Hand polishing electrodes

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# Overview

Cathode electrodes for the CEBAF and FEL DC photoguns are polished to a sub-micron surface finish through a hand polishing process.

Electrodes are machined, preferably from vacuum remelt stainless steel, to the best possible finish which is between 16 and 32 micro-inch RMS surface roughness. The electrodes are then degreased using a solution of Cole-Parmer Micro-90™ degreaser and deionized water.

# Sandpaper polishing

Carbide sandpaper, available from Buehler LTD, is used for initial polishing of a machined electrode. The sandpaper is categorized by its “grit”, or the average number of particles in one linear inch, so polishing starts with a lower grit number, typically 300, and progresses toward a fine grit, typically 800 before switching to diamond paste polish.

To minimize the chance of an abnormally large particle of grit in the sandpaper from gouging the surface, it is a good practice to lightly rub the dry sandpaper against another, same grit, piece of sandpaper to knock any large particles loose. However, this is not critical for the coarsest grades, and doing this on the very fine grades will destroy the sandpaper quickly, so it is primarily used for the intermediate grades.

The surface finish of an electrode from the machine shop will vary between 16 and 32 micro-inch RMS roughness. Polishing usually starts with around 300 grit sandpaper, though coarser machined finishes requiring coarser sandpaper and some very good finishes allow you to begin using 320 grit. If the initial paper isn’t removing the scratches with reasonable pressure, switch to a coarser grit (200 grit is as coarse as used typically).

Set up a polishing station with a bright light to help see scratches, and a comfortable chair.

When polishing with sandpaper, cut the sandpaper into small pieces (about 1”x2”). Prepare a soap and water solution for lubrication – both in a squirt bottle to rinse the electrode and in a dish to rinse the sandpaper. The soap used is Bullen/Harley Company’s Coconut oil hand soap, BUL520-1. Change the sandpaper very often as it clogs up and stops removing metal, and rinse very often during the use of the sandpaper (often starting with a new piece of paper every minute or so – the finer grits wear more quickly, so change accordingly).

For initial polishing, use firm pressure (typically from a thumb), and rub the piece in one direction paying particular attention to areas where deep scratches are evident. After the scratches mainly go one direction, change to another direction, either in an x pattern or at a 90degree angle from the first direction.

If the piece is symmetric, spinning the piece on a potter’s wheel can speed up the initial polishing steps. However, concentric grooves will appear on the electrode when using the potter’s wheel. You need to stop the wheel and polish radially until the concentric grooves disappear, then you can re-start the wheel.

For particularly deep gouges or a deep depression, depression on the electrode surface, don’t try to bring the whole surface down. Tools such as a toolmaker’s scraper, a honing stone or even a file can turn a gouge into a shallow depression with no sharp radius. Extreme care needs to be used if you are using a scraper: one slip can cause another gouge and make more work.

Initial polishing for each grit of sandpaper is done with moderately heavy pressure, and you continue working with one grit of paper, use a successively lighter touch until you can change the direction of the scratches with very little pressure. Once this is the case over the entire electrode, it is time to move to a finer grit. Typical progression of sandpaper proceeds from coarse (280-300) to medium (400-600) to the very fine (800). 800 grit paper should be used with minimal pressure to begin (light pressure from an index finger) and end with extremely light pressure (light pressure from a middle finger). The finer grit paper also clogs up very quickly and needs to be changed quite often.

To clean off the electrode to better see scratches in the midst of polishing with one coarseness of sandpaper, use a squirt bottle of isopropanol and cotton balls. The cotton balls will get dirty quickly: Rotate through several throwing away the dirtiest, using the slightly dirty for the next initial cleaning, and using a clean cotton ball for the final cleaning.

# Cleaning

Cleaning needs to be done each time you change to a finer grit of paper or diamond paste to ensure that no larger particles remain that will leave big scratches when using the finer paper. Any larger particles of the coarser grit sandpaper or diamond paste that contaminate your work area once you switch to a finer grit will leave larger scratches in the electrode, and require more work to remove. Moving to coarser grit doesn’t require cleaning up the entire work area.

