COPPER, NICKEL and COBALT

Copper

Pure copper is extremely ductile and malleable. Copper and its alloys come in a wide range of compositions, including several variants of nearly pure copper for electrical applications to highly alloyed brasses and bronzes and to precipitation hardened high strength alloys. Copper and its alloys can be easily damaged by rough sectioning and grinding practices and the depth of damage can be substantial. Scratch removal, particularly for pure copper and brass alloys, can be very difficult. Following the preparation cycle with a brief vibratory polish using colloidal silica is very helpful for scratch removal. Attack-polish additions have been used in the past to improve scratch removal but usually are not necessary using the contemporary method followed by vibratory polishing, see Table 24.

Planar grinding can be performed using the 45 or 15µm metal-bonded or the 30µm resin-bonded UltraPrep discs. Use the resin-bonded disc for the soft copper grades and copper alloys.

Alpha grains containing annealing twins in phosphorous-deoxidized arsenical bronze that was annealed and lightly cold drawn (Klemm's I reagent, polarized light, 50X).

Table 24: 5-Step Method for Cu and Cu Alloys

Sectioning	Abrasive Cutter with a wheel recommended for use on non-ferrous materials				
Mounting	Compression or Castable, typically with PhenoCure or VariDur				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	220 [P240] to 320 [P400] grit SiC water cooled	5 [22]	300		Until Plane
TexMet C	9µm MetaDi Supreme Diamond*	5 [22]	150		5:00
VerduTex	3µm MetaDi Supreme Diamond*	5 [22]	150		3:00
VerduTex	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*	**Plus MetaDi Fluid Extender as desired*		***Plus attack polishing reagent (see text for details)*	
Imaging & Analysis	Grain Size, Coating Thickness Layer, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop				

Copper, Nickel, Cobalt

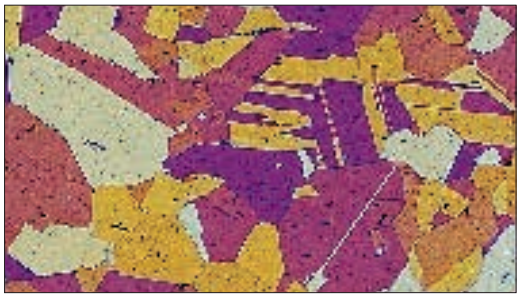
Nickel

Nickel and its alloys have face-centered cubic crystal structures and are prepared in basically the same way as austenitic stainless steels. Pure nickel is more difficult to prepare than the alloys. The Ni-Fe magnetic alloys are rather difficult to prepare scratch free unless vibratory polishing is used. The Monel (Ni-Cu) and the highly corrosion resistant (Ni-Cr-Fe) alloys are more difficult to prepare than the nickel-based superalloys. Solution annealed superalloys are always more difficult to prepare than age hardened superalloys. Age hardened superalloys can be prepared using the Apex Hercules H disc; for all other nickel alloys, use the Apex Hercules S disc for best results. The following practice works well for nickel based superalloys (and Fe-Ni based super alloys) and the highly corrosion resistant Ni-Cr-Fe alloys, see Table 25.

If color etching is to be performed, follow the last step with a brief vibratory polish using the same materials as in the last step. This step is also helpful for the most difficult to prepare solution annealed alloys. Alternatively, for the most difficult specimens, or when color etching is being performed, a 1µm diamond step on a Trident cloth can be added before the final step.

For pure nickel, nickel-copper and nickel-iron alloys, a five step practice is preferred, as given below. The planar grinding step can be performed using either the 30µm resin-bonded UltraPrep diamond disc or with 240 [P280] or 320 grit [400] SiC papers with equal success, see Table 26.

Attack-polishing agents are not often used with these alloys to eliminate fine polishing scratches or residual damage. If this is a problem, and some of these grades are very difficult to get perfectly free of scratches and deformation damage, a brief vibratory



Alpha grains containing annealing twins of solution annealed and double aged Waspaloy nickel-based superalloy (Beraha's reagent, 100X).

