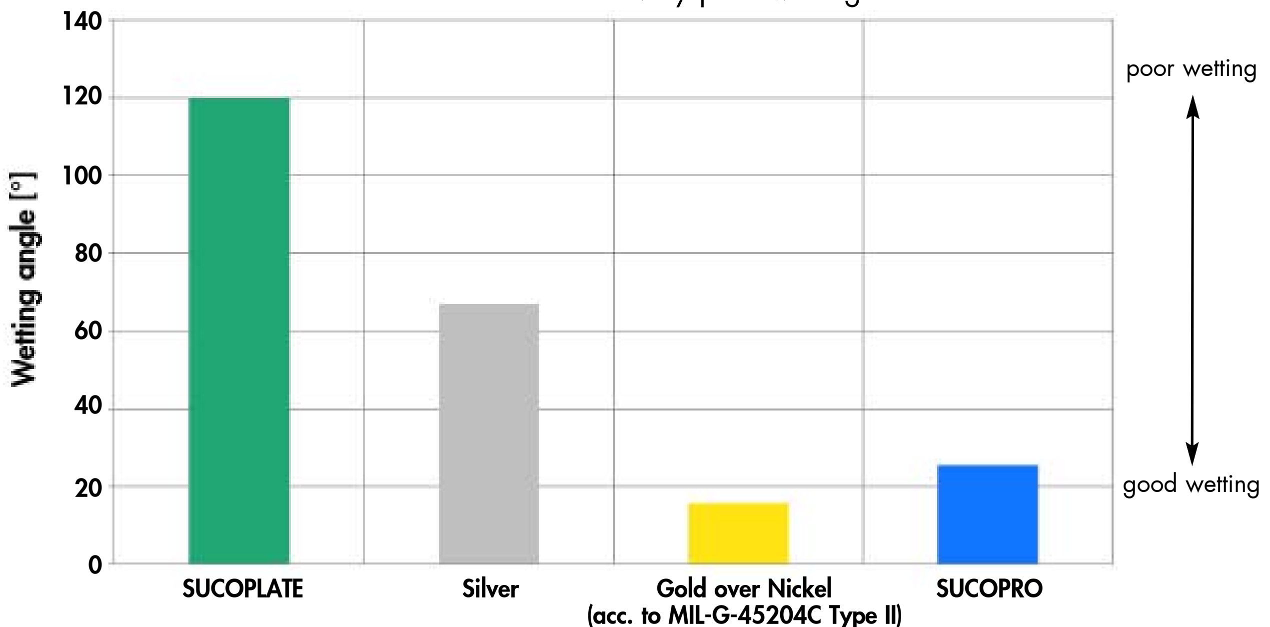
θ	=	Meniscus angle
F	=	Capillary forces
p	=	Specific weight (solder alloy)
v	=	Volume of the component part immersed in the molten alloy
γ_{LV}	=	Surface tension solder alloy / flux
P	=	Sampler Diameter

The solderability can be judged by its meniscus angle[6].

CATEGORIES OF SOLDERING QUALITY, DETERMINED AFTER A DIPPING TIME OF 4 SECONDS:

Wetting Angle θ:

$0° < \theta < 10°$	perfect wetting
$10° < \theta < 20°$	excellent wetting
$20° < \theta < 30°$	very good wetting
$30° < \theta < 40°$	good wetting
$40° < \theta < 55°$	acceptable wetting
$55° < \theta < 70°$	poor wetting
$70° < \theta$	very poor wetting