The electrode needs to be cleaned in the clean room, using Micro ™ degreaser, then DI water rinses and solvents if desired. Before starting the next step, also change your soap water bowl, change gloves, wipe down your work surface and squirt bottle using isopropanol - make sure that everything that may be contaminated with grit is thoroughly cleaned.

# Diamond paste polishing

Diamond paste polishing is performed similarly to the sandpaper polishing, with increasingly light pressure and polishing in a crossing patter to change the direction of the scratches.

The diamond paste is used on fabric, which is backed with a piece of “FabWipe” cleanroom paper to give the fabric a more rigid feel. Put a tiny amount of the diamond paste (~ 1/16” long squirt from the tube or less) on the fabric, then put a drop of oil on the paste to use as a lubricant and dispense the paste.

The fabric used (also available from Buehler LTD), can be either nylon, silk or microcloth. The nylon and silk both have a coarse and a smooth side – use the smoother side.

Once the electrode has a good 800 grit sandpaper finish, clean up well and go to 6 micron diamond paste for the next polishing step. This is typically followed by 3 micron and 1 micron pastes.

With the 6 micron paste, start using nylon since it is more coarse. Keep going until scratches change direction with light pressure. Rinse with isopropanol, and wipe with cotton balls, going through cotton balls frequently (typically reusing the lightly dirty ones).

While using diamond paste, polish with one section of cloth until it gets black from the metal particles, then move to a new section of the cloth, a new dab of paste and a drop of oil. Throw away the cloth and get a new piece when there are no clean spots left.

Before moving to the next grit or paste, clean the part with microclean (ultrasonic cleaner in the clean room) and rinse with DI water (also in the ultrasonic cleaner) so that you can see if you have big scratches left or if you are ready to move to the next finer paste, then blow dry with nitrogen. You will see all the scratches much better (paste and isopropanol hides the scratches). Continue with polishing as needed.

As with the sandpaper, you are ready to switch to the next finer abrasive when the scratches all go in the same direction and change direction with very light pressure.

To avoid having to go back to a coarser paste and clean again, if you are using 3 micron paste and nylon isn’t working to get the scratches out (6 micron scratches left in the finish), try something more abrasive like the silk cloth with 3 micron paste. The silk cloth gives a bit more bite from the paste than you’d get if you continued using the nylon to get rougher scratches out. Move back to the nylon after the larger scratches are removed. This allows you to polish bigger scratches out without having to go through the whole cleaning process again.

Use the micro-cloth (fuzzy cloth) with the final steps of the 3 micron paste and for the 1 micron paste.

Final cleaning of the electrode after the finish is good at 1 micron:

Ultrasonic cleaning and Micro ™, then rinses with acetone and methanol, and finish with a rinse in boiling DI water. After this final cleaning, do not touch the electrode with gloves.

# Supplies

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| Product | Description | Manufacturer | Part Number |
| Soap | Coconut oil hand soap | Bullen/Harley Co | BUL520-1 |
| Polishing oil | 32 oz. polishing oil | Buehler | 40-8142-032 |
| Nylon cloth |  | Buehler | 40-7062 |
| Silk |  | Buehler | 40-7412 |
| Microcloth |  | Buehler | 40-7222 |
| Polishing paper |  | Buehler | 320,400,600,800 |
| Other sandpapers | Carbide@240, 320, 400 | Carbimet @280,320 |  |
| Diamond paste | 0.25 micron (gray) | Buehler | 40-6241 |
| MetaDi II | 1 micron(blue) | Buehler | 40-6244 |
| medium concentration | 3 micron (green) | Buehler | 40-6247 |
|  | 6 micron (yellow) | Buehler | 40-6250 |
| Gloves | Vinyl cleanroom | oak technical | 96-334  (stockroom 841544040) |
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# Conclusion

Successful polishing requires patience, plenty of time, correct technique and extreme care in keeping things clean.