Table 25: 4-Step Method for Ni-Based Superalloys

Sectioning	Abrasive Cutter with a wheel recommended for use on SuperAlloys				
Mounting	Compression, typically with EpoMet				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	240 [P280] grit SiC water cooled	6 [27]	300		Until Plane
Apex Hercules S Rigid Grinding Disc	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	6 [27]	150		5:00
ChemoMet	0.02 - 0.06µm MasterMet Colloidal Silica**	6 [27]	150		2:00
= Platen	*= Specimen Holder*	**Plus MetaDi Fluid Extender as desired*			
Imaging & Analysis	Grain Size, Porority Assesment, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop				

polish, using the same materials as in the last step, will provide the needed improvement. MasterPrep alumina may give better results than colloidal silica for the more pure nickel compositions.

Table 26: 5-Step Method for Ni, Ni-Cu and Ni-Fe Alloys

Sectioning	Abrasive Cutter with a wheel recommended for use on SuperAlloys				
Mounting	Compression, typically with EpoMet				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	240 [P280] grit SiC water cooled	6 [27]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TriDent	3µm MetaDi Supreme Diamond*	6 [27]	150		3:00
TriDent	1µm MetaDi Supreme Diamond*	6 [27]	150		2:00
ChemoMet	0.02 - 0.06µm MasterMet Colloidal Silica**	6 [27]	150		2:00
● = *Platen* ❁ = *Specimen Holder*			**Plus MetaDi Fluid Extender as desired*		
Imaging & Analysis	Grain Size, Porority Assesment, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop				

Cobalt

Cobalt and its alloys are more difficult to prepare than nickel and its alloys. Cobalt is a tough metal with a hexagonal close-packed crystal structure and is sensitive to deformation damage by mechanical twinning. Grinding and polishing rates are lower for Co than for Ni, Cu or Fe. Preparation of cobalt and its alloys is somewhat similar to that of refractory metals. Despite its hcp crystal structure, crossed polarized light is not very useful for examining cobalt alloys compared to other hcp metals and alloys. Following is a practice for preparing Co and its alloys, see Table 27.

Two steps of SiC paper may be needed to get the specimens co-planar. If the cut surface is of good quality, start with 320 grit [P400] paper. Cobalt and its alloys are more difficult to cut than most steels, regardless of their hardness. Attack polishing has not been reported but chemical polishing has been used after mechanical polishing. Morral (2) has recommended two chemical polishing solutions: equal parts of acetic and nitric acids (immerse) or 40mℓ lactic acid, 30mℓ hydrochloric acid and 5mℓ nitric

Equiaxed grain structure of Elgiloy (Co – 20% Cr – 15% Fe – 15% Ni – 7% Mo – 2% Mn – 0.15% C – 0.05% Be) after hot rolling and annealing revealing annealing twins (Beraha's reagent, crossed polarized light plus sensitive tint, 100X).

acid (immerse). A wide variety of Co-based alloys have been prepared with the above method without need for chemical polishing. The 1µm diamond step could be eliminated for routine work.

Table 27: 5-Step Method for Co

Sectioning	Abrasive Cutter with a wheel recommended for use on SuperAlloys				
Mounting	Compression, typically with EpoMet				
Surface	**Abrasive / Size**	**Load - lbs [N] / Specimen**	**Base Speed [rpm]**	**Relative Rotation**	**Time [min:sec]**
CarbiMet 2	320 [P400] grit SiC water cooled	6 [27]	300		Until Plane
UltraPad	9µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TexMet C	3µm MetaDi Supreme Diamond*	6 [27]	150		5:00
TexMet C	1µm MetaDi Supreme Diamond*	6 [27]	150		3:00
ChemoMet	0.02 - 0.06µm MasterPrep Alumina	6 [27]	150		2:00
 *= Platen*  *= Specimen Holder*		**Plus MetaDi Fluid Extender as desired*			
Imaging & Analysis	Grain Size, Porority Assesment, Measurement & Analysis Applications				
Hardness Testing	Vickers, Knoop				