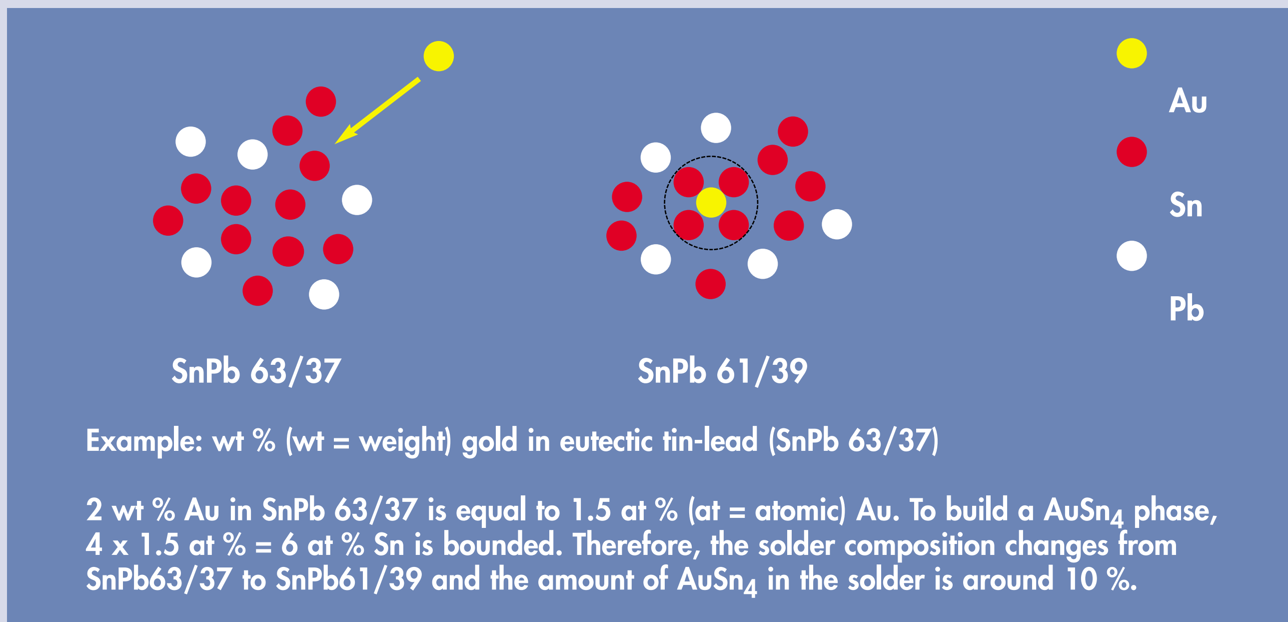
SOLDER EMBRITTLEMENT BY GOLD

The following physical processes cause solder embrittlement:

Gold dissolves in hot solder
The dissolution rate of gold in tin-containing solders is always extremely high, this being due to the strong interaction between gold and tin. A solder bath will therefore take up gold when gold plated component terminations are soldered.

The dissolution rate of gold in tin at temperatures above 200°C is higher than 1 m per second[7]. Therefore, when gold plated terminations are soldered, all the gold dilutes in the tin bath.

Cold solder cannot dissolve all the gold = gold-tin intermetallics are created
The solubility of gold in tin decreases as the temperature rises. At ambient temperature hardly any gold is dissolved in tin. The gold is precipitated by forming $AuSn_4$, $AuSn_2$ and AuSn intermetallic phases[8]. The amount of these phases compared with the tin and lead amount is small.
Intermetallic phases are also created wherever gold and tin are in contact, as at the edge of a solder joint. Those intermetallics grow with time and temperature as a result of diffusion processes.



Plastic deformation cannot be followed by the intermetallics = solder joint breaks
All the gold-tin intermetallic phases are known to be brittle. This means they will break under low plastic deformations.

To prevent solder embrittlement, the amount of gold in the solder joint shall be lower than 3 wt %. The standards indicate that 0.2 wt % gold (10 - 15 times lower!) is the limit in solder baths, and this means costs for new solder or for expensive pre-tin-dipping processes.

Therefore, the proportion of gold and solder in the solder joint shall be calculated and the composition of the solder bath must be checked periodically.[9; 10; 11]

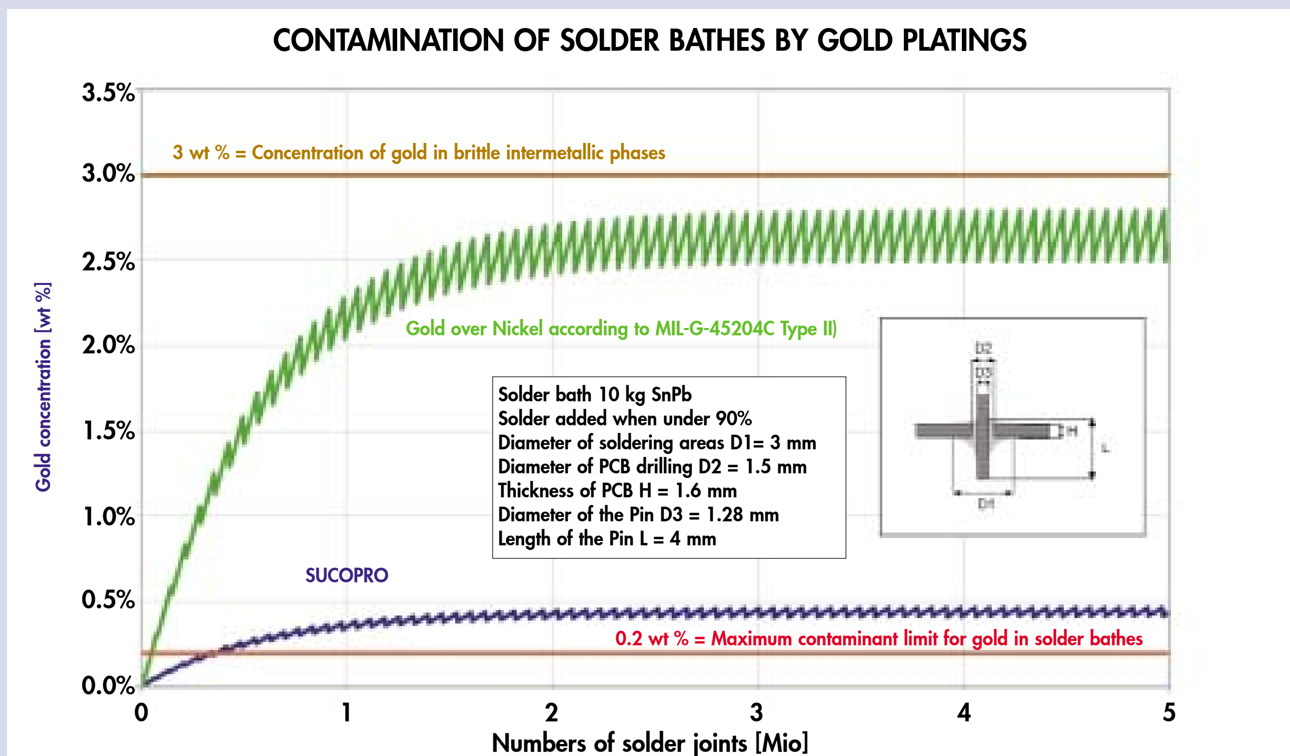
Maximum limits of solder bath contaminant

