STAINLESS STEEL FOR JEWELRY MANUFACTURING

Chris Ploof

Today, many companies manufacture jewelry from stainless steel. This is especially attractive with the high prices of precious metals. There is little jewelry manufacturing information published for those that sit at the bench and who may come across stainless steel or desire to create with it. This presentation will remove the mysteries of working with stainless steel in the small shop setting, detail common, readily available alloys, highlight steps for working with stainless steel, as well as showcase examples of stainless-steel jewelry in production today. From the skills necessary to touch up a stock piece of stainless-steel jewelry all the way through cutting, fabricating, machining, soldering, and finishing, this paper will leave the reader with the skills necessary to work with stainless steel and also how to combine it with precious metals.

Chris Ploof is the owner of and principal designer at Chris Ploof Designs, a manufacturer of high-quality wedding rings and other jewelry specially created using laminated materials. His background includes studies ranging from large-scale casting and glasswork to lapidary, blacksmithing, and machining. He is a recipient of the Santa Fe Symposium® Ambassador Award, the Jewelry Technology Leader Award, a two-time recipient of the Industry Leader Award and a three-time recipient of the Collaborative Research Award.

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Chris Ploof
Chris Ploof Designs
Leominster, MA, USA

PLOOF

INTRODUCTION

The purpose of this paper is to discuss the types of stainless steel most suitable for work at the bench, and to share techniques for working with stainless steel at the jeweler's bench. By no means are these the only techniques, but they are the techniques we have been using for over 20 years at Chris Ploof Designs to get exceptional results.

Stainless steel is a highly corrosion resistant, low-cost silvery grey metal that can be fashioned into jewelry using many traditional techniques. It is plentiful, easy to find in a multitude of shapes, and extremely easy to recycle. In fact, at least 60% of all the steel in any given item is recycled. There are more than 60 grades of stainless steel, but our focus is on 304 and 316 stainless steels. Both of these steels are highly workable, and lend themselves to many manufacturing techniques including casting, machining, open and closed die forging, hydro forming, welding, brazing, laser and water jet cutting, and stamping. Stainless steel parts are also made from powdered metal that is then sintered and 3D printed using direct metal laser sintering. At the bench you can cut, file and engrave these alloys with standard tools, braze (solder) it with the proper flux, and it is easy to laser and TIG weld.

In order to be stainless, the steel must contain at least 10.5% chromium. This chromium content is what makes stainless steel "stainless". The chromium reacts with the oxygen in the air to form a transparent, "passive" layer of chromium oxide on the surface of the stainless steel which protects and prevents the steel from oxidizing. If scratched, this chromium oxide readily reforms. The addition of nickel also helps increase the corrosion resistance of the steel. As mentioned above, stainless steel needs at least 10.5% chromium to develop a passive oxide film, and most stainless steels have more than 12% chromium in order to maintain this corrosion resistance after thermal processing such as welding and casting.

304 stainless steel is an alloy of iron and at least 18% chromium, 8% nickel, and less than 1% of carbon with a few other trace elements. 316 has a very similar composition but includes 2-3% of molybdenum to further increase the corrosion resistance.

Both of these steels are highly corrosion resistant and can't rust when handled and treated properly. The Vickers hardness is in the 150 range, making it similar to some of the nickel white golds out there, so they work and bend in ways familiar to the bench jeweler. It typically is not attracted to a magnet, BUT parts that have been welded or subjected to extensive machining or other work can become slightly magnetic. They won't rust if passivated properly even if subjected to extreme conditions. These grades of stainless steel are considered surgical grades of steel and are the most common grades of stainless steel. In short, they are highly suited to jewelry making.

But isn't nickel bad when used in jewelry manufacturing?

Stainless steel holds the nickel in solution and releases at an extremely low rate when compared to gold alloyed with nickel. Nickel Allergic Contact Dermatitis is a very real thing, and the Nickel Institute estimates that on average, 12-15% of women and 1-2% of men are allergic to nickel. As a reference though, 3 series and other high quality stainless steels containing up to 28% are commonly used to make wrist watches. The nickel release rate is so low for these steels that it's not a problem to use them for jewelry., either.

