Silicon Carbide Grinding of Stainless Steel

1 Introduction

The stainless steel electrodes in the 500 kV gun must meet two requirements. First, they must withstand electric fields in excess of 13 MV/m without breaking down. Second, they must not interfere with the gun's achieving a base pressure of $\sim 10^{-11}$ torr.

To simultaneously achieve both these goals, we will silicon carbide (SiC) rough-grind and diamond paste polish the electrodes to smooth their surface. While we have borrowed both the grinding and the polishing procedures from Jean Francis of SLAC's Physical Electronics department (415–926–2533), only the SiC rough-grinding will be discussed here.

2 Motivation

The SiC grinding procedure we will use has been specially developed at SLAC to circumvent the problems associated with normal grinding processes. The two major problems with normal grinding involve the turning over of the steel (instead of removing it) and the imbedding of the polishing medium in the steel's surface.

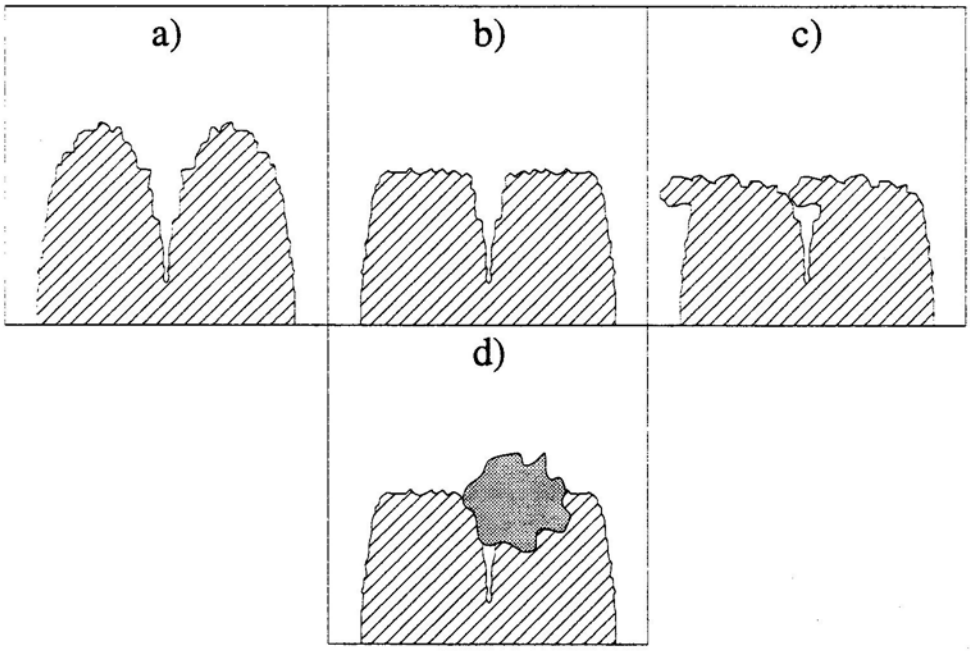

Figure 1: Visualizations of electrode surface before and after grinding.

Turning over the steel is problematic with respect to our vacuum requirement. The surface of the electrode can be visualized as a series of peaks and valleys as shown in figure 1a. Ideal grinding (shown in figure 1b) smoothes the surface by *removing* material from

the peaks, thus reducing the distance from valley to peak. Bad grinding (shown in figure 1c) smoothes the surface by turning over the peaks and covering up the valleys. These covered valleys, which trap air and other substances, act as virtual leaks and degrade the vacuum performance of the electrode.

Imbedding the polishing medium is problematic with respect to our breakdown requirement. The polishing medium is a dielectric and the electrode is a conductor. If, as indicated in figure 1d, a particle of the polishing medium is partially embedded in the electrode, the already high electric field in the region is locally enhanced, thereby leading to breakdown.

In order to avoid the pitfalls outlined above, we have two cardinal rules for our SiC grinding:

1. DO NOT BEAR DOWN WHEN POLISHING.
2. DO NOT POLISH AT HIGH SPEEDS.

3 Materials Needed

The following is a list of all the materials necessary to permit us to SiC grind.

- SiC paper in the grit sizes 240, 320, 400, and 600.
- Scissors, wiped down with methanol to eliminate contamination.
- Texwipe sheet.
- 3M double-sticky tape.
- De-ionized water.
- Liquid coconut-oil soap.
- Drop bottle.
- Graduated cylinder.
- 500 mL squirt bottle.
- $\sim$ 10 L graduated carboy.
- Tygon tubing.
- 10$\times$ magnifier.

4 Methods Used

The following is a step by step process of the actual polishing procedure.