	Maximum contaminant limit (weight %)	
Contaminant	**Preconditioning (termination tinning)**	**Assembly soldering (pot, wave)**
copper	0.750	0.300
gold	0.500	0.200
cadmium	0.010	0.005
zinc	0.008	0.005
aluminium	0.008	0.006
antimony	0.500	0.500
iron	0.020	0.020
arsenic	0.030	0.030
bismuth	0.250	0.250
silver	0.750	0.100
nickel	0.025	0.010

The soldering pads should be big enough and apply as much solder as possible. For a correct amount of solder, parameters such as velocity, angle, pressure etc. of the wave soldering machine should be taken into consideration. Also, the use of thicker stencils or screens for printing the solder paste in reflow soldering will support a successful soldering result.

To ensure low contamination of solder baths, gold platings with low gold thicknesses should be used.

Mechanical stress at the solder joint should be avoided. Mechanical stress can also be caused by thermal effects. Different thermal expansion coefficients of printed circuit boards, pads, solder and components lead to mechanical stress.



ELECTRICAL PROPERTIES

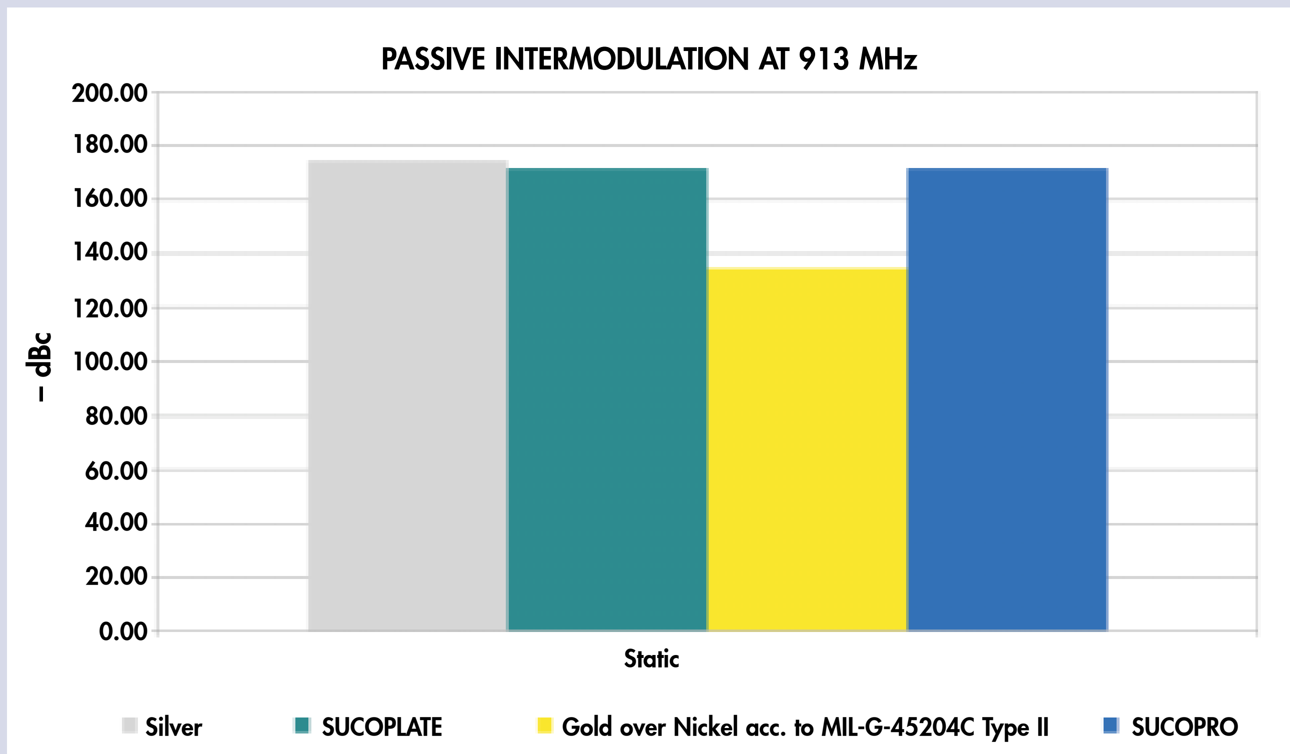
Passive Intermodulation

