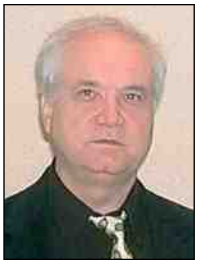
Frank Altmayer, MSF, AESF Fellow
AESF Foundation Technical Education Director
Scientific Control Labs, Inc.
3158 Kolin Ave., Chicago, IL 60623-4889
E-mail: altmayer@sbcglobal.net



Aluminum

Dear Advice & Counsel,
I am the new foreman at an airline plating shop and my experience in metal finishing is minimal. I was wondering if you could provide me with a quick primer on the kinds of metals used in the airline aerospace industry.

Signed, New Guy

Figure 1—Effect of silicon inclusions on buffing.

Dear New Guy,

This month's metal is Aluminum.

The basic physical/chemical properties of this metal are:

Symbol:	Al
Atomic number:	13
Valence:	+3
Crystal structure:	CCP (Cubic-close packed)
Density:	2.7 g/cm^3
Melting point:	660°C (1220°F)
Soluble in:	Most acids, soluble in alkali
Insoluble in:	Nitric acid, acetic acid
Color:	Silvery white
Discovered:	1825
Commercialized:	1885-86
Unusual property:	Powder is flammable
Magnetic:	Not magnetic
Corrosion resistance:	Low except for pure metal
Joining methods:	Welding, Brazing, Adhesives

While the existence of aluminum as the compound Al_2O_3 (alumina) was well known early in the eighteenth century, it was not until 1825 that Oersted first isolated impure aluminum powder by reduction of aluminum chloride with sodium amalgam. By 1850, Henri Sainte-Claire Deville was producing aluminum via reduction with sodium, but at an uneconomical cost (the price of the produced aluminum would have been the same as gold).

In 1885, the Crowle brothers produced aluminum alloys containing iron and copper, and in 1886, after the invention of the dynamo, the electrolytic production of aluminum made it economical enough to be a viable commercial metal.

While pure aluminum is very soft and ductile, aluminum alloys have exceptional strength for the weight, making it ideal in weight-critical applications such as aerospace and automobile components.

Aluminum can be heat treated to obtain surface hardness combined with core ductility for use in fatigue-wear applications. Pure aluminum has excellent corrosion resistance, in the absence of corrosive chemicals, as it quickly forms a clear oxide film immediately upon exposure to air. It is one of the few metals that are not chemically attacked by nitric acid. Once aluminum is alloyed with more noble metals such as copper and zinc, it loses some of its corrosion resistance and requires treatment for adequate service life. Copper has the most pronounced effect on the corrosion resistance of aluminum, while silicon and iron have a moderate effect.

After silver and copper, aluminum has the next highest electrical conductivity of all commercially available metals. Aluminum is so low in magnetism that it can be used in EMI shielding applications. Aluminum can readily be separated from steel using magnets or devices that depend upon difference in density.

Aluminum can readily be recycled by melting scrap. While there may be some yet to be fully proven links to adverse health effects by exposure to aluminum, it is considered a non-toxic metal, suitable for use with food contact applications and its corrosion products generally are low in toxicity.

Aluminum is an amphoteric metal that is readily attacked by common acids (nitric and acetic being exceptions) and by alkaline solutions.

Aluminum is a highly active metal

that will convert to aluminum oxide almost instantaneously, if clean aluminum is brought into contact with oxygen (from the air for example). Some processes take advantage of this tendency and actually produce a thin oxide film over cleaned aluminum by chemical action (sometimes called controlled oxidation).

The third method of inhibiting the movement of dislocations involves deforming the crystal structure of the aluminum by physical means such as pressure rolling, so that there is no clear path for the movement of dislocations and so that they tend to be so numerous that they pile up into each other creating barriers to the movement of others.

Aluminum alloys

Pure aluminum is very soft and ductile because of the presence of numerous dislocations in its crystal structure. Movement of these dislocations along slip planes prevents pure aluminum from carrying any significant load without deformation.