On their webpage about nickel allergy, the Mayo Clinic has this to say about nickel allergy, regarding jewelry with nickel: *Avoid jewelry that contains nickel. Purchase jewelry that's made of materials that aren't likely to cause allergic reactions. Look for jewelry made from such metals as nickel-free stainless steel, surgical-grade stainless steel, titanium, 18-karat yellow gold, or nickel-free yellow gold and sterling silver. Surgical-grade stainless steel may contain some nickel, but it's generally considered hypoallergenic for most people. Be sure that your earring backings also are made of hypoallergenic materials.*

Typically, we don't use simple stainless steel for our designs; we use laminated stainless steel (similar to mokume gane or damascus steel) that is comprised of layers of 304 and 316. I'll touch briefly on how to reveal the pattern through acid etching in this paper. Throughout the rest of this paper, I will use the term stainless steel to describe 304/316 and this laminate interchangeably. Working 304 or 316 or 304/316 laminate uses identical techniques.

AT THE BENCH WITH 3-SERIES STAINLESS

Handling and Sourcing

Important first note! Stainless steel is not the easiest material to remove from your refining lots, so whenever possible, keep your sweeps and machining scraps separate. Also make sure you use a reputable refiner who understands your particular needs. Make sure they know that you will have contamination from steel and that they will refine the material for best returns. This refining approach takes longer but yields far superior returns.

3-series stainless steel is generally sold in the annealed condition and is available in a large variety of shapes and finishes. The standard mill finish for many companies is a dull grey, as rolled surface. Small quantities can be purchased from large number of suppliers.

Cutting and Forming

There are many options for forming stainless steel. For smaller pieces and quantities, stainless steel cuts very easily at the bench using jeweler's saw blades. It will dull saw blades more quickly than other materials, and use of a lubricant is necessary. After extensive trials and testing, we have settled on Pike Platinum Saw Blades as giving the best performance for cutting stainless steel at the bench. We use Boeshield stick (produced by Orelube) as the lubricant for cutting and abrasives. It is a great option for many applications, is also available in a liquid and paste, and is readily available from various industrial suppliers.

Figure 1: Pike Platinum blades, Boeshield Stick Lubricant and Saw Frame

Other options for cutting parts include laser or water jet cutting, both locally available in most regions of the United States, and allow for inexpensive, rapid production of small and large quantities of parts. A note about water jet cutting: the process can leave an angled or tapered edge, unlike other cutting techniques and tools that may be more familiar. Water jet cutters not equipped with a tilting head kerf compensator will leave this tapered edge, especially on thicker parts. Both laser and water jet cut part edges will have some surface roughness that may need to be addressed prior to further manufacturing. These edges and any resulting burs are easily removed using files and/or abrasives. You can use cutting dies for thinner pieces of stainless steel, but proper heat treatment of dies for use on stainless is very important.

I'm a huge fan of Valorbe Valtitan brand files for hand filing. Valtitan is a chromium plating process that leaves a surface hardness of 72 Rockwell c. This coating enhances performance and extends the life of the file. It also acts as an anti-corrosion treatment and negates the need for lubrication. These files are superior for all harder or denser materials such as stainless steel and platinum.

For forming, you can certainly use standard tools such as dapping blocks and punches, especially for thinner material. We use a Bonny Doon Press and tooling for much of our forming. This is much easier than hand forging and makes quick work of shaping thicker cross sections. The bracelet pictured in Figure 3 takes minutes to form and is 3.3 mm thick x 20 mm wide.

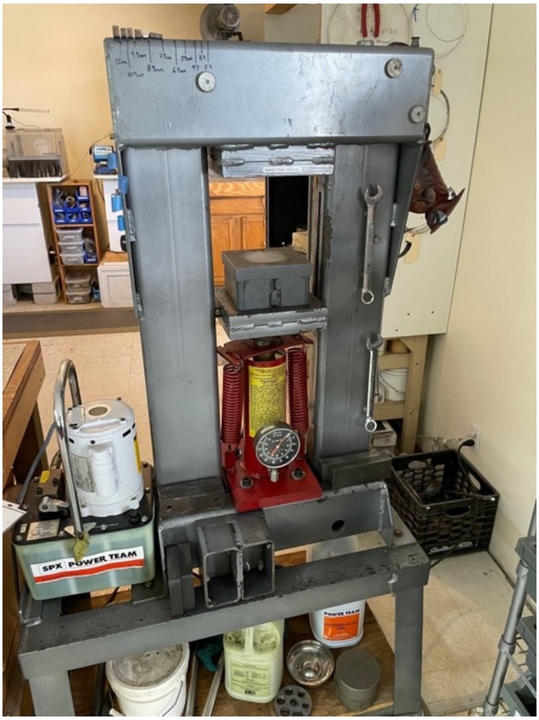

Figure 2: Bonny Doon 50 Ton Press

Figure 3: Stainless Steel Damascus Cuff Bracelets Formed on Bonny Doon Press

Figure 4: Bonny Doon Bracelet Forming Tools

We've also used the Bonny Doon Drawing and Forming Tools to draw 1 mm thick stainless steel with great results.

