

LIGHT METALS: Al, Mg and Be



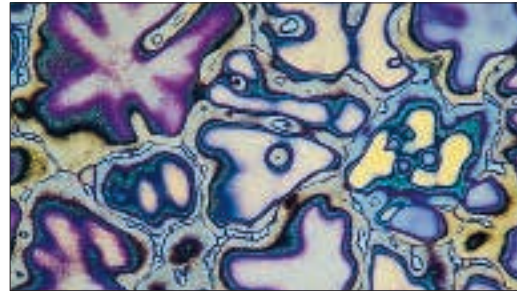
Aluminum

Aluminum is a soft, ductile metal. Deformation induced damage is a common preparation problem in the purer compositions. After preparation, the surface will form a tight protective oxide layer that makes etching difficult. Commercial grades contain many discrete intermetallic particles with a variety of compositions. These intermetallic particles are usually attacked by etchants before the matrix. Although the response to specific etchants has been used for many years to identify these phases, this procedure requires careful control. Today, energy-dispersive analysis is commonly performed for phase identification due to its greater reliability.

Five and four-step practices for aluminum alloys are presented below. While MgO was the preferred final polishing abrasive for aluminum and its alloys, it is a difficult abrasive to use and is not available in very fine sizes. Colloidal silica has replaced magnesia as the preferred abrasive for the final step and is finer in size. For color etching work, and for the most difficult grades of aluminum, a brief vibratory polish may be needed to completely remove any trace

of damage or scratches. The five-step practice is recommended for super pure (SP) and commercially pure (CP) aluminum and for wrought alloys that are difficult to prepare.

Either 240 or 320grit [P280 or P400] SiC waterproof paper may also be used for the planar grinding step. An UltraPol cloth produces better surface finishes than an UltraPad cloth, but the UltraPad cloth has a longer useful life. A ChemoMet cloth is recommended when edge retention is critical. Pure aluminum and some alloys are susceptible to embedment of fine diamond abrasive particles, especially when suspensions are used. If this occurs, switch to diamond in paste form, which is much less likely to cause embedding. SP and CP aluminum can be given a brief vibratory polish (same products as last step) to improve scratch control, although this is generally not required. MasterPrep alumina suspension has



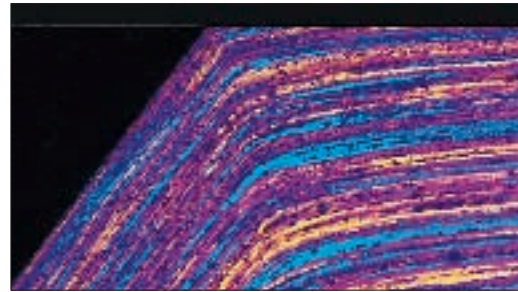
Dendritic segregation in as cast 206 aluminum revealed by color etching with Weck's reagent (polarized light, 200X).

Table 11: 5-Step Method for Soft Aluminum Alloys

Sectioning	Abrasive Cutter with a wheel recommended for use on non-ferrous materials				
Mounting	Compression or Castable, typically with PhenoCure, EpoxiCure, EpoThin or SamplKwick				
Surface	Abrasive / Size	Load - lbs [N] / Specimen	Base Speed [rpm]	Relative Rotation	Time [min:sec]
CarbiMet 2	320 [P400] grit SiC water cooled	5 [22]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	5 [22]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	5 [22]	150		4:00
TriDent	1µm MetaDi Supreme Diamond*	5 [22]	150		2:00
ChemoMet	0.02 - 0.06µm MasterMet Colloidal Silica	5 [22]	150		1:30
= Platen = Specimen Holder *MetaDi Fluid Extender as desired					
Imaging & Analysis	Dendritic spacing, Porosity Assessment, Grain Size (depending on the type of aluminum and its processing)				
Hardness Testing	Vickers, Knoop				

been found to be highly effective as a final polishing abrasive for aluminum alloys, however, the standard alumina abrasives made by the calcination process are unsuitable for aluminum.