1. Thoroughly clean and degrease the stainless part. The usual ultrasonic cleaning in baths of alkaline detergent (eg a solution of Alcanox and deionized water), deionized water, acetone, and methanol or isopropanol should suffice.

2. Install the electrode on the polishing fixture in the lapping area. **Note: Electrode should never be left unattended without first covering it with a poly bag.**

3. Determine the state of the polishing area. Polishing is allowed only when both doors leading into the polishing area are closed and no one else is using the lapping tables. Under no circumstance shall electrode polishing be allowed to occur when either of these conditions is violated. The chances for stray material getting on the electrode and marring the finish are too great.

4. Make up a soapy solution for the carboy and the squeeze bottle. For the squeeze bottle, fill the bottle with deionized water, add 14 drops of soap from the drop bottle, and shake to dissolve. For the carboy, fill with deionized water to the line marked on its side, add 225 drops of soap from the drop bottle, and shake to dissolve. It is extremely important to get the proper amount of soap in solution. Too much soap causes the grinding process to stop. Too little soap allows loosened material (steel and SiC) to conglomerate in the paper and effectively act as a larger grit paper, thereby introducing deeper scratches than desired in the surface. This process is referred to as "loading".

5. Fashion a polishing pad with 240-grit paper. As the polishing proceeds, we will change to 320-grit, then 400-grit, and finally 600-grit paper.

   - For flat surfaces:
     (a) Roll up the SiC paper loosely to help soften it.
     (b) Using scissors, cut a Texwipe into quarters and cut a square of SiC paper that is marginally larger than the Texwipe quarters.
     (c) Using double-sticky tape, tape together two of the Texwipe quarters and the SiC square.
   - For radiused surfaces:
     (a) Roll up the SiC paper loosely to help soften it.
     (b) Using scissors, cut strips of Sic paper 0.5 in wide to desired length.
     (c) Using double-sticky tape, tape the strips of paper to the appropriate fingers of the glove you will wear during polishing.

6. Turn on the lapping table spindle, and dial in a comfortable speed. **Note: Lapping table speed shall not exceed 20 rpm when grinding a flat, or 10 rpm when grinding a radius.**

7. Wet the polishing pad and the metal's surface with the soapy water in the squeeze bottle. Also start a slow, soapy-solution drip from the carboy and direct it onto the surface being ground. It is important to keep things wet in order to avoid loading the polishing pad.

8. Begin to grind the metal by stroking it at a right angle to the grain with a *very* light touch (**let the paper do the work**). Note that when grinding radiused areas, you must move the pad along a series of tangents to the curve. The paper is too stiff to conform to the curve without exerting excessive pressure on the metal. Pay close attention to how the grinding process feels. Sometimes there are flaws in the SiC paper which cause it to deeply gouge the metal. If you suspect that you have a faulty piece of paper, discard the polishing pad and make a new one from a fresh sheet of paper.

9. Periodically (every 10–15 minutes) use the squirt bottle to cleanse the polishing pad and the stainless of the buildup of removed material.

10. When the current SiC paper wears out (after $\sim$ 30 minutes), fashion another pad as in step 5.

11. Repeat steps 3–10 until the surface finish (as observed both by the naked eye and through a 10$\times$ magnifier) does not change with continued grinding.

12. Continue to polish the metal until one or two additional pads have worn out.

13. Contact Dave Engwall to confirm that the grinding for the current grit is complete.

14. Remove the electrode from the polishing fixture and thoroughly clean it in ultrasonic baths of an alkaline detergent followed by deionized water. This step is to assure that there are no remnanats of the previous grit left on the metal's surface when the next grit is used.

15. Thoroughly wipe down the exposed areas of the polishing fixture with methanol and Texwipes so that the chances of cross-grit contamination are eliminated.

16. Repeat steps 2–15, each time with the next highest grit paper, until all four grits have been used.

5 Comments

It takes a relatively long time to remove machining lines with the 240-grit paper. I estimate that 1–2 weeks of grinding may be necessary for the electrodes. Fortunately, the grits following 240 go about 10 times faster.

Gloves should be worn as much as possible when handling the SiC paper. Gloves should always be worn when handling the stainless part and when actually polishing. This prevents body oils from coming in contact with the stainless, and also provides protection from the irritating effects of the SiC. If skin ever comes into contact with the stainless piece

after grinding has begun, rinse the part off thoroughly with soapy water from the squeeze bottle.

The polishing area is designated as a no smoking area.

The grinding process is critical to obtaining electrodes that meet our requirements. It is also physically and mentally stressful. To keep from inadvertently damaging the electrodes, you should grind only when you are alert. You should take several breaks during your shift when you start to feel fidgety or tired. As the timing of breaks varies from person to person, the individual is responsible for arriving at a break schedule that is most comfortable for him.