

How to Spray Silver a Telescope Mirror

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In 1857, Karl August von Steinheil and Léon Foucault (yes, *that* Léon Foucault) developed the process to deposit an optical quality silver coating on glass telescope mirrors. Although effective, it was a rather noxious process where the surface of the mirror was bathed in the silvering chemicals.

In the 1930's William Peacock developed the process of spraying the silvering chemicals on glass where they were combined in a fine spray from two nozzles, which greatly simplified the silvering procedure.

This is about the same time that John Strong developed the method of depositing aluminum on glass in a vacuum chamber. Aluminum doesn't tarnish like silver and Strong's process quickly became the best choice for a durable telescope mirror coating. Silvering fell to the side.



A freshly silvered 28-inch mirror, June 2019

Several forces have come together recently to make spray silver coatings an attractive option for telescope mirrors again, especially those 12-inches and larger in diameter:

- The cost of aluminizing has gone up, and for a large homemade telescope it can be the single most expensive element, especially if the coating is enhanced.
- The spray silver technique creates a coating with very high initial reflectivity.
- Spray silvering techniques developed at Tinsley Labs and the University of Arizona in the 1970's clarified the process of how to achieve a great spray silver coating.
- In 2019, members of the informal Oregon Scope Werks group tested a chemically deposited protective overcoat that looks like it will greatly slow tarnishing of a silver coating. See step 6 for an update.

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Jerry Oltion gave an overview of our progress in his January 2020 *Astronomer's Workbench* column, and here we'll go through the entire process step by step. A few points up front though:

- You don't need to be a trained chemist to successfully spray silver a mirror. We certainly aren't.
- You do need to be methodical and well prepared for each step.
- There are no shortcuts to get a great coating, so carefully follow these instructions.
- You can create an excellent coating in an afternoon.
- If you mess up, it's easy and inexpensive to start over.

Although we present a detailed account of how to spray silver a mirror, we don't pretend to know everything about the process yet. By sharing what we've learned since we began spray silvering in July 2018 it's our hope that others will give it a go, and their efforts will lead to an even more robust process.

Equipment



There are two ways to go with spray silver equipment - purchase it all from Angel Gilding (<https://angelgilding.com/pump-spray-silver-kit.html>) or piece together your own kit. The Angle Gilding spray silver kit has everything you need, including the chemicals. You can purchase just the chemicals from Angel Gilding and make your own sprayers – or use hand pump spray bottles. Although less expensive, hand pump spray bottles require tireless hands because you'll be squeezing the spray bottles a lot during the process. The result can be quite excellent though.

This link takes you to a series of short videos showing how this method works:

<https://www.youtube.com/playlist?list=PLGgnKBRPmU3V5oP-QHGNoE31tmPGUebYg>

The authors have successfully spray silvered a 28-inch mirror using the Angel Gilding kit and 24-inch and 20-inch mirrors using hand spray bottles. Our experience shows that Angel Gilding's kit is easier to use and gives more consistent results. For what its worth, we have no incentive to promote Angel Gilding other than we've used their products and like how they work.

Whether you get the Angel Gilding kit or not, we suggest you also buy a one-gallon yard sprayer – the type used for spraying insecticide on plants. You'll use it to spray distilled water for rinsing. There's a lot of rinsing during the spray silvering process and you'll be glad to have a sprayer you don't need to refill every few minutes.

Handling chemicals involves some level of risk so you will need to obtain personal protective equipment such as a respirator (if working in a closed area such as a garage), goggles and gloves. Angel Gilding provides instructions in their proper use at:

(<https://angelgilding.com/other-supplies/safety-supplies.html>).

Preparation

It's imperative that you calibrate your sprayers so you know they're spraying the same amount of silvering chemicals each time you press the trigger or squeeze the hand pumps.

Before doing anything else, put the same amount of distilled water into your spray bottles and spray them for the same amount of time.

You want to make sure the bottles empty at the same time. If not, adjust the nozzles until they spray the equally.

Now explore the links in this article to see how the entire process is done. Watch them a few times, so you get a good feel for the entire process.

Then read the detailed instructions from Angle Gilding about mixing the silvering chemicals. This involves measuring a prescribed amount of distilled water along with a relatively small amount of silvering chemicals. You'll actually mix them in Step 2.

Other items you'll need *(updated 1 May 2021)*

Ferric chloride for stripping an old aluminum coating.

Baking powder to neutralize the used ferric chloride.

A large plastic tub that's about 25% larger diameter than the mirror.

Precipitated calcium carbonate or unscented talcum powder. These are easily purchased online – you only need one, and they work equally well. Whichever you choose, they are essential part of the cleaning process.