The trend to continuously extend communications systems is likely to continue unabated in the coming years. Especially in the field of mobile communications, the interactions taking place between channels and systems operated in parallel are becoming increasingly problematic.

These problems can be reduced by minimizing the level of the interference signals to all electromagnetic emissions with a spectrum outside the specified transmission channels.

SUCOPRO is a non-magnetic plating (above a content of 10.5 % phosphorus in the nickel, the alloy changes from ferro-magnetic to non-magnetic), as well as non-magnetisable, which is why no intermodulation products are created.

Passive intermodulation test performed with the 3rd order intermodulation products at 913 MHz and a carrier power of 2 x 20 Watt.

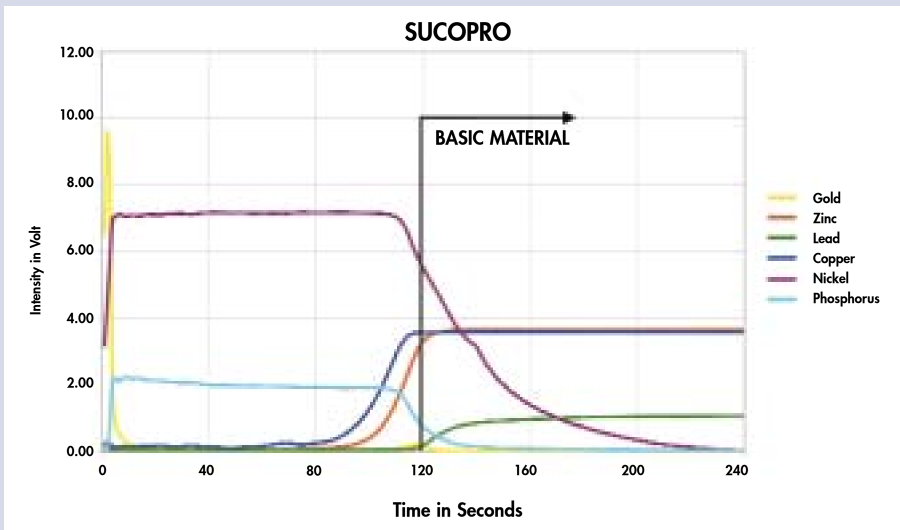


Diffusion

Diffusion of base material to the surface should be prevented in order to minimise the oxidation of the surface which influences the contact resistance and the solderability. Therefore a barrier material such as nickel is applied on connectors.

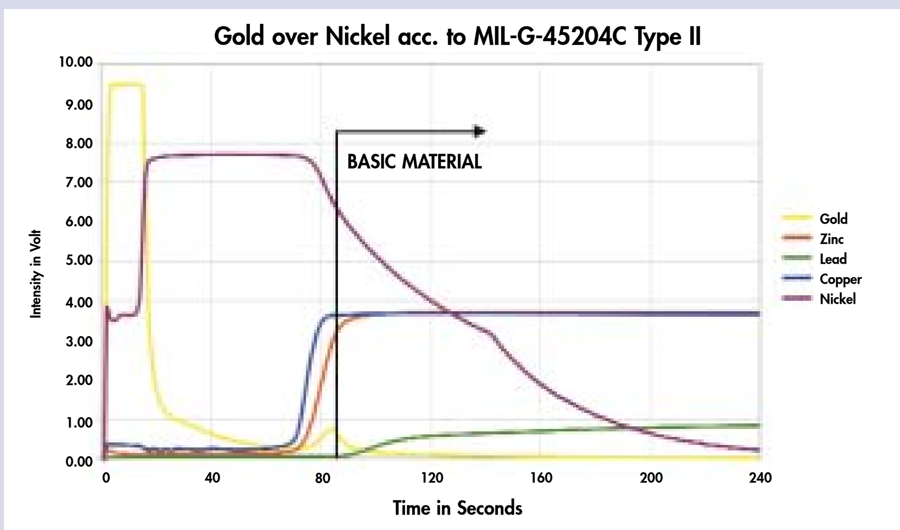
To test the barrier property, the samples were aged at 300°C for an hour and the position of the elements was measured.

