



Overview

NanoLab was awarded a Small Business Innovative Research (SBIR) grant in November 2011 by NASA to study nanostructured optical black materials for glare suppression on their equipment, which eventually led to the development of the original Singularity™ Black paint formulation. The Singularity™ Black utilizes the strong light absorbing characteristics of carbon nanotubes that are dispersed in the paint to form a coating that is extremely effective at trapping light in the broadband. The paint formulation was named "Singularity™ Black" as a reference to the center of a black hole, where even light cannot escape from.



Singularity™ Black is suitable for application to materials that are tolerant to the paint solvent and the thermal treatment temperature necessary to drive off the binder inherent in the coating: glass, metals, ceramics, and certain thermally stable plastics & composites. It is not recommended for polypropylene, PTFE, and other low friction substrates.

Safety Protocol and Suggested Protective Gear

The solvent used for the Singularity™ Black paint is tetrahydrofuran or THF. This is a relatively non-toxic solvent, but requires proper safety precautions:

- Handle the paint with gloves to prevent it dissolving into the skin. THF will dissolve latex, so use nitrile or neoprene rubber gloves
- Exposure to THF fumes causes irritation to the eyes, so use eye protection such as safety goggles.

The following safety protocol is recommended when spray-coating the Singularity Black to limit exposure to aerosolized carbon nanotubes and solvent fumes:

- A spray-booth, fume hood, or well ventilated atmosphere is also recommended to host the spray-coating. If this environment is unavailable, the use of a mask that can also ventilate organic solvents is required.
- A respirator with a P95 cartridge that can filter out particles dispersed in the air during spray-coating is recommended. More information on selecting respirators can be found at <https://blogs.cdc.gov/niosh-science-blog/2011/12/07/resp-nano/>.
- Keep in mind that an airbrush may discharge the paint onto a larger area than what you are spray-coating, so a spray-booth that can withstand THF is recommended to encapsulate any extraneous paint.

Directions for Use

Masking

Precise patterns with sharp edges can be formed using the Singularity Black paint through the application of masking materials on the substrate surface prior to coating. We recommend the use ScotchBlue Brand painters tape as a mask because of it does not leave behind adhesive residue after coating the Singularity Black. Vinyl masking materials have also been demonstrated to withstand careful spray-coating procedures.



Mixing

The coating is a single system, which can be diluted with tetrahydrofuran, but this is not recommended. The paint should be mixed thoroughly (a paint shaker, sonication or 2-3 minute manual stirring is recommended) just before coating.

Spray-coating

The Singularity™ Black paint is compatible with many spray guns & air brushes. For spraying relatively small volumes of paint, we recommend the Badger Model 150, with a medium tip and an operating pressure of 35psi. This reservoir holds 2oz (60ml) of the coating. For larger parts, we recommend the Devilbiss Compact MINI HVLP Touch-Up Spray Gun. This gun operates well at 10 psi, and has a 9oz (265ml) cup. Follow included instructions for these sprayers.



Badger Model 150



Devilbiss Compact MINI HVLP Touch-Up Gun

Spray-coating technique tips:

- Lay the substrate flat and steadily scan the spray gun to apply an even coating, about 8-10in from the substrate. Multiple coats are applied, with typically 3-5 seconds between passes to allow the solvent to dry between layers. Each coating should scan over the edges of the intended area to prevent any edge defects. At no point should the coating look wet or congealed.
- Apply about 1mL per cm² of the coating area, or until each pass doesn't appreciably change the color of the wet coating.
- Dry the coating at warm temperatures between 80-100°C for 20-30min or in air for 1-2 hours to fully evaporate the solvent and settle the wet coating prior to any mask removal or thermal post-treatment.

Brush-coating

The Singularity™ Black paint can be applied with brushes and applicators that tolerate the paint solvent; however, a synthetic sable brush with a flat brush head is recommended, which can be found at an art supply shop. Organic solvents such as mineral spirits are capable of cleaning any brush head used for applying the Singularity™ Black paint. The application thickness can vary due to differences in technique and brushes, and so the recommended technique can achieve slightly varying results.



Brush-coating technique tips:

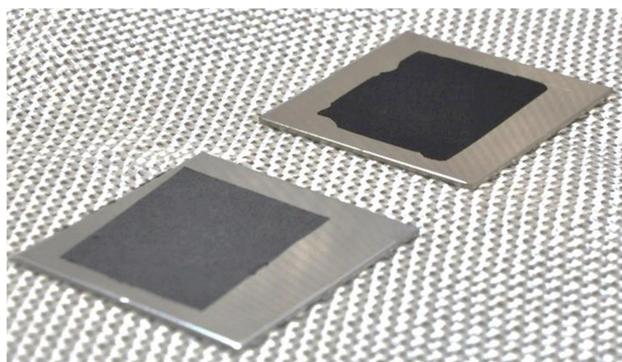
- Lay the substrate flat and steadily brush an even thin layer across the surface. Applying thick volumes of paint with each brush stroke will trap bubbles in the dried coating, which will form defects after the thermal treatment.
- Allow adequate solvent drying between each coating layer, usually 3-5 seconds.

- Apply about 10-15 uniform thin coating layers onto substrate surface in order to achieve maximum light trapping efficiency.

Post-treatment

After spraying, the coating must be dried in warm air for 1-2 hours to allow the solvent to evaporate from the coating. All masking materials must be removed after the coating is dried prior to the thermal treatment. The dried coating is a hardened plastic, which can be cut with a razor and peeled off the substrate around the mask edge or directly on the coating in desired patterns.

The thermal treatment can be conducted in a variety of ways. The critical goal is to heat the coating to the necessary temperature to burn-off the binder. The binder can be removed in air using an oven, furnace, or kiln at a temperature of 300°C, which subsequently yields the supremely black coating. The heating rate affects the porosity of the CNT network yielded after the binder is removed, and thus rapid insertion into an environment pre-heated to the required temperature is most effective. Heating & cooling rates of approximately 360°C/hour are recommended.



(below left) dried Singularity™ Black coating before thermal treatment, (above right) thermally treated Singularity™ Black coating

A direct heat source, such as a torch or heat gun, can also be employed to remove the binder from the coating; however, concentrated heat sources applied to large coatings removed the binder non-uniformly and can sometimes leave pinholes or defects in the coating.

After the thermal treatment, the coating should be tolerant to 450°C in air, above which the carbon nanotube constituents begin to oxidize. Much higher temperatures can be achieved in inert atmospheres.

Packaging:

The Singularity™ Black is packaged in lined steel cans or in polypropylene canisters depending on the volume. Additional package sizes are available on request. Samples are supplied in 20mL glass vials.



Handling

Although the cured coating is adhered to the substrate during rigorous vibrations, it is not highly scratch resistant, and thus careful handling is recommended. Avoid directly rubbing, scratching, or excessive handling to prevent damage to the film. Damaged coatings can be recoated if needed by repeating the coating/curing procedures on the affected area. If you are interested in a more abrasion resistant surface for easier handling, please contact sales@nano-lab.com to hear more about our adhesive primer coating currently available as part of NanoLab's coating services.