Figure 5: Drawn Stainless Steel Vessels

For more complex shapes such as rings, clasps, and certain pendants, we rely on machining. 3-series stainless steel has good machinability and can be worked with a lathe and mill as basic as the Sherline Machine Tools.

Figure 6: Sherline Lathe

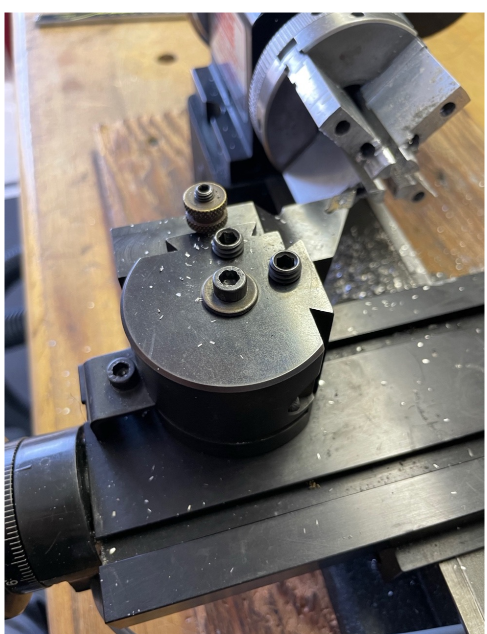

Figure 7: Quick Change Tool Post for Sherline Lathe

We use carbide end mills and replaceable carbide insert tools on our lathes and mills. Carbide has the benefit of not needing flood cooling (although flood cooling does increase tool life), so if you have a small space with small machine tools it is far less messy than using cobalt or high-speed steel tools which must be cooled with flood coolant. Even with flood cooling, HSS and Cobalt tools don't last as long as non-flood cooled carbide tools. These carbide tools do benefit from lubrication, however, and we also the Orelube Boeshield stick when using the Sherline Machines. A small amount applied directly to the part makes it much easier to cut and extends tool life. For larger projects or production runs, we are equipped with CNC lathes and mills. We do use flood cooling when using these machines so we can squeeze the longest service life out of our tools.

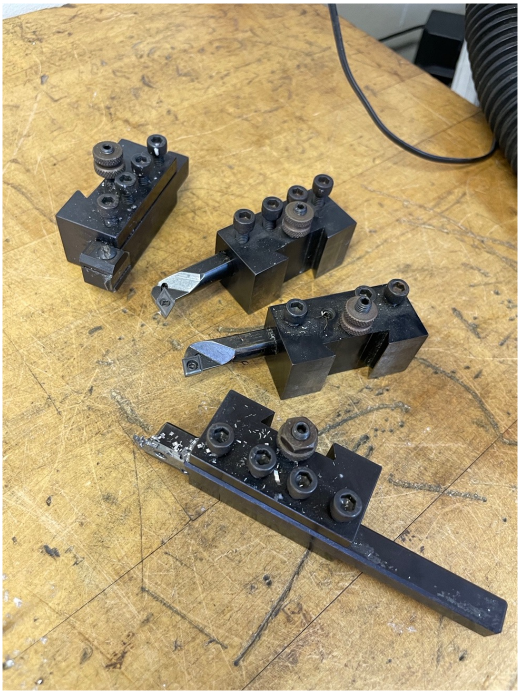

Figure 8: Variety of Indexable Carbide Tools from Sherline

If machining stainless steel is in your plans, there is a lot of information out there about speeds and feeds based on the particular steel you are working with. We typically run our Sherline lathe at around 1700 RPM and remove 0.10 mm of material at a pass. Our larger lathes we run at 1000 RPM and remove 0.25 mm per pass. For milling, we like to use a spindle speed of 660 and a depth of cut of 0.5 mm when facing stock with an indexable carbide mill. These are general guidelines; your approach may vary.