For many aluminum alloys, excellent results can be obtained using a four step procedure, such as shown below in Table 12. This procedure retains all of the intermetallic precipitates observed in aluminum and its alloys and minimizes relief. Synthetic napless cloths may also be used for the final step with colloidal silica and they will introduce less relief than a low or medium nap cloth, but may not remove fine polishing scratches as well. For very pure aluminum alloys, this procedure could be followed by vibratory polishing to improve the surface finish, as these are quite difficult to prepare totally free of fine polishing scratches.



Deformed, elongated grain structure of extruded 6061-F aluminum after shearing revealed by anodizing with Barker's reagent (polarized light, 100X).

HELPFUL HINTS FOR ALUMINUM

Many low-alloy aluminum specimens are difficult to polish to a perfect finish using standard methods. A vibratory polisher can be used quite effectively with MasterMet colloidal silica to produce deformation-free, scratch-free surfaces for anodizing or color etching and examination with polarized light or Nomarski DIC.

Table 12: 4-Step Method for Aluminum Alloys

Sectioning	Abrasive Cutter with a wheel recommended for use on non-ferrous materials					
Mounting	Compression or Castable, typically with PhenoCure, EpoxiCure, EpoThin or SamplKwick					
Surface	Abrasive / Size	Load - lbs [N] / Specimen	Base Speed [rpm]	Relative Rotation	Time [min:sec]	
CarbiMet 2	320 [P400] grit SiC water cooled	5 [22]	300		Until Plane	
UltraPad	9µm MetaDi Supreme Diamond*	5 [22]	150		5:00	
TriDent	3µm MetaDi Supreme Diamond*	5 [22]	150		4:00	
ChemoMet	0.02 - 0.06µm MasterMet Colloidal Silica	5 [22]	150		1:30	
= Platen = Specimen Holder *MetaDi Fluid Extender as desired						
Imaging & Analysis	Dendritic spacing, Porosity Assessment, Grain Size (depending on the type of aluminum and its processing)					
Hardness Testing	Vickers, Knoop					



Light Metals



Magnesium

Preparation of magnesium and its alloys is rather difficult due to the low matrix hardness and the higher hardness of precipitate phases that lead to relief problems, and from the reactivity of the metal. Mechanical twinning may result during cutting, grinding, or handling if pressures are excessive. Final polishing and cleaning operations should avoid or minimize the use of water and a variety of solutions have been proposed. Pure magnesium is attacked slowly by water while Mg alloys may exhibit much higher attack rates. Some authors state that water should not be used in any step and they use a 1 to 3 mixture of glycerol to ethanol as the coolant even in the grinding steps. Always grind with a coolant,

as fine Mg dust is a fire hazard. Because of the presence of hard intermetallic phases, relief may be difficult to control, especially if napped cloths are used. Following is a five-step procedure for magnesium and its alloys, see Table 13.

MasterPolish is nearly water-free and yields excellent results as the final abrasive. After the last step, wash the specimens with ethanol. Cleaning after the last step, without using water, is difficult. Holding the specimen under running water for about a second eased the cleaning problem and did not appear to harm the microstructure. Cosmetic cotton puffs can scratch the surface when swab etching. For best results, etch-polish-etch cycle may be needed. Magnesium has a hexagonal close-packed crystal structure and will respond to polarized light. To enhance the response, use a brief vibratory polish with the materials used in the last step.



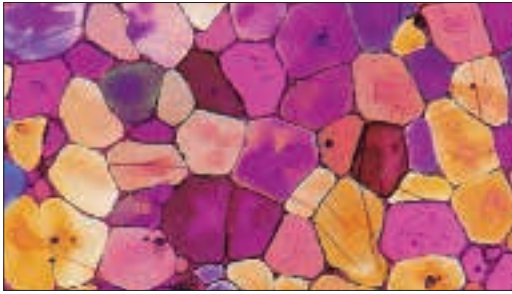
Mechanical twinning in deformed high-purity magnesium (99.8% Mg) (acetic-picral etch, crossed polarized light plus sensitive tint, 50X).