The diagrams hereafter show the distance to the surface on the x-axes and the amount of the elements on the y-axes. On the left is the surface, followed by the top plating, the underplatings and the base material. Some of the nickel migrated into the base material and a few elements of the base material into the nickel-phosphorus. But the nickel-phosphorus prevented the migration of copper or zinc into the gold or to the surface. Therefore the nickel-phosphorus layer is a diffusion barrier for copper, zinc, lead and gold.



Diffusion measurement - SUCOPRO

Starting on the surface only gold was detected. Going through the sample (from left to right) the gold is followed by nickel and phosphorus. Only a very small area contains gold, nickel and phosphorus together. Deeper in the sample the copper, zinc and lead occur.



Diffusion measurement - Gold (acc. to MIL-G-45204C Type II)

With the gold applied over the nickel, the effect is the same. Therefore it is also a diffusion barrier for copper, zinc, lead and gold.

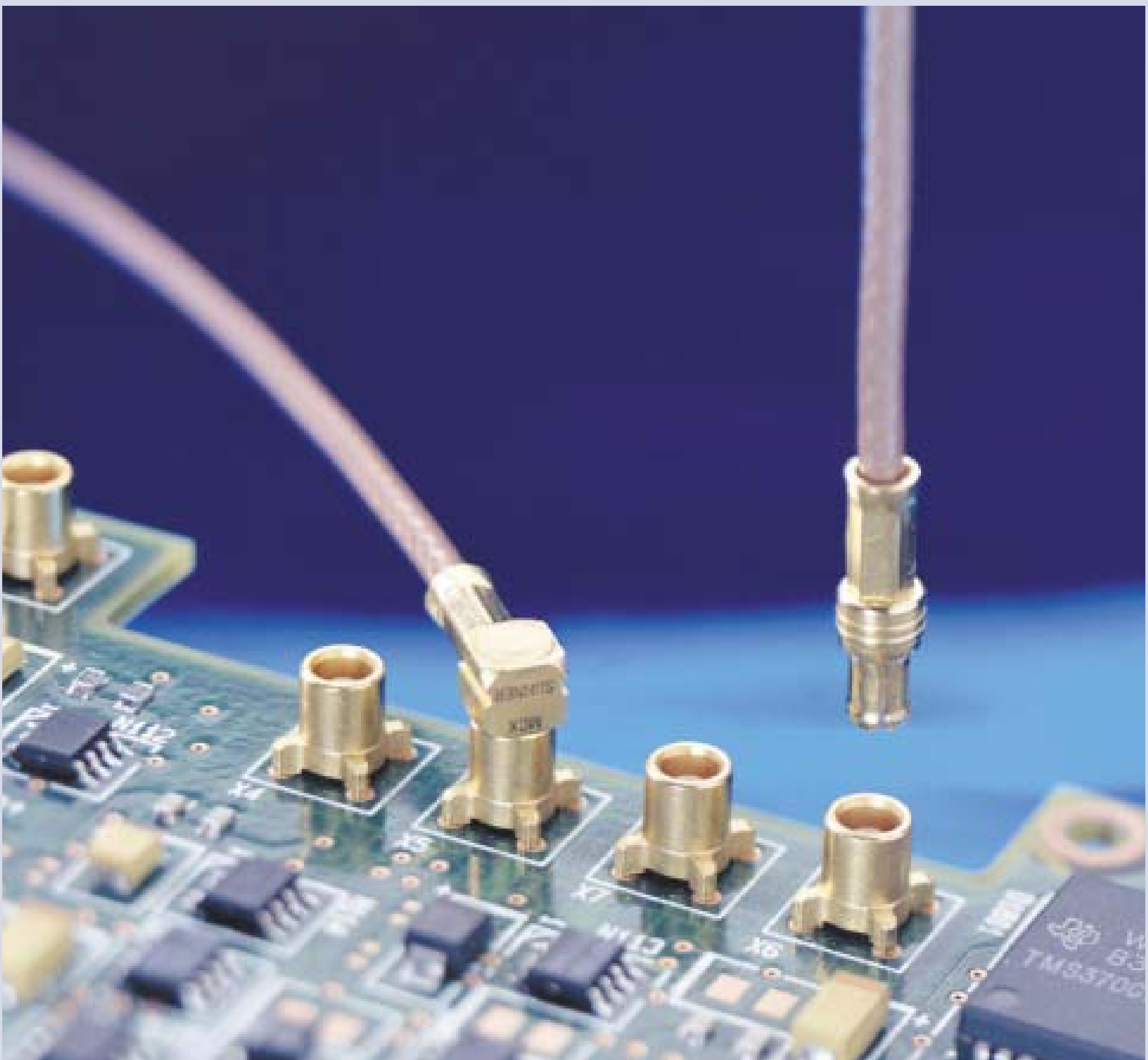
Application

SUCOPRO is mainly applied for PCB connectors, but more and more end users are selecting this plating also for cable connectors and adaptors.

