Mirror Silvering Process

Liam Plybon - Astronomical Society of East Texas

This standalone document outlines the mirror silvering process I currently use as of 5-5-24, as outlined in the 2023 lab journal, modified for public use. Minor alterations have been made in my experiments, which will be outlined in a bottom section over time. To date, I've successfully silvered 5 mirrors ranging from 5" to 16" with this process.

Cost per silvering operation is ~$17.50, and takes about 4 hours once you have gained some experience. Mirrors of any size can be silvered with this method cheaply and safely.

The following materials are required.

- Ammonium Hydroxide (25%-28% Concentration, Lab Grade) ☠
- Distilled Water (bulk quantity)
- Glucose (Lab Grade)
- Sodium Hydroxide (Lab Grade) ☠
- Silver Nitrate (Lab Grade) ☠
- Muriatic Acid (Cleaning Grade) ☠
- Calcium Carbonate Powder (Lab Grade)
- Cotton Balls
- Fume Hood or Well Ventilated Room+Ammonia Cartridge Respirator
- Gloves
- Scale (0.1 g precision or better)
- Weigh Boats
- 2 Plastic Cleaning Product Spray Bottles with Adjustable Nozzles
- 2 150 mL Beakers
- 400 mL Beaker
- Dropper or Pipette
- Large, Shallow Plastic Bin/Tub (cleaning)
- Large Plastic Basin/Tub (silvering)
- Angled stand for mirror (can be made with wood or plastic)

Red indicates chemicals available on Amazon. ☠ indicates a hazardous chemical.

==Safety==

All work with the concentrated ammonia or silver solution should be done in a fume hood or well ventilated area, ideally with a respirator mask to protect the lungs. **Respirator with ammonia cartridges is REQUIRED if done outside of a fume hood.** Concentrated ammonia will burn the lungs and airways, and the mist of silver spray will offgas much faster than you will expect.

Wear gloves while handling silver nitrate, muriatic acid, ammonia, sodium hydroxide, or silver solution. Silver salts can stain skin easily, although the stains can be removed from skin by copiously scrubbing with steel wool. Ammonia can irritate skin. Sodium Hydroxide, better known as Lye, will turn your skin into soap. Muriatic Acid will burn skin and eye tissue, and damage lungs if inhaled. In case of skin contact with any of these chemicals, run hands under flowing water. In case of eye contact, wash eyes for ~10 minutes and get medical attention. **Don't take the risk lightly, and wear gloves/eye protection during this process.**

If allowed to sit for a long period of time, silver nitrate and ammonia will react to form silver nitride, a contact explosive. Reducing temperature can extend the shelf life of the silver spray, but the waste products formed should never be allowed to sit more than half an hour. Treat all containers, spray bottles, and waste containers that contain unneutralized silver solution as potentially explosive- use only plastic containers, and wear gloves + long sleeves. Do not use glass with potential explosives, as glass creates shrapnel. *I have personally experienced explosions from silver nitride after an extremely concentrated waste product was left to sit for ~1.5h. Silver nitride will appear as a shiny, gray, beautiful crystal film on the waste product. Should this happen, understand that you have created an explosive and are in a very dangerous situation. Under no circumstances attempt to move the crusted solution, as vibration can detonate it. Your best bet is likely to safely detonate the silver nitride in place- the way I resolved my situation.* **Untreated waste product is not sink safe, as silver nitride may detonate in pipes. Make sure that all silver waste is properly neutralized!**

==Waste Handling==

All silver waste should immediately go into a container of dilute HCl. Prepare this solution by adding approx. 50 ml muriatic acid to 150 ml

distilled water. This prevents the formation of silver nitride, an explosive. Silver compounds instantly react with the acid to form a white precipitate of silver chloride, which can be easily gravity-separated and set aside. The white powder can be rinsed with distilled water to remove any leftover acid/base/glucose. The silver chloride will slowly decompose into elemental silver and harmless amounts of chlorine gas over several weeks in the presence of sunlight. Keeping the solution suspended will make this process easier. The silver powder can then be melted to recover the metal. I've successfully recovered some silver this way, although it is more trouble than it is worth, financially speaking, without silvering hundreds of mirrors.

==Solution Preparation==
For an 8" or 12" mirror, the following solution should be sufficient. For a 16" mirror, 3x the solution should be sufficient. Solutions should be prepared only when a mirror is already stripped, and you are ready to apply the silver same-day.

Before preparing the solutions, calibrate the spray bottles to make sure they spray the same amount of fluid per spray. Aim to get as fine of a mist as possible. Mark the spray nozzles with a sharpie to make sure you can quickly return to the calibrated nozzle state without spraying.

Solution 1 = 1.6g $AgNO_3$ + 150 mL H_2O

Solution 2 = 2.5g NaOH + 150 mL H_2O

Solution 3 = 16.0g Glucose + 300 mL H_2O

Solution 3 goes straight into a spray bottle marked 'Reducer', and is set aside. Reducer spray is shelf stable; I keep the reducer spray in the fridge with the silver spray.