Figure 9: Indexable Carbide Mill Used for Facing Stock

For machining at the bench, I highly recommend carbide burs. Proper bur speed as indicated by the manufacturer is really important, as is the use of lubricant. I don't recommend a flex shaft for this, as they don't spin fast enough. An adjustable micromotor handpiece is perfect for the job. Carbide is more brittle than high speed steel, so good technique is also important. I find the carbide burs last about four times as long as the high-speed steel burs when lubricated with (you guessed it) Boelube. Carbide burs also have the advantage of cutting more cleanly than HSS burs.

Engraving is also possible, we use C-Max Graver or tungsten carbide graver blanks for best tool life and cleanest cuts, but these gravers tend to fracture or break at the tips if technique isn't perfect. Engraver.com stocks a high-speed steel graver blank specifically heat treated for use in stainless steel that she says is prone to dull rather than fracture, but we have not tried these blanks. As for all cutting, we recommend the use of lubricant for engraving, and I'm quite fond of power assisted engraving on stainless steel instead of hand push.

Annealing and Soldering/Brazing Stainless Steel

Stainless steel is sold annealed, and I can count on one hand the number of times I've had to anneal 304 and 316 stainless steels. It takes a long time to work harden, and due to the huge variety of shapes it comes in, you can typically get something close enough to your desired finished project that you never reach a point where it needs annealing. We do, however, anneal our 304/316 Damascus that has been twisted and otherwise manipulated to create patterns to relieve residual stresses the patterning process can impart to the material prior to machining.

Figure 10: Machined Part That Was Not Annealed (note curve and thicker ends)

Figure 11: Closer View of End of Figure 10

If material requires annealing, it is accomplished with a high temperature kiln or a dual fuel torch. We prefer propane or natural gas with oxygen if using a torch, but typically use a kiln for annealing and stress relief. Acetylene and oxygen torches, although capable of high heat, are a dirtier option. Stainless steel, like most metals, is best served with clean working techniques and the shorter heating times.

Figure 12: Smith Oxygen/Propane Little Torch and Tips

To anneal 304 or 316, heat the material to over 1900°F (1037°C). If you are using a torch, and accustomed to working with more traditional jewelry alloys, this is slightly higher than typical platinum annealing temperatures. Then, quench in water. For very thick cross sections, hold the temperature for one minute per mm of thickness. This process will create an oxide layer on the piece, and cause discoloration. If you have to anneal, and end up with heat staining or oxides, they can easily be removed by mechanical means. Heat staining (colors ranging from blues to purples, to greens and yellows) can be removed with a stainless-steel brush. For thicker black oxides, our typical removal method is grinding using coarse abrasives. Additionally, there are various gels and liquids that will act as a pickle for stainless steel. They can be helpful if you've welded the steels, as even with a cover gas you can get some discoloration. Derustit.com has a variety of gels and liquids that work very well. You need to be use caution and follow all ventilation and personal protection warnings- these products rely on the active ingredients calcium nitrate, nitric acid, hydrofluoric acid and ammonium biflouride. So, be careful!

Muriatic acid can also remove oxides, but will attack the 304 stainless steel as well. More on that to come.

3-series stainless steels lend themselves readily to brazing but have a few special requirements. We use a Smith Little Torch with propane and oxygen and a high temperature flux, with a specific silver solder with 63%Ag/28.5%Cu/6%Sn/2.5%Ni or gold solders. You'll notice that the solder does contain 2.5% nickel- this is critical to prevent crevice corrosion failure of the brazed joint, especially for rings or other items that will see contact with sweat. Solders containing either cadmium or zinc can result in corrosion to the stainless steel due the formation of phases that can result in some preferential corrosion, so should be avoided. Another option that removes nickel from the equation is to simply use gold solders. We particularly like the solders from Hoover and Strong. My personal favorites for soldering stainless to yellow gold are the 18K royal yellow hard solder and the 18K yellow medium wire solder. For white gold and platinum or palladium, we use 14K palladium white gold hard solder from Hoover.

Like all brazing, starting with cleaned parts is a big part of the process and will help ensure success.

Keep in mind that stainless steel is a poor conductor of heat as compared to precious metals, so using a slightly larger flame than you would for gold soldering is very helpful when soldering precious to stainless. This also helps things happen more quickly so you are less likely to have issues with oxides.