Initially, SUCOPRO was developed for piece parts which demand excellent solderability and/or wear resistance, that is, PCB connectors and adaptors.

Meanwhile, SUCOPRO has been found to be an excellent standard plating for almost all subminiature connectors.

PCB connectors plated with SUCOPRO



SUCOPLATE®

THE BEST-PROVEN OUTDOOR PLATING OVER THE LAST 25 YEARS

SUCOPLATE is a copper alloy composed of the three components: copper, tin and zinc. The composition is 55% copper, 25% tin and 20% zinc. Being non-magnetic and non-allergenic (nickel-free), SUCOPLATE is an attractive alternative to nickel plating.

It has a good electrical performance and corrosion resistance. The non-magnetic property in the contact area is also important for obtaining negligible passive intermodulation products (PIM) in communication systems such as base transceiver stations. SUCOPLATE performs just as well as silver, having a PIM level of less than -155 dBc at a carrier power of 2 x 20 Watt.

SUCOPLATE has been used for more than 20 years to protect RF connectors in both indoor and outdoor applications. It gives the majority of HUBER+SUHNER products - in addition to other well-tried platings - their proven properties and consistent light metal appearance. RF connectors with SUCOPLATE plating meet and even exceed the requirements specified in the international coaxial connector standards MIL-C-39012, IEC 169-1 and CECC 22000. SUCOPLATE provides numerous advantages for contact plating over that of customary silver, tin and nickel based plating materials, including a very attractive finish.

SUCOPLATE offers the following important performance highlights:

- **Superior electrical conductivity and low contact resistance**
- **Non-magnetic**
- **Excellent passive intermodulation performance equal to silver**
- **Uniform plating thickness**
- **High abrasion resistance**
- **Low surface friction**
- **Excellent adhesion and ductility (no cracking when bending parts)**
- **Tarnish-resistant**
- **High corrosion resistance**
- **Non-allergenic**

As one of the world's leading RF connector manufacturers, HUBER+SUHNER has supplied several hundred million coaxial connectors with SUCOPLATE plating to demanding customers worldwide, providing products with unique mechanical and electrical properties. They are used in a wide range of applications, such as off-shore, airframes, space, test and measurement, telecommunications and wireless.

ELECTRICAL PROPERTIES

Conductivity

SUCOPLATE provides very good electrical conductivity. The specific electrical resistance is 4 to 7 Ωcm.

Contact resistance

SUCOPLATE provides minimal contact resistance. For example a usual coaxial connector interface (e.g. a BNC plug) using a SUCOPLATEd outer conductor has a typical contact resistance of 1 mΩ. After standard environmental testing, based on international specifications, the resistance may increase to a maximum of 3 mΩ.

RF losses

SUCOPLATE has a relative permeability r close to 1 and is therefore non-magnetic. Because of this, no additional RF losses are incurred at higher frequencies due to magnetic hysteresis, as is the case with nickel.

Passive Intermodulation

The non-magnetic properties of SUCOPLATE, apart from the metallurgical and corrosion resistance aspects, also play an important part in achieving negligible passive intermodulation products (PIM) at the contact area. This is particularly important for coaxial connectors and microwave components used in the transmit and receive paths of mobile phone base transceiver stations (BTS).

High PIM values may degrade the performance of a BTS, even causing equipment failure or interrupted calls.

Our knowledge and experience in the field of PIM have kept HUBER+SUHNER at the leading edge of current technology, even to the point of developing our own extensive test and measurement facility. Our commitment to the market has allowed us to set the standard for today's and tomorrow's low PIM requirements. Co-operation and active participation in IEC standardisation committees are just as important as controlled processes in serving our customers.

In a large number of tests HUBER+SUHNER has confirmed that SUCOPLATE provides the same superior intermodulation performance as silver.

SUCOPLATEd connectors can achieve a PIM level of less than -155 dBc. Nickel-based plating materials decrease the PIM performance by at least 15 dB compared to SUCOPLATE.

MECHANICAL PROPERTIES

Scratch resistance

The hardness of SUCOPLATE lies between 600 and 700 on the Vickers scale, superior to nickel and several times better than that of silver. SUCOPLATEd coaxial connectors boast a high scratch resistance.

Abrasion resistance

In practical tests performed on typical contact parts, SUCOPLATE exhibited an excellent abrasion resistance to itself, hard gold, silver, nickel and stainless steel. SUCOPLATEd connectors have a durability 10 times greater than that of silver. Standard HUBER+SUHNER plating thicknesses permit several thousand mating cycles before wear deteriorates the contact characteristics.

Surface friction

In this connection the low surface friction also plays an important role. As a result, low insertion forces and low torque are achieved for all threaded coupling mechanisms. This allows easy connector assembly, and especially the force required to connect and disconnect threaded connectors can be minimised.

