National Radio Astronomy Observatory
Electronics Division Technical Note

EDTN 229

Plating Specification for CDL Components

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13 May 2021

This note is an updated version of CDL internal memos dated 6/7/2007 [1] and 4/24/2007 [2]. It gives details of how gold plating should be specified under the current standard ASTM B 488 - 18 (2018) and describes the appropriate types of plating for some common NRAO and ALMA components.

ASTM B 488 - 18 (2018) for gold plating contains several sub-classifications which must be specified:

(i) TYPE specifies the purity of the plating:

Type I	99.7%
Type II	99.0%
Type III	99.9%

Note that the order is not simply increasing purity – this was done to conform to the older MIL spec.

(ii) CODE specifies the Knoop hardness of the plating:

Code A	$\leq$ 90 KH_{25}
Code B	91 - 129 KH_{25}
Code C	130 - 200 KH_{25}
Code D	> 200 KH_{25}

Note that the CODE in the ASTM spec. corresponds to GRADE in the old MIL spec.

(iii) CLASS specifies the minimum plating thickness in microns:

Class 0.25	0.25 µm	(~10 µ-inches)
Class 0.50	0.50 µm	(~20 µ-inches)
Class 0.75	0.75 µm	(~30 µ-inches)
Class 1.0	1.0 µm	(~40 µ-inches)
Class 1.25	1.25 µm	(~50 µ-inches)
Class 2.5	2.5 µm	(~100 µ-inches)
Class 5.0	5.0 µm	(~200 µ-inches)

(iv) UNDERPLATING with nickel is the default for parts made of copper or copper alloys. Normally at least 1.2 µm (~48 micro-inches) of nickel is used as a diffusion barrier, to reduce overall porosity, and to produce a brighter surface. The standard notes that the underplating can be omitted in cases such as waveguides in which the nickel may increase the electrical loss.

NRAO has found that inter-diffusion of gold plating and the constituents of brass is not significant if the part is not heated above ~150 C for extended periods. Hence the 300-350 C heat test specified in ASTM 488 should be omitted for gold plated brass components which have no nickel underplate.

Specifying Gold Plating per ASTM B 488 - 01 (2006) requires that the plater be given the above parameters and also details of any testing to be done on the plating (see the standard for particulars).

Not all combinations of Code (hardness) and Type (purity) are possible. According to ASTM B 488 - 01 (2006), the following combinations are considered representative of good commercial practice:

Purity	Type	Hardness	Code
99.9%	III	$\leq 90\ HK_{25}$	A
99.7%	I	$\leq 200\ HK_{25}$	A, B, C
99.0%	II	$> 90\ HK_{25}$	B, C, D

Note that high purity Type-III gold is not listed in combination with the higher hardness Codes B, C, or D. However, the bright gold used at NRAO, Enthone BDT 200, is specified by the manufacturer as having a purity of 99.9% (*i.e.*, Type III) with a hardness of 130-200 (*i.e.*, Code C). Enthone says that BDT 200 does in fact achieve plating of the claimed purity and hardness, although it may not be as pure as that of some other Type III baths nor as hard as that of other Code C baths. Alexandria Metal Finishers, however, stated that if high purity Type III gold was needed, they could only obtain hardness Code A (≤ 90).

RF loss of gold plated transmission lines and waveguides

Room temperature and cryogenic RF loss measurements of some transmission lines and waveguides, unplated and plated with NRAO's standard "hard" and "bondable" gold are given in [3] and [4].

Recommendations for NRAO and ALMA gold plating

Amplifier bodies (brass)	ASTM B 488-01 (2006) Type III, Code A, Class 7.5 , with no nickel underplating. (Soft gold, 99.9%, $\leq 90\ KH_{25}$, 300 µ-inches (7.6 µm), no Ni.)
Amplifier lids (brass)	ASTM B 488-01 (2006) Type I, Code C, Class 2.5 , with no nickel underplating. (Bright gold, 99.7%, 130 - 200 KH_{25}, 100 µ-inches (2.5 µm), no Ni.)
Mixer blocks (brass)	ASTM B 488-01 (2006) Type I, Code C, Class 1.5 , with no nickel underplating. (Bright gold, 99.7%, 130 - 200 KH_{25}, 50 µ-inches (1.27 µm), no Ni.)