There are three main methods used to strengthen aluminum. By adding alloying elements, "foreign" atoms take up the vacancies producing the slip planes and act as barriers to the movement of dislocations. Similarly, by dispersing microscopic particles (examples Mg_2Si and $CuAl_2$) of alloying elements, through heat treatment methods additional/different barriers to dislocation movement can be created. When this heat treatment is not well controlled, there can be too much localized variation in composition which can lead to problems in cleaning, etching, and anodizing. For example, Mg_2Si does not etch as readily as bulk aluminum. If it is not finely dispersed, localized pitting can result. Buffing/polishing problems and appearance issues after cleaning and etching are the most common issues resulting from poor thermal treatment processing.

Silicon is a major alloying element in all casting alloys and in 4000 and 6000 series wrought alloys. The role of silicon, as well as most all other alloying elements is to add strength, fatigue resistance and/or toughness to the metal. In castings, silicon acts to allow aluminum to flow better into thin cavities and crevices of molds. For this reason, some castings may have more than 12% silicon.

Unless dispersed in the alloy as fine inclusions of Mg_2Si, large silicon-based inclusions yield buffing problems, as illustrated in Fig. 1. Silicon is very hard and when the aluminum is buffed, the softer aluminum is abraded away from the inclusion, leaving a protruding hard particle in the surface. Subsequent cleaning and etching operations will tend to undercut this inclusion, removing it and leaving a pit behind.

Silicon and silicon-bearing compounds tend to be insoluble in most any chemical solution, except acids containing fluorides. If not removed by etching, the silicon alloys in the surface may result in the coloration (tan shades) of the anodic film.

Iron is typically an impurity in the alloy and it has the most dramatic impact on anodizing aluminum, as even very small percentages tend to reduce brightness and at higher levels can cause dark gray coatings.

Manganese can affect the color of the anodic film at concentrations as low as 0.3%, yielding brown tones when heavy thicknesses are produced.

Magnesium tends to produce clear oxides under anodizing conditions. High concentrations can yield reduced clarity.

Copper does not impact the color of the anodic film unless it is present at concentrations over 2%. At levels above 2%, the hardness and clarity may be impacted.

Zinc may be present at up to 5% without impact on the color of the anodic coating, unless the zinc is present as discrete particles, in which case it may produce brown, streaky coatings.

Titanium is added to aluminum alloys as a grain refiner. The impact of titanium on the anodic film is similar to that of iron.

Chromium at levels over 0.3% can add yellowish tones to the coating. Its presence lowers electrical conductivity dramatically, making anodizing (without burning) difficult). Chromium may be found in trace amounts in many alloys of the aluminum-magnesium, aluminum-magnesium-silicon and aluminum-magnesium-zinc groups.

Figure 2—Aluminum with uniform element distribution.

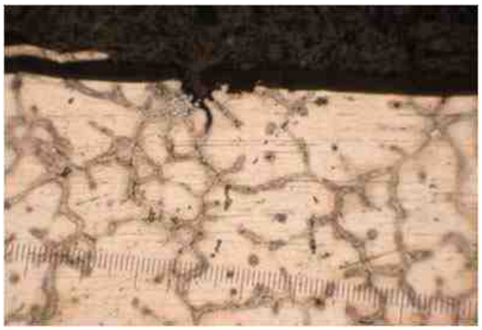


Figure 3—Aluminum with non-uniform element distribution.

If present in amounts above 0.35%, chromium can yield very large inclusions especially in alloys containing manganese, iron and titanium.

When finely dispersed in wrought products, chromium can inhibit nucleation and grain growth in aluminum-magnesium alloys. Chromium can also prevent recrystallization in aluminum-magnesium-silicon or aluminum-magnesium-zinc alloys during hot working or heat treatment.

Making aluminum parts

At aluminum production facilities the aluminum alloy is "chill cast" into ingots (direct casting of the molten alloy is also possible). The molten aluminum is poured into molds and water is sprayed onto the molded aluminum in an attempt to solidify it as rapidly as possible (to produce the smallest grains). Because the outside cools faster than the inside, and because alloying elements have different solidifying temperatures than aluminum, the composition of the ingot is not homogeneous throughout a cross section of the ingot.