Lots of distilled water. When everything goes well, it took about 8 gallons of distilled water for the 28-inch mirror, but double what you think you'll need because that's how this process tends to go.

A large bag of natural cotton balls from the grocery or drug store. You'll use a lot of these, so don't be cheap and buy a little bag – get the big one.

Paper towels.

Extra vinyl or nitrile gloves – make sure they don't have powder in them. You'll get some with the Angel Gilding kit, but more is better because you'll need to change gloves after every step.

Red optical rouge (optional).

Angel Guard anti-tarnish liquid (<https://angelgilding.com/angel-guard.html>)

Spraying jig



The two jigs shown here have been used to successfully spray silver several mirrors. But do you really need to make a jig to hold your mirror?

Experience says yes – the jig allows you to tilt the mirror as needed, and makes the process go more smoothly while reducing the chance

for cross contamination from rinse runoff.

The plastic tub needs to be large enough to catch rinse water that will flow off the mirror. It should also be easy to empty – small enough to easily pick up, or so large it has a hole in the bottom so the rinse can flow into a small, easy to handle bucket underneath.

You can get by without making a jig for mirrors smaller than 12-inches, but you'll still need a stand that fits inside a fairly large plastic container for the mirror to rest on.

Step 1 - Stripping the old coating



The first step is removing the old aluminum coating first. Ferric chloride is a good choice because it dissolves aluminum while leaving the glass alone. It does an excellent job but may take an overnight soak for it to completely remove the old coating.

It also dissolves an old silver coating nearly instantaneously, but the Angel Gilding kit includes a silver remover that works just as fast.

If you've never made a mirror or stripped an old coating before, this step will probably give you pause. "Telescope mirrors are delicate, precision optics and shouldn't be touched!" Mostly yes, but sometimes it's not only ok, it's the only way to proceed. Stripping the old aluminum coating is one of the times it's ok – to create a new silver coating you have to get rid of the worn-out aluminum coating first.

Before getting started, give a thought to all the great images that old coating gave you throughout its useful lifetime. This is your last chance to touch it on purpose, so let your fingertips feel the old coating that served you so well.

Now take a deep breath and let's get going.

Start by peeling off the old center donut. Use nothing harder than your finger nails – don't scratch the glass!

If there's any adhesive left on the mirror, use a little acetone or finger nail polish remover to get it off. Old adhesive may get in the way of the ferric chloride doing its job.

Before getting started be aware that ferric chloride will stain just about anything it comes in contact with except polished glass. Wear old clothes you don't mind getting stained, and handle the bottle of ferric chloride with care so you don't spill it inadvertently.

To get started, position the plastic tub under the jig and put on a pair of vinyl gloves. Place the mirror horizontally on the jig. Cover the mirror with white paper towels and then slowly pour on the ferric chloride. It will soak into the paper towels and spread throughout, while also incompletely pressing the paper towels to the surface of the old coating. Once the entire surface is soaked with ferric chloride, place clear plastic kitchen wrap on top, and press down all over to make sure the entire coating is in constant contact with the ferric chloride-soaked paper towels.

An unenhanced aluminum coating may dissolve in an hour or two, but an enhanced coating will take longer. Make it easy on yourself and do this before going to bed, so in the morning you'll wake up to a bare glass mirror.

After removing the plastic wrap and paper towels, wring out the ferric chloride from the paper towels and put in back in the container it came in – you can reuse this stuff many times. Then toss the wrung-out paper towels and plastic wrap in the plastic tub where there's probably a few dribbles of ferric chloride. Tilt the mirror to about 30 degrees and rinse thoroughly with distilled water.

Once the mirror is rinsed you may notice a few spots where the coating didn't come off. Get two or three cotton balls that are soaked with ferric chloride and with light pressure gently scrub these areas and the coating spots will come off. Rinse with distilled water again. Also, do not touch the optical surface of the glass with your bare hands – this will make cleaning the mirror more difficult.

Once the coating is 100% removed and the mirror is well rinsed, pour in a liberal amount of baking powder in the runoff in the plastic tub. This will neutralize the ferric chloride, and once the foaming stops you can safely dispose of this waste down the drain.

By the way, ferric chloride is the main reason you want to use a *plastic* tub.



Step 2 – Mixing the chemicals *(updated 1 May 2021)*

Because you'll want to move smoothly and quickly from cleaning to silvering – so the mirror stays wet - it's a good idea to mix all the silvering chemicals before starting the cleaning process. Carefully follow Angel Gildings mixing instructions. Once mixed, set the chemicals aside on a nearby work table that you don't mind getting a little stained. Or cover the table with a plastic sheet made for picnics.