Connector housings coming out of the plating line

ENVIRONMENTAL PROPERTIES

Corrosion resistance

SUCOPLATE is applied by HUBER+SUHNER in a thickness and quality forming a non-porous protecting surface. This, together with the alloy's properties, ensures that the requirements for excellent corrosion resistance are met.

SUCOPLATE easily passes the standard salt spray test to MIL-STD-202, Method 101, Condition B and also the equivalent tests according to CECC specifications, performing better than silver and nickel. The resistance to various industrial atmospheres is much better than silver and generally superior to nickel. The results of comparative tests are dependent upon the chosen type of test, the corrosive gas mixture, concentration (of H2S and SO2) and the exposure time.

Tarnishing

SUCOPLATE has a high resistance to tarnishing. This includes surface corrosion normally caused by handling (sweat).

Temperature

SUCOPLATE is temperature-resistant with regard to all its physical characteristics within the usual coaxial connector operating temperature range up to +165°C. The thermal coefficient of expansion for SUCOPLATE is identical to that of the copper-based materials to which it is applied, therefore preventing cracking or blistering of the plating.

ELECTROCHEMICAL POTENTIAL

The static electrochemical potential, measured in a brine solution to ASTM D1141-90 against a calomel (mercurous chloride) electrode, is typically -250 mV (with silver underplating -200 mV). The MIL-STD-recommendation (MIL-F-14072 EL) states that the maximum potential difference between two different metals should not exceed 250 mV. Therefore SUCOPLATE is compatible with the following materials:
silver - nickel - copper alloys - stainless steel - tin - tin/lead.

Important: The classification to ASTM D1141-90 conforms to MIL-F-14072 and proved convenient for contacting metals in electronics. It must not be confused with the academic consideration of chemistry textbooks. The tables shown refer to a hydrogen gas reference electrode and a salt solution of the specimen metal between the electrodes.

The prevention of allergic skin reactions to materials is becoming an increasingly important consideration. SUCOPLATE can be used without causing any allergic reaction to skin contact - this is not the case with nickel or nickel based platings.

An overview of the various electrochemical potential differences between the most important metals is shown in the table below.

Magnitude of the electrochemical potential difference between different surface metals:

Values in Volt	Gold	SUCOPRO	Silver	SUCOPLATE and commercial alloys of copper	Stainless steel	Chromium	Aluminium
Gold	**0.00**	**0.00**	**0.15**	0.40	0.50	0.60	0.75
SUCOPRO	**0.00**	**0.00**	**0.15**	0.40	0.50	0.60	0.75
Silver	**0.15**	**0.15**	**0.00**	**0.25**	0.35	0.45	0.60
SUCOPLATE and commercial Alloys of copper	0.40	0.40	**0.25**	**0.00**	**0.10**	**0.20**	0.35
Stainless Steel	0.50	0.50	0.35	**0.10**	**0.00**	**0.10**	**0.25**
Chromium	0.60	0.60	0.45	**0.20**	**0.10**	**0.00**	**0.15**
Aluminium	0.75	0.75	0.60	0.35	**0.25**	**0.15**	**0.00**

The magnitude of the electrochemical potential between two contacting materials should not exceed 0.25 V.

QUALITY AND PROCESSING

HUBER+SUHNER has more than 25 years' experience in electroplating SUCOPLATE. Over this period the company's proprietary formula and production technology have been continuously improved. Today the manufacturing process is governed by the latest computer controlled equipment. Statistical process control of the galvanic bath composition and the plating process guarantee a reproducible plating at a high quality level.

This forms the basis for a consistent metallurgical structure and therefore steady performance - in particular in terms of electrical characteristics, hardness and resistance to wear and corrosion.

Adhesion and ductility of SUCOPLATE are excellent. As a result, metal components can be deformed even after the plating process. This is very important for parts such as crimp ferrules, which are exposed to high mechanical stress during the final application.
The solderability (according to IEC 68-2-20) of new parts is good. They can be soldered with a standard resin flux. For aged parts an activated flux is recommended to achieve good results.

The plating thickness distribution of SUCOPLATE is much more consistent than that of nickel due to its contour accuracy and high electrolytic throwing power. Therefore even complicated, highly profiled metal parts can be plated in a uniform manner. Also extreme pits such as long blind holes can be covered successfully.

This is another important condition for the high quality of HUBER+ SUHNER coaxial connectors and microwave components forming - together with the other above-mentioned SUCOPLATE characteristics - important reasons to select HUBER+ SUHNER products.

APPLICATION

HUBER+SUHNER applies SUCOPLATE onto copper-alloy components such as outer conductors and connector bodies. It is used essentially in two different variants:

> Connector body plating (no RF signal transmission):
> Only SUCOPLATE is used.

