

# Stainless Steel Pulse Electropolishing

by  
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Electropolishing is widely used for components in the medical and electronic industries. Electropolishing provides a smooth surface that is resistant to bacteria growth and particulate contamination.

Using pulsed current instead of DC current increases the operating range of the solution for both chemistry and temperature. Frequently when electropolishing large flat pieces, the edges are bright and the center is dull. Pulsed current eliminates this effect. It also tends to even out the polishing on complex shaped parts.

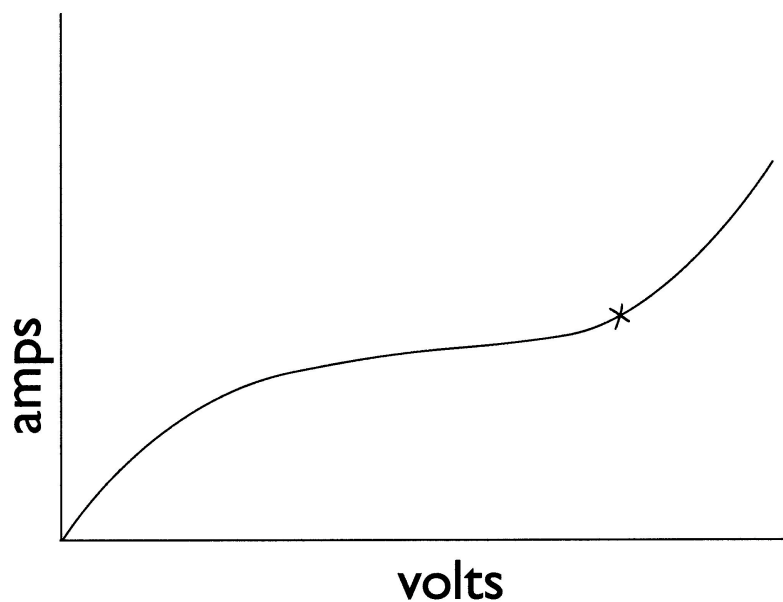
## Recommendations

For a warm solution composed of half phosphoric and half sulfuric acid, we recommend using constant voltage mode at approx 5 volts, 10 ms on, 30 ms off. If pitting occurs increase the voltage.

## Theory

During the on time of the pulse, metals from the high spots of the surface loose electrons, react with the oxygen evolved from the electrolysis of water and form metal oxides. Some of these oxides stay on the surface, some sloughs off the surface, and some dissolves in the acidic solution. The metal oxides are much more resistive than the metals and block metal atoms under them from being removed.

A plot of current versus voltage shows a knee at about 4 volts. In this voltage region the



substrate is acting primarily as a soluble anode and metal is being removed from the surface and dissolved in the EP solution. Above this region the substrate is acting

primarily as an insoluble anode and the water is being electrolyzed to oxygen gas and hydrogen ions. In order for polishing to occur, the current and voltage must be above the knee of the curve, this location is marked with an X in the above graph

If the substrate functioned as a 100% soluble anode, the following would occur during the anodic portion of the pulse:

1. Metal atoms become free from their crystal structure and are mobile on substrate surface
2. Ions adjacent to the substrate align themselves into layers of alternating charge (capacitive or double layer)
3. Mobile atoms lose electrons - (charge transfer)
4. Metal ions are solubilized by water or other ligands and form a viscous layer next to the substrate.
5. Soluble ions move away from the substrate and become part of the bulk solution.

If the substrate functioned as a 100 % insoluble anode the following would occur during the anodic portion of the pulse:

1. Ions adjacent to the electrode align themselves into layers of alternating charge (capacitive or double layer)
2. Water loses electrons and is oxidized to oxygen and hydrogen ions and forms a viscous layer next to the substrate.
3. Oxygen and hydrogen ions diffuse away from the substrate and become part of the bulk solution.

Since the polishing occurs when the substrate functions primarily as an insoluble anode and slightly as a soluble anode, all of the steps listed above take place. In addition the soluble metal ions can react with oxygen gas or monatomic oxygen to form metal oxides, which are insoluble and will either stay on the metal surface, fall off as sludge, or dissolve in the electropolish solution.

The first step is making the metal atoms mobile on the surface. One can think of each metal atom as being cubical. Metal atoms on a planar surface are attracted or bound to each other by Vanderwall's forces. Each atom on the surface has 7 neighboring atoms. This is a strong attraction and these surface atoms are not likely to become mobile. Another type of surface feature is a step. Atoms on the surface in the middle of the step edge are bound on 6 sides and atoms on the surface and corner of the step are bound on 5 sides. The corner atoms are more likely to become mobile. Next case is for metal atom sitting on top of a surface. These are bound only on one side and are most likely to

become mobile. Fortunately these are also the atoms that we need to remove during the electropolishing process.

The charge transfer and either the complexing by water or other ligands can take place nearly simultaneously. The double layer ( layer of charge separation) extends only about the distance of 4 metal ions from the surface. The viscous layer rich in metal ions, oxygen and hydrogen ions diminishes with distance from the anode and reaches the same chemistry as the bulk solution at a distance of 100 to 200 microns from anode. Exact distance depends upon the magnitude of the current and the amount of time the current is on.

During the off time, the double layer discharges, the viscous layer stops increasing in thickness and starts to diffuse into the bulk solution. Gas bubbles formed on the anode have time to release from the substrate and rise to the surface.

### **Function of bath constituents**

Sulfuric acid and phosphoric acid provide conductivity to the solution as well as anions for metals that are soluble.

Water increases the conductivity of the solution and helps solubilize metal ions.