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Is Silver-Plating Worth While in RF Applications ?

The question is being asked more and more frequently: Has silver-plating my component actually done any good, or have I gone to all that trouble for nothing? You can't always tell from the measurements, but the scientific proof is unambiguous. The following article is intended to show under what conditions it makes sense to silver-plate material in radio-frequency technology.

1. Principles

Coaxial cable and resonant cavities are the radio-frequency conductors used in communications engineering in which powerful radio-frequency currents can flow. These currents heat the sheath and the internal conductor of coaxial cables and the resonance chamber of resonant cavities. Coaxial plug-and-socket connections come under particular stress. If the radio frequency field is contained, as is always the case in resonant cavities and coaxial cables, it tries to penetrate into or out of the screening material. This displacement increases as the frequency rises. This also influences the phase position of the surface currents in relation to the currents in the conductor interior, thus an inductive reactance component is generated. The permeability number, μr, of the material used thus becomes the second decisive influencing variable for radio-frequency current displacement. The effect is described as the skin effect. It means that the current density and current distribution in the metal is not constant.

2. Material characteristics

In radio-frequency technology only diamagnetic metals (μr < 1; e.g. copper) and paramagnetic metals (μr ~ 1; e.g. aluminium) are used. Brass is a particularly popular construction material in amateur radio circles, but is controversial because of the zinc component. When the zinc component and other metal fractions are high, these alloys almost tend towards ferro-magnetism. Ferro-magnetic metals such as tinplate and nickel should, not be used, at least not where powerful radio-frequency currents are flowing (μr>1; tinplate: μr~ 10 to 2000; it is important to know that at high frequencies the μr value of the tinplate becomes lower!).

Good radio-frequency characteristics are

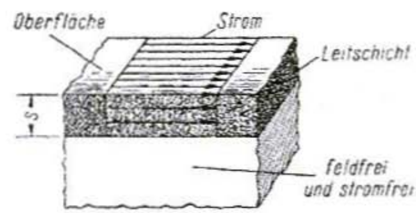

Fig 1: High conductance coating carrying the RF field current with no current flow in the underlying material

incorrectly given to the metal brass (see appendix), whereas these characteristics are worse than the radio-frequency characteristics of metals such as copper and aluminium. Due to the constituents of zinc, the good characteristics of the copper are lost, and the characteristics of zinc, which are poor anyway, are made noticeably worse in the alloy. Tinplate housings are said to be absolutely unsuitable however if the field strength is low and the frequency is high, there is no noticeable sheath current heat losses. In this case, tinplate housings are thoroughly acceptable.

The radio-frequency characteristics include:

1. Diamagnetic grading
2. Equivalent material conducting layer
3. Electrical material conductance

Special attention should be paid to the fact that the electrical conductance (κ) and the equivalent conducting layer (s) are apparently opposite to one another