Following Angel Gilding's instructions, pump up the sprayers and make sure they are at equal pressure.

Depending on the size of your mirror, you may not need to mix the full amount recommended by Angel Gilding. The temperature of your spraying area also makes a difference – the lower the temperature the more you'll need to spray.

Our experience shows you may better control the rate of silver deposition on your mirror by using less than the amount specified by Angel Gilding, but here too the temperature of your work space comes into play. If it's about 80 degrees F and above - use about half as much chemicals. If it's significantly cooler than that use the specified amounts.

Step 3 – Cleaning *(updated 1 May 2021)*

This is the most crucial element of the process.



No joke, if you don't do a perfect job cleaning the mirror you won't get a good a good silver coating. Without exaggeration, the mirror must be perfectly clean. Perfectly. Any kind of dirt, oil or residue on the glass will end up as an imperfection in the coating.

Now that your mirror is bare glass, only touch it with your gloved hands. Oils from your skin will adhere to the glass and will prolong how much cleaning you need to do. Only touch the mirror if you have vinyl gloves on both hands.

As tempting as it may be, don't try to shortcut the cleaning process. You'll only need to start over from the beginning, and that takes more time than doing a thorough job the first time. To be successful, you must be thoughtful, meticulous and patient throughout the cleaning process.

To start cleaning, tilt the mirror back to horizontal on the jig and put on a new pair of vinyl gloves. The mirror is still wet from rinsing the ferric chloride off the mirror, so sprinkle on

a tablespoon or so of the precipitated calcium carbonate, or unscented talcum powder, on the mirror. Scrunch two or three cotton balls together and work the calcium carbonate into a thin paste. You may need to spritz on a bit of distilled water to get the proper watery consistency.

Starting on the side of the mirror, scrub the glass with a small circular motion. That's right, start on the **side** of the mirror. Yes, it seems like this has nothing to do with the optical surface, but if the side isn't clean, contaminants will seep onto the optical surface and ruin the new silver coating. Be meticulous, and use about two pounds of pressure while scrubbing.

With a new set of cotton balls start scrubbing the outer edge of the optical surface with the same circular motion and pressure. You want to keep the entire surface wet during all this so depending on the humidity you may need to spritz a little more distilled water now and then. Work your way toward the center of the mirror, then repeat the process.

All this should take no more than 15 minutes.

Two pounds of pressure may sound like too much – won't it change the optical figure? No, and that's because calcium carbonate and talcum are way too soft to change the shape of the glass or to scratch it. Two pounds of pressure is plenty safe.

Tilt the mirror to approximately 30 degrees and rinse with distilled water.

As the water runs off the surface of the mirror, examine the flow from about a 5 to 10-degree angle from the side, and look for any areas where the water is creating small wakes or small spots that look dry, especially along the edge of the mirror. These areas need more cleaning.

Important tip – the angle you inspect the water runoff is critical to see the water runoff accurately. Angles more than 10 degrees will not show the runoff in enough detail.

When the water is running off so smoothly over its entire surface that you can barely tell the glass is wet, you have a mirror that's clean enough to silver. But be sure you've thoroughly inspected the water runoff and are certain there are no spots needing additional cleaning.

One more thing to look for when your mirror is clean enough to silver: the glass looks wonderfully clearer than when you started.

If you still see dry areas during the rinse, keep at it until the distilled water rinse really is a nearly invisible and completely continuous sheet. Only then is your mirror ready for silvering, and the extra effort will be worth it. Now the action speeds up – if all goes well, you'll have a beautiful silver coating on your mirror in about fifteen minutes.

Before going on to Step 4, drain the cleaning rinse water waste from the plastic tub.

Step 4 - Sensitizing

Put the mirror back to horizontal on the jig, then put on a new pair of vinyl gloves. You mixed up the sensitizer at the beginning of the process so it's ready to go. Put on the respirator and eye protection, swish the spray bottle a little to make sure the sensitizer is well mixed and spray the surface of the mirror as evenly and completely as you can. For a large mirror use the entire amount.

Now wait for about 30 seconds. Have a clock nearby so you're sure 30 seconds has passed.

Then tilt the mirror to about 30 degrees and rinse with distilled water. And keep rinsing – rinse it way more than you think you should because you want to make sure that only the sensitizer that's adhered to the glass remains.

All this will take about 5 minutes or so.