HELPFUL HINTS FOR MAGNESIUM

For polishing, apply diamond paste and use lapping oil, or use oil-based MetaDi diamond suspension, available down to a 0.10µm size, with a medium nap cloth.

Table 13: 5-Step Method for Magnesium Alloys

Sectioning	Precision saw, with no water and a 15HC blade recommended for use on Metal Matrix Composites, PCBs, Bone, TI, TSC				
Mounting	Castable, typically with PhenoCure, EpoxiCure, EpoThin or SamplKwick				
Surface	Abrasive / Size	Load - lbs [N] / Specimen	Base Speed [rpm]	Relative Rotation	Time [min:sec]
CarbiMet 2	320 [P400] grit SiC* water cooled	3 [13]	300		Until Plane
TexMet C	9µm MetaDi Oil-based Diamond	3 [13]	150		6:00
TexMet C	3µm MetaDi Oil-based Diamond	3 [13]	150		5:00
TexMet C	1µm MetaDi Oil-based Diamond	3 [13]	150		4:00
ChemoMet	0.05µm MasterPolish	4 [18]	150		1:30
= Platen = Specimen Holder *SiC surfaces were coated with wax to minimize embedment					
Imaging & Analysis	Dendritic spacing, Porosity Assessment, Grain Size				
Hardness Testing	Brinell				



As-cast microstructure of a magnesium alloy with 2.5% of rare earth elements, 2.11% Zn and 0.64% Zr showing a film of the rare earth elements in the grain boundaries, alloy segregation within grains (“coring” revealed by color variations within grains) and a few mechanical twins in the grains (acetic-picral etch, crossed polarized light plus sensitive tint, 100X).



Beryllium

Beryllium is also a difficult metal to prepare and presents a health risk to the metallographer. Only those familiar with the toxicology of Be, and are properly equipped to deal with these issues, should work with the metal. The grinding dust is extremely toxic. Wet cutting prevents air contamination but the grit must be disposed of properly. As with Mg, Be is easily damaged in cutting and grinding forming mechanical twins. Light pressures are required. Although some authors claim that water cannot be used, even when grinding Be, others report no difficulties using water. Attack-polishing agents are frequently used when preparing Be and many are recommended [2]. Table 14 shows a four-step practice for beryllium.

For the final step, mix hydrogen peroxide (30% concentration – avoid physical contact!) with the MasterMet colloidal silica in a ratio of one part hydrogen peroxide to five parts colloidal silica. Oxalic acid solutions (5% concentration) have also been used with alumina for attack polishing. For optimal polarized light response, follow this with vibratory polishing using a one-to-ten ratio of hydrogen peroxide to colloidal silica.



Grain structure of wrought, P/M beryllium (unetched, cross-polarized light, 100X).

HELPFUL HINTS FOR LIGHT METALS

Small diamond abrasive sizes are prone to embedment when applied as a suspension or by spraying. Charge the cloth using diamond paste to eliminate embedding. Another technique is to use both a fine diamond paste and Master-Prep alumina suspension – simultaneously – to prevent embedding.

Table 14: 4-Step Method for Beryllium

Surface	Abrasive / Size	Load - lbs [N] / Specimen	Base Speed [rpm]	Relative Rotation	Time [min:sec]
CarbiMet 2	320 [P400] grit SiC water cooled	4 [18]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	4 [18]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	4 [18]	150		4:00
ChemoMet	0.02 - 0.06µm MasterMet Colloidal Silica	3 [13]	150		2:00

= Platen
 = Specimen Holder
 *MetaDi Fluid Extender as desired

Imaging & Analysis	Dendritic spacing, Porosity Assessment, Grain Size
Hardness Testing	Brinell