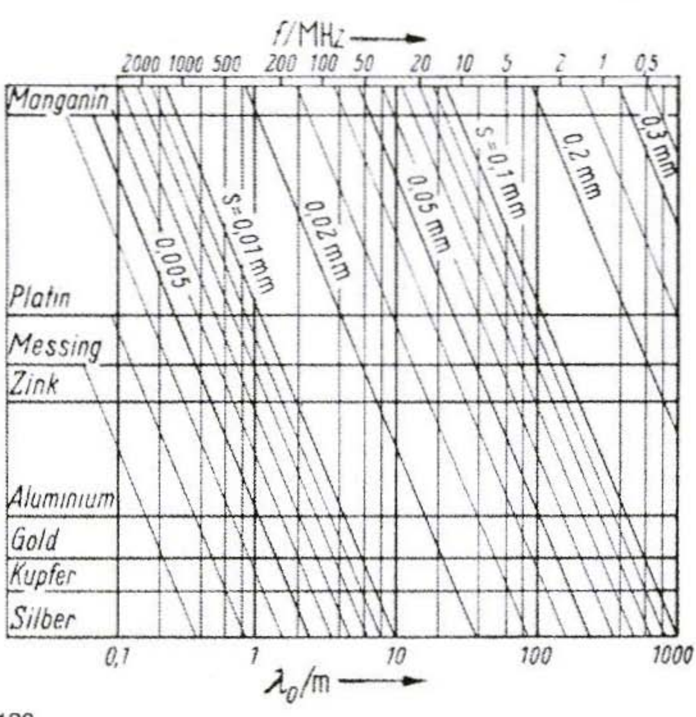

Fig 2: Diagram showing the effects of plating with various materials

Material	$x / \frac{S}{cm}$ (at 20° C)	K_1	$\alpha / \frac{1}{°C}$
Silver	62×10^4	1.00	4×10^{-3}
Copper	58×10^4	1.03	4×10^{-3}
Gold	45×10^4	1.17	4×10^{-3}
Aluminium	33×10^4	1.37	4×10^{-3}
Zinc	16×10^4	1.97	4×10^{-3}
Brass	12 to 14×10^4	2.20	1.5×10^{-3}
Platinum	9.0×10^4	2.62	4×10^{-3}
Magnesium	2.3×10^4	5.20	$\pm 0.01 \times 10^{-3}$
Constantine	2.0×10^4	5.57	-0.05×10^{-3}
Carbon	$\sim 0.02 \times 10^4$	~50	$-0/3 \times 10^{-3}$

Table 1: Parameters of various materials

in all metals i.e. a metal which is a good conductor has a low radio-frequency penetration depth and thus a low equivalent conducting layer. The metal layer under the equivalent conducting layer has no current flowing and is field-free. In this inner metal layer, no heat can be generated, and thus no energy can be absorbed from the field.

When metal is coated by a thin conducting layer with a high conductance (Fig. 1) it is shielded from the radio-frequency field hence the problem of eddy currents is reduced. In practice this means that the internal radio-frequency field of a resonant cavity can not penetrate through the metal coating in order to generate eddy currents and thus heat. This energy would be absorbed from the radio-frequency field thus reducing the output obtainable. These radio-frequency eddy current and heat losses increase exponentially with the internal field strength. In accordance with the diagram below (Fig. 2) a 2 µm thick silver layer at 500 MHz would make the metal layer below it almost completely current free. In non plated aluminium, the current free state would be achieved at 3 µm and in non plated brass it would be more than 5 µm. From Fig. 2 it can be seen that brass has markedly poorer conductance (κ = 12) than aluminium (κ= 33).

Copper and silver are shown as close neighbours in the diagram. In addition, both metals also have similar conductance levels (Cu: κ = 58 S/cm; Ag: κ = 62 S/cm). It follows from this that silver-plating copper is not worthwhile.

Aluminium lies in the boundary area of

the good conducting layer group (silver, copper, gold, aluminium). But here too, silver-plating would appear to be merely something to please the eye, and to be less important as regards efficiency.

Silver-plating begins to be useful with brass. Moreover, the conductance is already falling away (κ= 12) but should still be described as good. It is surprising that zinc plate has slightly better radio-frequency characteristics than brass. But what we might at first sight be reluctant to believe has been scientifically demonstrated to be true. Zinc has better conductance (κ = 16) and, in the 500 MHz range, has an equivalent conducting layer of 4.5 µm.

Manganese (κ = 2.3) is a metal with extremely poor radio-frequency characteristics; it is mentioned for the sake of completeness. As regards conductance is almost as poor as constantine and would have a penetration depth of 15 µm in the same frequency range.

Particular importance is given to the calculation of the sheath current heat loss for coaxial cables. The conducting layer of the sheath and the inner conductor carry an enormous current density when high levels of power are transmitted, this noticeably heats the cable. For this reason, all manufacturers specify a maximum transferable power at a specific frequency. If the limiting sheath temperature is exceeded, then an exponential rise in heat loss takes effect. The specified attenuation values are then no longer valid.

3. Appendix - Brass

The main constituents of brass are copper and zinc. Reddish brass has a high copper fraction. In yellow brass, the copper and zinc fractions are roughly the same. If the zinc fraction is even higher, brass becomes almost white. For various commercial applications, so-called delta metals (brass with a low zinc fraction) and durana metals (brass with admixtures of aluminium, manganese, tin, lead, nickel and iron) are manufactured to secret recipes. Cold working is possible, thanks to these addatives. The important value for diamagnetic grading, µr, considerably exceeds 1 in all cases. For durana metals, µr can be as high as 100. The yellow brass with high zinc fractions, which can be obtained commercially at prices that represent good value, is often made use of in amateur radio projects. This brass is graded with the equivalent conducting layer in the diagram.

4. Literature

Küpfmüller: Theoretical electrical engineering, Springerverlag

Kuchling: Physics; tables and laws; Buchverlagsgesellschaft; Cologne

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