Step 5 - Spraying the silver

The moment of truth has arrived. While still wearing the respirator and eye protection, swish the silver solution and reducer bottles a little to make sure they're both well-mixed. Do a tiny test spray into the plastic tub to make sure they're spraying properly.

If you're using hand sprayers, do a quick spray test into the plastic tub as well to make sure both bottles spray equally.

With the spray nozzles about 18 inches from the surface of the mirror, spray for about five seconds, stop and watch the mirror turn splotchy grey. Spray another five seconds as the silver develops and within about ten more seconds, you'll see an incredibly bright and shiny silver coating start to appear.

On my goodness, this is actually working! Spray one or two more five second bursts to make sure the entire mirror gets an even coat, then carefully put down the sprayers and thoroughly rinse your beautiful new silver coating with distilled water. Wow!

Spraying and rinsing will take about another ten minutes.

To get an idea what the entire spray silver process looks like, see the video's at:

<https://angelgilding.com/pump-spray-kit-video>

and for using hand pump spray bottles:

<https://www.youtube.com/playlist?list=PLGgnKBRPmU3V5oP-QHGNoE31tmPGUebYg>

Step 6 - Anti-tarnish overcoat (*updated 1 May 2021*)



Tilt the mirror to horizontal again, put on a new pair of vinyl gloves, and gently shake the bottle of Angel Guard anti-tarnish liquid to mix up the residue from the bottom of the bottle. Then pour a small puddle of Angel Guard onto the mirror, about one fourth the diameter of the mirror.

Scrunch up two or three cotton balls to *gently* – with almost no pressure on the silver coating – move the Angel Guard around the entire surface of the mirror, and do this for about five minutes. You may need to add a bit more as the cotton balls absorb the liquid.

Don't scrub like in the cleaning process because the new coating is fairly fragile and all you're doing is keeping the silver coating in contact with the Angel Guard.

After five minutes, tilt the mirror to 60 degrees or so and rinse well with distilled water. You'll notice that the water will practically jump off the mirror now – Angel Guard makes the surface hydrophobic.

It forms an incredibly thin barrier. Thin enough to not be detectable in a professional interferometer, but thick enough to slow down the tarnishing process. Amazing stuff.

Please note – Angel Guard is available in one-gallon jugs as Midas Anti-Tarnish if you plan on protecting a lot of mirrors: <https://www.riogrande.com/product/midas-tarnish-shield/335037>

Rob Brown's [Life Test Results](#) article will give you an idea how well Angel Guard/Midas protects silver from tarnishing. However, experience shows that Angel Guard/Midas only slows down tarnishing. Experience has shown the silvered mirror will tarnish but more slowly than it would otherwise, and the environment it's stored in makes a big difference. The more closed off from an indoor human environment you can keep the mirror the better.

Also, bug poop, spit, dust, and pollen that settles on the mirror can create spots on the silver coating even when protected with Angel Guard.

Blowing dust off the mirror will help, and anything that doesn't come off is best left on the coating. Washing the mirror will probably remove both the contaminant and the silver below it.

When a spray silver coating starts to get spots it still has excellent overall reflectivity. You can reassure yourself by doing the ingeniously simple reflectivity test developed and described by Rob Brown in his second accompanying article, [Photographically Measured Reflectivity for Telescopes](#), and comparing the results to the numbers of your newly coated silver mirror.

That said, we know the pain of seeing your once perfect coating develop spots, so even though you may not see signs of significant tarnish, you may still want to re-spray your mirror every year or so. In the meantime, we're looking for other overcoatings that may fully protect a spray silver mirror - stay tuned.

Step 7 - Drying

Using either a hand held hair dryer - or better yet an electric air mattress pump - chase off the remaining droplets of water from the new coating. You may be surprised at how fast the larger water droplets can be chased off the now protected coating, but the smaller ones may take a few minutes to evaporate.

The coating is now complete. You'll want to show it off to everyone you can, but don't let anyone get close enough that they can blow off a random speck of dust with their breath. It's an almost irresistible reflex, and don't you do it either.

One droplet of spit on your brand-new coating will not only be maddening, it will probably dissolve the silver below it, even with the Angel Guard Anti-Tarnish overcoat.

Let the sides and back of the mirror air dry overnight before putting on a new center donut and placing the mirror back in your scope. Recollimate, and you're ready to observe with your new high-performance, tarnish-protected silver coating. Congratulations!