In a fume hood or while wearing an ammonia cartridge respirator, 100 mL of Solution 1 is poured into a 400 mL beaker. Add ammonia dropwise. The drops will create a short-lived brown precipitate. Continue adding ammonia until it seems like the brown precipitate persists, but disappears when the flask is swirled. No more than 10 mL of ammonia should be needed- if you pass this volume, order fresh

ammonia and retry. If the beaker goes dark brown and doesn't clear up, you have added too much ammonia and need to retry.

The entire beaker of Solution 2 is then added to the large beaker. Next, the rest of Solution 1 is added. The best results occur when it looks like a brown jet as you pour in the rest of Solution 1. Finally, pour the large beaker contents into a spray bottle marked 'Silver'. The silver solution can be kept for 1 day in the fridge, but the silver solution must be neutralized and disposed of if not used by that time period. Over time, the solution in the bottle will start turning hazy and brown. If the bottle begins looking opaque and cloudy, neutralize the contents. *If gray crystals form in the solution, you have created an explosive. Don't touch the bottle unless you want it to detonate.*

Close the nozzles on the spray bottles before storage. The ammonia in the silver solution has a high enough vapor pressure to push the solution out of the bottle if not closed.

==Mirror Preparation==

If the mirror is already coated, strip with Green River solution in a closed plastic bin. This can be cheaply prepared with hardware store muriatic acid and copper sulfate (root killer). Stripping a silver coat takes a minute, stripping an aluminum coat takes an hour, and stripping an enhanced aluminum coat can take a week. Don't be afraid to soak the mirror in green river solution for as long as it takes- weeks if needed for particularly abused mirrors.

While wearing gloves, wash the mirror with copious tap water in a shallow plastic tub. Add dish soap if the mirror has been particularly abused. Rub gently with cotton balls and Calcium Carbonate powder until water adheres perfectly to the surface in a sheet. Then, wash off the Calcium Carbonate with tap water. Repeat at least once. Finally, wash the tap water off with distilled water. The mirror must be perfectly clean. Expect to use one gallon of distilled water and one large bag of cotton balls per 8" mirror. Pay particular

attention to the edges of the mirror. Chalk residues and oils will crawl back up the side of the mirror and onto the face.

If it is your first time silvering mirrors, I suggest doing a trial run with microscope slides before attempting a larger mirror. This gives you an idea of what you are doing, and helps you check if the process is working properly.

==Silvering Process==

This should only be done in a well ventilated area or inside of a fume hood. Concentrated ammonia burns the lungs if inhaled. Make sure that from this point, all waste products are captured and neutralized.

Drill a small hole into one end of the bottom of a large, deep plastic tub. Plug the hole with a plastic pipette. This will allow you to capture waste that falls off of the mirror into a secondary container for waste processing without spilling. Pressing the pipette into the hole firmly stops flow, while loosening the pipette allows waste to drip down from the pipette tip into a waste container of your choice. Empty distilled water jugs from the cleaning process work well for this. Angle the tub to a ~5 degree incline with the stoppered end downhill, so that runoff can immediately go into a waste container.

To apply silver, angle the mirror in the plastic tub at about 15-30 degrees so that solution can fall off into the tub. Using a mirror bracket makes this easy, but I have also done it with a 3d printer spool. Wet the entire mirror surface, front, sides, and back, with distilled water. Switch the waste container to one with ~50 mL muriatic acid and 150 mL of distilled water for neutralizing the silver. Then, use both spray bottles on the pre-calibrated mist setting, cover the surface in equal amounts of both solutions at the same time. Bottles should be held ~25 cm from the surface of the mirror, so that particles can mix in the air. Then, every three seconds, make a few sprays in a circular motion around the mirror

with both bottles at the same time. Go slowly, and a silver layer will begin to form. It may take up to 15 minutes to completely silver the surface. When both bottles are empty, wait two minutes and rinse the leftover solution off with some distilled water from a spray bottle. Make sure all of the waste goes into the neutralizing container.

Inspect the finished mirror by looking through the bottom of the mirror at a ceiling light or flashlight. If you can see the light through the mirror, then the coating needs to be thickened further. Immediately cover the mirror to prevent dust from settling on the mirror surface, and prepare a second batch of solution. A second coat can then be applied to the mirror. To start a second coat, start by spraying the whole mirror with reducer solution, then follow the exact same process as before. Spraying with the silver spray first will pierce holes in your first layer of silver.

==Troubleshooting==

If holes in the silver start to form, double the reducer sprays or use more glucose in the reducer mix.

The mirror will look yellowish at first while the water evaporates. This is normal, and will go away when the water dries.

If the edges of the mirror look rough or poorly coated, you likely had contaminants creep over the edge of the mirror during silvering. Review your cleaning process, and try again.

Poor coats can be stripped and recoated. This almost always results in a superior coat, particularly on abused mirrors.

==Experiments to be attempted==

There are a number of things I would like to test with this process, that I simply havn’t had the time to do.

Mirror protection with Midas or Angel Guard. I feel like this would be a great thing to use, although there may be alternatives yet discovered as well.
Slow coatings are reported to work better than fast ones. Refrigerating the mirror may slow down the reaction and result in a better mirror. In addition, the cold surface may form dew, which would improve wetness and prevent dry spots.

Orthogonal array testing of the chemical components may improve coats going forward. Ammonia, sodium hydroxide, and dextrose should all be varied. People online suggest using a stannous chloride sensitizer. I have not tried this yet, although it may improve coat durability.