The next step is to homogenize the ingot by heating it up to a temperature where the alloying elements can be redistributed by a diffusion process. This temperature is high enough to accomplish the goal without re-melting the aluminum. If this operation is conducted under the best of control, an ingot will display a uniform distribution of alloying elements, shown in the cross-section of Figure 2 (100×. A non-uniform distribution of the alloying elements results from poor homogenization of an ingot, as in Fig. 3 (100×).

The ingots must be converted to basic shapes. This is performed by either extruding the aluminum, rolling it into sheets, casting or forging, followed by final machining and surface finishing operations.

More on aluminum next month. *P&SF*

Test Your Plating I.Q. #465
By Dr. James H. Lindsay

Stripping metallic coatings

1. Why are immersion strippers preferred over electrolytic ones?
2. Why have electrolytic strippers at all?
3. Hydrochloric acid can be used to strip chromium from steel. What precautions should be considered?
4. The most common anodic nickel stripper from steel, brass, copper, aluminum and zinc die-castings is based on __________ _____.
5. What is the easiest plated metal to strip?

Answers on page 49.

People in the News

David Crimp Appointed Executive Vice President, Enthone Europe

Cookson Electronics (West Haven, CT) is pleased to announce the appointment of Mr. David Crimp as Executive Vice President, Enthone Europe. This appointment extends Mr. Crimp's current role as Executive Vice President of Cookson Electronics' Alpha business in Europe.

In his expanded role, "David will look for opportunities to create synergies between the Enthone and Alpha businesses wherever feasible," said Steve Corbett, CEO Cookson Electronics. "He will utilize his experience and knowledge to blend the best from both organizations. David's appointment will allow us to fulfill the potential of our excellent businesses."

Mr. Crimp has been with Cookson Group (UK) for more than 20 years. He brings to Enthone Europe an inclusive, engaging and visionary leadership style together with a wealth of business and commercial experience. Mr. Crimp's key achievements at Cookson have included the successful transition of the Alpha business from autonomous country business units to a single Pan-European entity.

Thomas Venarge named President of APV Engineered Coatings®

Thomas Venarge has been named President of APV Engineered Coatings® (Akron, OH). Venarge had served as the company's Vice President of Manufacturing since 2004, and has also been the Plant Manager since 1999.

"Thomas has learned every aspect of this business since his initial involvement back in 1990," says David Venarge, Chairman of APV Engineered Coatings, a custom engineered products company. "The timing is ideal for him to take over the reins of the company to assure its sustained growth and success. He will lead us forward on a continued path of innovation in this specialty business and help us to grow into different markets in the future."

Despite the challenging state of the economy, APV had its fifth best sales month ever in August of 2010. This milestone is especially impressive when considering that the company is more than 130 years old.

"I plan to continue along the same paths as we have been traveling for years focusing on continuous improvements and growth," says Thomas Venarge. "We're the ultimate niche business, and we have a great deal to offer the world with our specialty formulations, innovative solutions and tolling capabilities.

"Everyone at APV is excited about the advances we're making in nanotechnology and the opportunities we have to develop superior coatings for all types of applications. We have experience in achitectural, automotive and aerospace Industries, to name just a few of our expertise areas. There are also many unchartered applications we have not tried … yet. We love the innovative nature of our business and thrive on the potential for new developments each day."

Venarge has played an active role in the family business since he was a student at the University of Akron in the early 1990s. His first position with the company involved the manufacture of industrial crayons. Through the years, he has operated nearly all of the company's equipment, performed most daily functions, worked in both inside and outside Sales and Service departments, and managed a satellite facility.

"I'm looking forward to developing more cutting-edge products in the near future that transform existing items and help extend the life of products in a wide variety of markets," according to Venarge. Thomas, his wife Marcy, and three daughters live in the Akron suburb of Green. David Venarge, who will remain Chairman of APV, spends his time between Ohio and Florida.

Founded in Akron, Ohio in 1878, APV Engineered Coatings manufactures innovative, custom products that are sold around the world, to a wide variety of industries. The company's custom formulated product lines include: adhesives, caulks and sealants, crayons, decals, dyes, inks, high temperature coatings, inspection markers, lubricants and release agents. For more information on products and solutions, visit www.apvcoatings.com or call (800) 772-3452. *P&SF*