> Outer conductor plating:
> A thin SUCOPLATE protection layer is applied over a silver plating. As the frequency rises, the skin-effect increasingly causes the transmitted signal to be carried in the outermost surface layers. Therefore, silver with its unbeatable high conductivity is used for carrying the majority of the signal. In this case the thin application of SUCOPLATE improves the silver plating properties as explained above.

GOLD AND SILVER PLATINGS

Gold acc. to MIL-G-45204C Type II

Gold, a good alternative to SUCOPRO, is a precious metal available both as a soft fine gold and a hard version. It is a good conductor of heat and electricity and unaffected by air and most reagents, which makes it a superb material for electrical signal transmission. Gold can be deposited on nickel or copper.
However, nickel is often deposited as an underplating to gold, because gold is quite expensive compared to other plating materials.

Attributes: Excellent wettability / solderability
Excellent protection against corrosion
Low contact resistance
Good wear resistance
The plating is magnetic (with nickel underlayer only)
Colour: Gold coloured

Application

The major use of gold in RF applications is for plating. Inner conductors are frequently gold-plated, when e.g. good conductivity, excellent oxidation resistance and continuous mating (repeatability) are required (e.g. in defence applications).
Even in highly polluted atmospheres a gold surface will be free of oxide.

Gold plated connector for space applications

SILVER

Silver is often used for the plating of coins. It is a little harder but also somewhat cheaper than gold. Its excellent electrical and thermal conductivity makes it very suitable for surface plating. Silver is used in RF applications for making solder, brazing and sliding contacts. Having the best conductivity of all metals also means that this metal can carry a high current load with the least loss. This characteristic is particularly advantageous when a low passive intermodulation product is desired.
The other features of silver are that it is easily shaped, provides very good heat conductivity , good corrosion resistance in air and water and - in addition - the lowest contact resistance. A disadvantage is that silver tarnishes (creates an oxide film on the surface) when exposed to ozone, hydrogen sulphide and sulphur. Tarnishing does not have any influence on the electrical performance. Tarnishing can be slowed down by passivation.

Attributes: Excellent electrical conductivity
Good corrosion resistance
Low contact resistance
Good solderability
Not resistant to tarnishing
Good Passive Intermodulation properties
Colour: Silver coloured

Application

Silver is the standard plating for connector bodies and inner pins of 7/16 connectors. Traditionally silver plating is well-known as a very good plating for low Passive Intermodulation components.
Thanks to its good solderability, silver is used for soldering ferrules and solder cable entries.

PLATING SHOP

The quality of HUBER+SUHNER piece parts plated in shops around the world all meet the same standards. In the HUBER+SUHNER plating shops, the piece parts for coaxial connectors receive the surfaces which have a major impact on the quality of the end products. In this key technology, various HUBER+SUHNER-specific processes are applied.

Due to the many variable influencing factors involved, electro-plating is particularly difficult to master, for example when ternary alloys are separated (e.g. with SUCOPLATE alloy of copper/zinc/tin). Therefore, the parameters for mastering the critical processes in HUBER+SUHNER plating shops have been "cloned". They essentially include:

- **Automatic plating equipment (hardware and software)**
- **Plating processes**
- **Systematic preventive maintenance of baths and equipment**
- **Laboratory technology (analysis technology)**
- **Quality standards and measuring processes**

According to our environmental policy we comply with all rules and local regulations wherever we conduct business. ISO 14001 qualification ensures continuous improvement concerning environmental aspects.

Process mastery

The mastery of all these processes (production, logistics, waste water treatment, laboratory, etc.) is the key to:

- **Low production costs**
- **Reproducible quality**
- **Short cycle times**
- **Motivated employees**

SATISFIED CUSTOMERS

Humans alone are simply overwhelmed by the task of reproducing all these characteristics in view of the immense variety of existing articles and platings. Therefore, HUBER+SUHNER applies fully automated plating equipment with programmable logic controls which allow every article to be plated according to its specific requirements.

Plating process

Before the plating of piece parts satisfies the quality demanded by HUBER+SUHNER, the piece parts are immersed in up to 50 active and flushing baths.

Individual baths contain up to 10 different chemicals. The quality of the chemicals used is critical for the plating quality. To ensure that the parameters of the active and the flushing baths will remain constant, the feed rate of the chemicals is controlled online.

Committed to the environment

HUBER+SUHNER applies specific state-of-the-art installations for waste water treatment which comply with the HUBER+SUHNER environmental policy.

Quality standards

Compliance with the plating specifications is monitored by various processes.

- **Plating thickness measurement by x-ray fluorescence**
- **Microscopic plating thickness measurement**
- **Standardised visual inspections**
- **Testing of adhesion strength**
- **Corrosion tests**
- **Monitoring of solderability**

Plating thickness tester

Partial view of the SUCOPLATE plating line