TECHNICAL BULLETIN

TECHNICAL BULLETIN #2-03

"Effects of Anodizing on Electrical Conductivity"

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Issued December 2003

Effects of Anodizing on Electrical Conductivity

Aluminum is commonly anodized to provide corrosion resistance and to add a decorative appearance. It is less common to use anodizing to put an electrical resistance layer on the surface to make it nonconductive. Applications such as magnetic or transformer windings and capacitor sheet use anodizing to put a durable, electrical resistance layer on the surface of the aluminum. This technical bulletin outlines the electrical properties of the anodic coating on aluminum.

When aluminum is anodized, a small amount of aluminum is converted to aluminum oxide on the surface of the aluminum. The anodic oxide layer is nonconductive and is considered to be a dielectric (i.e., a nonconductor of direct electric current). The book "The Surface Treatment and Finishing of Aluminum and Its Alloys" by S. Wernick, R. Pinner and P.G. Sheasby lists the specific resistance of anodic films along with other materials.

Specific Resistance of Various Insulation Materials*

Material	Specific Resistance ohms per cm	Approximate Temperature Centigrade	Fahrenheit
Slate	1×10^{8}	20-22° C	68-72° F
Hard fiber	2×10^{10}	20-22° C	68-72° F
Glass	5×10^{11} to 5×10^{13}	20-22° C	68-72° F
Porcelain	3×10^{14}	20° C	68° F
	4×10^{13}	97.5° C	208° F
	1.7×10^{11}	160° C	320° F
	2×10^{7}	400° C	752° F
Dry anodic film	4×10^{15}	20° C	68° F
(50 µm, 2 mil thick)	8×10^{14}	100° C	212° F
	1.1×10^{14}	200° C	392° F
	9×10^{12}	300° C	572° F
Hard Rubber	2×10^{15}	20° C	68° F

As you can see, the anodic film has a resistance about equal to that of hard rubber. This gives the resistance of the anodic layer to be about 1.4×10^{21} that of aluminum alloys. This resistance is too high to measure with most ohmmeters.

In many cases, when people look at the electrical resistance, they use the measurement of breakdown voltage. The breakdown voltage is the voltage needed to get current flow through the dielectric layer. As the thickness of the anodic coating is increased, a higher voltage is required to get current to flow. The breakdown voltage varies with the anodizing process. "The Surface Treatment and Finishing of Aluminum and Its Alloys" gives information about different anodizing processes and their breakdown voltage.

Specific Breakdown Voltage*

Anodizing process	Specific Breakdown voltage (V/μm)
Oxalic acid, a.c.	8-5
Oxalic acid, polarized a.c.[1]	
50 cycles per second (Hz)	23-45
1,000 cycles per second (Hz)	45-53
10,000 cycles per second (Hz)	16-46
100,000 cycles per second (Hz)	17-58
Sulfuric acid, d.c.	37
Sulfuric acid, a.c.	25
Ematal (oxalate film)	27-35

[1] "Polarized a.c." refers to polarization of an alternate –current sine wave to yield a direct-current, "one-half" sine wave (e.g., through use of a rectifier).

The breakdown voltage can also be affected by the composition of the alloy. This table is also given.

Effect of Composition of Aluminum or Alloy on Breakdown Voltage*

	Film Thickness (in μm)	
Approx. Breakdown Voltage (V)	Without [2] Cu or Si	With [3] Cu or Si
100	2	2-3
200	3-4	5.8
300	5-8	10-14
400	8-12	16-22
500	11-17	
600	16-22	
800	26-38	

[2] Aluminum or alloy without Copper (Cu) or Silicon (Si)
[3] Alloy containing Copper (Cu) or Silicon (Si) in quantity sufficient to exceed solid solution

As you can see from the above table, a coating of 26 μm or about 1 mil will effectively insulate up to approximately 800 volts. A coating of 8 μm or about 0.3 mils will hold up to a voltage around 400 volts.

Benefits of the use of anodized aluminum over the use of copper.

Aluminum wire is commonly used for high-tension electrical wires. At the same size, aluminum wire has around 57 percent the conductivity of copper wire. Copper is much heavier, and is about 3.3 times heavier than aluminum. At the same weight, you can have a wire that is 3.3 times the area. On an equal weight basis, aluminum would be 1.89 times more conductive than copper. In addition, aluminum is presently much lower in price than copper.

Electromagnetic windings can be made using either aluminum or copper. An aluminum winding would weigh less than a copper winding when sized to carry a given amount of electrical current.

When electromagnetic windings are made, an insulating material has to be applied to the material. When windings are made with copper, they are wound with a thin plastic film or given a lacquer or varnish coating. These processes can also be used on aluminum. Aluminum has the benefit that the insulating material can be an anodic coating. When the windings are used, insulating layers can break down over time due to mechanical wear as the windings vibrate with the current change. Insulation made of plastic films or lacquer coatings are not as durable as that of the anodic coating. The life span of plastic or lacquer-coated electromagnetic windings is less than those made from anodized aluminum. Anodized aluminum typically would be more durable, lighter in weight, and cost less than windings made from copper.

- Data in these three tables are derived from *The Surface Treatment and Finishing of Aluminum and its Alloys* by S. Wernick, R. Pinner and P. G. Sheasby. Published by ASM International®. Used by permission.

> Aluminum is a good conductor of electrical current. The book "Aluminum Standards and Data 2000" published by The Aluminum Association gives some information on the electrical conductivity of different alloys. This data is given as a percent of copper and ranges between 53% and 62% of copper based on alloy. International Annealed Copper Standard (IACS) has a value of 1/58 ohm-square mm/meter at 68° F. That means that a copper wire 1 meter in length and 1 square millimeter in cross-sectional area would have a resistance of 1/58 (0.017241) ohms at 68° F. Conductivity is 1/resistance so it would be expected that aluminum will have an electrical resistance 1.61 to 1.89 that of copper. Calculating this to ohms, a 1 meter length of aluminum with a 1-square-millimeter cross-sectional area would have resistance of 0.0277 to 0.03258 ohms. Conversion to ohms per cm length per square cm of area (ohms per cm) yields values between 0.00000274 to 0.00000325 (2.736×10^{-6} to 3.253×10^{-6}) ohms per cm.