Black flux is critical; it lasts longer and works better at high temperatures. It does require proper ventilation since it does contain potassium fluorides. As you might guess, the flux is black at room temperature, but turns clear at just about braze temperature, so it's a handy indicator of when to apply your solder. Once the joint has been soldered, and the piece has cooled, we rinse off excess flux before using an ultrasonic with diluted Citranox to remove the remaining flux. After a few minutes in the ultrasonic there may still be a bit of flux here and there on the surface, but it is pretty easy to flake off. You may also use mechanical means to remove the residual flux while also removing any heat staining/oxides caused while soldering.

Figure 13: Black Flux

You can also use citric acid pickle, but we have noted that you can have a reaction and end up with copper plating on your parts. Interestingly, it doesn't always happen, and we are not sure why. I suspect it has to do with free iron (see passivation below), but since it has the potential make a huge mess, we tend to avoid it, especially with pieces that have lots of detail.

Welding Stainless Steel

3-series stainless steels weld beautifully. Laser welding is accomplished at low power even in open air, and superior results are achieved when using argon as a cover gas. Tungsten inert gas welding (such as the Orion and PUK systems) also works extremely well.

When laser welding, we typically make two passes, one at a higher power with filler wire to join the steel followed by a lower power/larger spot size pass with no filler to blend the weld and make it less visible. You can weld stainless to precious metals, but this can be a bit difficult as the stainless steel uses a much lower power than most precious metals, so the weld seam can look wide.

Finishing Stainless Steel
The good news about stainless steel finishing is that if you have been finishing platinum, you probably have the skills and most, if not all, of the tools to finish stainless steel well.

The best abrasives for stainless steel tend to be ceramic or zirconia based, but aluminum oxide also works well and is easy to find. I personally really like the the 3M diamond abrasives as well. The key is the harder and more regular the abrasive particle, the better the performance. And once again, lubrication is key; we use the same Boelube stick referenced earlier. In fact, lubricating your rotary abrasives with Boelube or Bur Life has advantages for all grinding operations, not just cutting with burs. Abrasives last longer and run cooler, and it also has the advantage of trapping dust which leads to better refining returns, especially in the case of working precious metals.

There are no shortcuts to bench finishing stainless steel. After filing and grinding with coarse wheels (such as 3M EXL, Mizzy wheels, and carbide burs), we start with 240 grit abrasives for our final shaping steps and our first finishing step. From here, for finishing at the bench, we continue to use lubricated abrasives in this order:

- 400
- 600
- 800
- 1000
- 1200
- 1500
- 2000

We take care to change direction of abrasive cuts to help create a uniform finish. For pre-polishing, we like a hard felt charged with White Diamond compound. For final polishing we use a hard felt charged with blue rouge and follow that up with a soft “ballon buff” naked or very lightly charged with blue rouge. These steps create a mirror finish.

If our goal is matte/brushed finish, we follow these steps to the 1000 grit abrasive, and then use a red 3M (220 grit) radial bristle disc to apply an even matte finish. It sounds counterintuitive to work your material to 1000 grit before using a 220-grit wheel to matte finish, but trust me, this is the only way to get an even and good matte finish - you have to remove deeper abrasive marks and then work back to the matte finish. You can also hand apply the finish with 3M woven abrasive pads- we like the 7447 Scotch-Brite general purpose pad (brownish-red).

Mass finishing is also an option, and we like this option for some of our larger pieces- we use an Avalon TE-18. We finish pieces to 240 grit, then use the Avalon set at 40 revolutions per minute, with a 50% solution rate with a clean cut plastic cone media medium cut, and a non-chelating deburring compound. We tumble for nine hours and then move on to polishing with White Diamond and blue rouge.

Other Surface Finishes

There are other finishes that you can use on stainless steel. You can plate it, or deliberately oxidize it for a dark coating. We have also used heat cured Cerakote and UV cured epoxies to fill the low spots after etching our Damascus steel.

Oxidizing is quite simple. We use a torch or gas forge to heat the material to approximately 1900°F and hold for sixty seconds. This forms a hard black oxide coating (quite hard- removal requires 240 grit abrasives) that is quite durable.

Notes about Stainless Steel Damascus

As mentioned, when using stainless, we are typically working with our laminations of 304 and 316 stainless steel patterned materials. 304 and 316 are superior for use in jewelry and decorative applications due to the extremely high corrosion resistance but are useless for making knife blades of any quality that need to hold an edge. You can certainly find stainless steel Damascus out there designed for knife making, and it’s great stuff, but it is much more prone to corrosion due to its composition, even when properly heat treated. We don’t use this material to make rings typically, unless the heat treatment is a useful attribute (for example, for tension set rings). The main difference between these steels is that the 304 and 316 are austenitic stainless steel, while the heat treatable knife blade materials are martensitic steel.