Step 8 - Neutralizing silvering chemical waste

Silvering chemicals must be neutralized and disposed of properly so it's a good idea to be aware of your municipal regulations ahead of time. Follow the easy to read manufacturer's instructions on the Angel Gilding website for proper neutralizing and disposal of their chemicals and physical waste:

https://angelgilding.com/media/documents/Waste_Treatment.pdf

Here's a short video explaining the whole waste treatment process:

<https://angelgilding.com/treating-mirror-waste-video>

It's as straightforward a process as it is important – these chemicals need to be properly treated before disposal. It's tempting to think of this part as optional – after all, because you drained your rinse water plastic tub after finishing the cleaning process there isn't all that much spray silvering waste to get rid of.

And who's to know if you just pour it down the sink? But don't be like that guy who gets rid of his used motor oil in the sewer, treating spray silvering waste is easy and is the right thing to do for the environment.

Plus, everything you need is included in the Angel Gilding spray silver kit. Please use it!

Troubleshooting

Maybe you've followed these instructions to the letter – or at least think you have - and the coating didn't turn out as well as you hoped. Here are a few things that might go wrong despite your best efforts:

There are blotches along the edge of the mirror where the silver didn't stick.



Insufficient cleaning is the culprit here. You didn't clean the side and / or the edge of the mirror properly, leaving enough dirt, oil or residue on the glass to prevent the coating from adhering.

It's too easy to ignore the side of the mirror because it seems so unlikely that any contaminants there could effect the optical surface of the mirror. Because silvering is a wet process all the way through, capillary action will pull oils and dirt from the side to the optical surface.

You can either live with a blotchy edge – the mirror will still produce excellent, bright images – or strip the coating and start from Step 3 again, paying extra attention to cleaning the side and optical edge of the mirror.

Again, from the side, look at the rinse water running off the mirror, paying attention to any areas along the optical edge where the water is catching or spots that look dry. These are the areas that need more attention during the cleaning process.

The coating looks even but not as shiny as it should.



For reasons that aren't yet clear, sometimes tiny silver crystals form on top of an otherwise perfect coating. Fortunately, they're easy to remove.

Put on a pair of vinyl gloves, take a fresh cotton ball, dampen it with distilled water and dab on a tiny bit of red rouge. Make sure the rouge is also damp.

Then *gently* drag the rouged cotton ball across the coating. The hazy silver crystal layer will come right off. Replace the cotton ball every few wipes because it will pick up tiny bits of silver, which will produce equally tiny scratches on the coating. Using a new cotton ball every few wipes will prevent this from happening.

An alternative to red rouge – which is infamously messy - is to use the same precipitated calcium carbonate from the cleaning process. It doesn't work quite as well though.

If you discover silver burn after you applied the Angel Guard overcoat, experience shows that the coating is mostly still there. However, it's best to treat the mirror again with Angel Guard to have maximum tarnish protection.

The coating has ugly brown stains.



There are several reasons this can happen:

- The spray nozzles for the silver solution and silver reducer were not calibrated to spray the same amount.
- One of the spray nozzles became clogged.
- The spray bottles weren't pumped up to a high enough pressure to properly mix the silvering chemicals in their combined spray.

You'll have to strip the bad coating and start the entire process over, but first make sure you calibrate the nozzles to spray the at the same rate, or clear the clog.

If the staining is limited to a small area, an alternative to starting over is to try removing the stain with a damp cotton ball dabbed with a bit of red rouge as described in the previous section.

On the other hand, stripping a silver coating takes just a few minutes. Angel Gilding includes silver remover chemicals in their kit that almost instantly dissolves silver. Ferric chloride works just as fast on silver. Then start from Step 3.

Practice



You can dive right in and silver your mirror, but if you can find an old piece of flat window glass, about the same size as your mirror, practice on it first. You'll get a much better feel for the process and the glass won't be nearly as intimidating as your telescope mirror.

Plus, it's less disappointing to fail on the practice glass. When you get it right on your practice glass, you'll have more confidence to produce a good coating on your precision optics. You can read these instructions a hundred times, but there's no substitute for getting your own experience.

The practice glass has the added benefit of providing a test bed for removing silver burn, and for cleaning a silver coating in general.

Expect to need a full afternoon for a successful coating, but if you need to redo the coating for any reason, you can come back the next day to start over. There's no reason to hurry – take your time, follow these instructions and be meticulous.

After all, perfect practice makes perfect.

References

Chemical Spray Silvering

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Applied Optics, Vol. 16, Page 2785, November 1977

Spray Silver for the Optics Shop

Mitch Ruda, Optical Sciences Center, University of Arizona
Memorandum, November 1977

Bob Schalck

Personal experience from Tinsley Labs

Using a Pump Spray Silver Kit

Angel Gilding

https://angelgilding.com/media/documents/Using_a_Pump_Spray_Silver_Kit.pdf