Heat straps (annealed copper)[1]	ASTM B 488-01 (2006) Type III, Code A, Class 2.5 , with no nickel underplating. (Soft gold, 99.9%, ≤ 90 KH_{25}, 100 µ-inches (2.5 µm), no Ni.)
Misc. brackets (brass or copper)	ASTM B 488-01 (2006) Type I, Code C, Class 2.5 , with no nickel underplating. (Bright gold, 99.7%, 130 - 200 KH_{25}, 100 µ-inches (2.5 µm), no Ni.)

Gold Plating of Tellurium Copper

Tellurium copper is desirable in some cryogenic applications which require high thermal conductivity. We have found that tellurium copper can be plated following the above guidelines for brass.

Gold Plating of Aluminum

Aluminum may be used for electronic components when weight is of concern, and it is also used for electroforming mandrels which are eventually chemically removed leaving gold plating in place on the electroform. When aluminum is plated, either by electro or electroless methods, the first plating step (after cleaning) is known as "double zincation". This involves electroless zinc plating, the removal of same with 20% Nitric Acid, and the application of a second zinc layer. The thickness of zincation is indeterminate but achieved by 30-60 seconds immersion in Caswell Zincate solution. This zinc layer is incompatible with both direct gold plating and the acid copper used for electroforming. A barrier layer must be used. The barrier can be an electroless nickel (Enplate 7601) or an alkali copper (Caswell Flash Copper). We tend to use electroplated alkali copper in situations where signal loss may be a concern. Alkali copper must be used in preparing electroforming mandrels, as the copper is easily removable for final finishing of the piece using 30% nitric acid. Electroless nickel is perhaps best used as a barrier when a very bright final finish is desired or an electroless process is required. Using electroless nickel as the final layer on plated aluminum results in a bright wear resistant finish, similar to chrome in appearance.

For the ALMA Warm Multiplier Assemblies, which are made of 6061-T6 aluminum, a 50 - 90 micro-inch (1.27-2.3 µm) electroless nickel underplate was followed by 50 - 75 micro-inches (1.27-1.9 µm) of bright gold (not to exceed 200 micro-inches (5 µm)), with no bake required. This corresponds to specifying either:

(a) ASTM B 488-01 (2006), Type I, Code C, Class 1.25, not to exceed 5 µm (200 µ-in), with a 1.27-2.29 µm (50-90 µ-in) electroless nickel underplate, no bake required.

or (b) ASTM B 488-01 (2006), Type II, Code C, Class 1.25, not to exceed 5 microns (200 µ-in), with a 1.27-2.29 µm (50-90 µ-in) electroless nickel underplate, no bake required.

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[1] Copper heatstraps sent out to a commercial electro-polisher were returned bright but unable to be plated. Subsequent cleaning with GDP 8007 cleaner was successful.

or (c) ASTM B 488-01 (2006), Type II, Code D, Class 1.25, not to exceed 5 microns (200 μ-in), with a 1.27-2.29 μm (50-90 μ-in) electroless nickel underplate, no bake required.

Of these, (a) has the more pure gold while (c) is the hardest.

Copper Plating Inside Stainless Steel Waveguides

To reduce the microwave loss of stainless steel waveguides, the inside can be plated with copper. For stainless steel WR-10 waveguide, 1.25 μm (50 μ-in) of copper has been found to reduce the loss to about that of coin silver waveguide while showing no effects of atmospheric corrosion in over twenty years exposure. This thickness is about 5 skin depths at 100 GHz. The copper is plated from an acid solution – details are given in a separate report [5].

Acknowledgments

These notes are a revision of an earlier document by G. Morris (15 August 2006), and resulted from subsequent discussions between, G. Morris, G. Petencin, and A. Kerr, with additional information from Eric Bryerton and J. Effland (NRAO), Jeannette French (Alexandria Metal Finishers), and Mike Lynch (Enthone).

References

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