Austenitic stainless has exceptional corrosion resistance and mechanical properties. Martensitic stainless alloys have more chromium and ordinarily no nickel in them. The key difference between austenitic and martensitic stainless steels are that the crystal structure of austenitic stainless steel is face-centred cubic structure whereas the crystal structure of martensitic stainless steel is body-centred cubic structure. This allows for the heat treatment of the martensitic alloys. An easy way to tell the material part is with a magnet- martensitic stainless steel is highly magnetic, while austenitic stainless exhibits very little to no magnetism.

Austenitic vs Martensitic Stainless Steel

More Information Online WWW.DIFFERENCEBETWEEN.COM

	Austenitic Stainless Steel	Martensitic Stainless Steel
DEFINITION	Austenitic stainless steel is a form of stainless steel alloy which has exceptional corrosion resistance and impressive mechanical properties	Martensitic stainless steels is an alloy which has more chromium and ordinarily no nickel in it
COMPOSITION	Iron, chromium, nickel and carbon are major constituents	Iron, chromium and carbon
NICKEL	Contains about 8 to 10% nickel	Contains no nickel
MAGNETIC PROPERTIES	Diamagnetic	Ferromagnetic
APPLICATIONS AT HIGH TEMPERATURES	Can use in lower and higher temperature as well	Cannot use at elevated temperatures
CRYSTAL STRUCTURE	Face-centred	Body-centred
CORROSION RESISTANCE	Exceptional corrosion resistance	Less corrosion resistance

Chart 1: This handy chart from differencebetween.com sums up the differences nicely

Unless you etch 304/316 Damascus after finishing, the pattern will not be visible. The slightly higher corrosion resistance of the 316 works in our favor here, since when etching stainless Damascus, the 304 is the only material attacked by the etchant. We etch Damascus stainless steel in muriatic (hydrochloric) acid, in an acid fume hood. We heat the muriatic acid to approximately 160°F (71°C) on a heated magnetic stir plate in a pyrex beaker. Heating the acid leads to fast etching times (under ten minutes), so be vigilant! It also yields a much more "crisp" definition between the pattern lines. Using the muriatic unheated can take hours and the pattern edges look "feathery".

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Passivating Stainless

Passivation is the final step and is necessary for the best possible product. Welding, brazing, grinding and other forms of manipulating stainless steel necessitate passivating of the item.

American Society for Testing and Materials (ASTM) A967 and Society of Automotive Engineers AMS 2700 are the most widely used standards for passivating stainless steel. According to ASTM A967 the definition of passivation is "the chemical treatment of stainless steel with a mild oxidant, such as a nitric acid solution, for the purpose of the removal of free iron or other foreign matter." ASTM A380 further states "removal of exogenous iron or iron compounds from the surface of a stainless steel by means of a chemical dissolution, most typically by a treatment with an acid solution that will remove the surface contamination but will not significantly affect the stainless steel itself … for the purpose of enhancing the spontaneous formation of the protective passive film." This free iron is what can lead to spots of rust appearing on the surface of 304/316 steels.

In the mid 1800's Christian Friedrich Schönbein discovered the effect of passivation. He found that iron dipped in nitric acid had little to no chemical reactivity compared to undipped iron. His name for the lack of reactivity was the "passive" condition. In the 1900's, as passivation practices became widespread, so did the knowledge of the dangerous environmental and safety issues of the use of nitric acid for this process. Research done by Adolf Coors Brewing Company in Germany identified citric acid as a much safer, effective alternative.

The purpose of passivation is to remove free irons and other contaminants. The acid bath leaves a clean, uniform surface which allows the chromium to react with oxygen forming the chromium oxide layer that gives stainless steel its non-reactive surface.

We use citric acid in the form of Citranox, made by Alconox in dedicated ultrasonic cleaner. We heat a 30% solution to 130°F (54°C) and allow the part to soak for 10 minutes.

CONCLUSION

In conclusion, I hope you have found these tips to be helpful and inspiring. Unlike most papers I have written, there are no conclusions to this one, other than to say, Happy Creating!

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