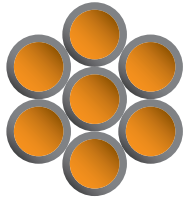


## CONDUCTOR COATINGS



Metal coatings are often applied to the surface of individual wire strands in electrical conductors to improve solderability, reduce oxidation (corrosion) or improve electrical properties at high frequencies. Three of the most common coating (plating) materials used with copper conductors are tin,

silver and nickel. A coated conductor with seven individual strands is illustrated above (coating thickness exaggerated for clarity). Decades ago metal coatings were also used to provide easy stripping of the insulation, i.e., to keep the insulation from sticking to the conductor. Improved insulation materials have made that practice unnecessary.

### COATING MATERIALS

Tin is the most common coating material. Conductors coated with tin are usually referred to as “tin plated” or simply as “tinned” conductors. Tin effectively prevents oxidation at temperatures up to about 150° C, but it is not as electrically conductive as copper. At higher temperatures, silver is often used to minimize oxidation in spite of its high cost. Silver is also used for high-frequency applications where silver’s excellent electrical conductivity and the skin effect<sup>[1]</sup> work together to reduce impedance and attenuation. At temperatures above 250° C, nickel is often used. Although it is also a relatively poor conductor of electricity, nickel provides effective protection from oxidation up to approximately 450° C. A summary of plating material properties is shown in the table below.

### APPLICATION METHODS

Two methods are commonly used to apply metallic coatings to the individual strands of a copper conductor. The first, called hot dip, is a process in which a bare copper strand is passed through a bath of molten metal. A second method, electroplating, applies the coating to each strand using an electrolytic process in which an electric current causes the coating material to be deposited on the copper.

### COATING THICKNESS

It is uncommon for industry standards to directly specify coating thickness. Instead, the thickness is usually indirectly controlled through various other requirements including continuity of coating, adhesion of coating, electrical resistance and weight. Many of those requirements are detailed in ASTM standards.<sup>[2]</sup> Coated conductors typically have coating thicknesses that range from 40 to 2,000 microinches (1 to 50 microns) or more depending on coating material and the specific wire involved.

### PLATING MATERIAL PROPERTIES

	Tin	Silver	Nickel
<b>Maximum Service Temperature (Typical)</b>	150° C	250° C	450° C
<b>Electrical Conductivity</b>	15% that of copper	106% that of copper	25% that of copper
<b>Crimp Contact Resistance</b>	Good but can deteriorate over time	Excellent	Good but can deteriorate over time
<b>Solderability</b>	Good but can deteriorate over time	Excellent	Requires active flux

## ADDITIONAL COATING TYPES

To reduce the risk of short circuits resulting from stray strands during connectorization, stranded conductors are sometimes dipped in molten tin after the insulation is stripped from the ends of the wire. To eliminate the need for this extra step by the wire user, the wire manufacturer can bond the individual conductor strands together at the factory using one of several methods. One of these methods is called prebonding. With prebonded conductors, tinned strands are heated to the melting point of tin after they are stranded—effectively soldering them together continuously throughout the length. Prebonding is not usually available with bunched conductors, i.e., those with randomly positioned strands. A second method is called overcoating. An overcoated conductor is one composed of individually tinned strands that the manufacturer has dipped into a molten tin bath after stranding. Overcoating is possible with both ordinary and bunched types of conductor stranding. A third method is called topcoating. Topcoated conductors are similar to overcoated conductors except that the overall tin coating is applied to a conductor composed of untinned copper strands rather than tinned strands. One disadvantage of all three types, however, is that they are less flexible and have a shorter flexlife<sup>131</sup> than ordinary conductors. Because of this, these wire types are usually only manufactured in relatively small gauge sizes (smaller than 16 AWG) and are not appropriate for flexing applications.

<sup>11</sup> Skin effect is an electrical phenomenon in which current tends to flow on the outer surface of a conductor.

<sup>12</sup> ASTM B-33 Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes, ASTM B-298 Specification for Silver-Coated Soft or Annealed Copper Wire, ASTM B-355 Specification for Nickel-Coated Soft or Annealed Copper Wire, [astm.org](http://astm.org)

<sup>13</sup> Flexlife is the maximum number of times a wire can be flexed around a mandrel of a specified diameter before failure occurs.



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