

Introduction

Under contract to NASA, NanoLab developed a number of coating processes for the production of very high absorbance optical blacks for stray light suppression. NanoLab offers three products to meet the needs of optical engineers: adVANTA, Singularity, and Singularity LT. NanoLab offers both coating services and the paint itself for those interested in applying the coating in their own facilities.

Singularity™ Black, Overview

Singularity is a carbon nanotube filled, solvent based paint that has exceptionally strong absorption in the visible, and is similar in performance to the vertically aligned arrays of nanotubes that are the blackest items known to mankind. Singularity has world class performance in the visible, NIR and IR (approaching 1% reflectance from 400nm to 3 microns), exceeding the optical properties of other commercially available products like Acktar's metal velvet and Martin Black. Singularity's grazing angle performance is unmatched. Special formulations are available for use as beam dump coatings, black body sources, etc.



Singularity™ Black, Application

The paint is solvent based, and requires application in a spray booth or fume hood, or with protective solvent vapor/particulate masks suited to the task. Brushing or air brush spraying are the recommended application techniques, but parts can also be dipped. Substrates and spray guns should be resistant to chemical attack from solvents such as MEK and THF. We find that a Badger 150 airbrush is well suited for small scale coating jobs. Coverage at $\sim 10\text{ml/in}^2$ results in a thick coating that performs well in the IR and visible. Thinner coats may perform well in the visible. After spray application, a heating step is required to activate the coating. Once activated, it is a 'no-touch' surface. We offer a toughened version on request that can be gently handled.

The heating step for original Singularity Black includes a ramp up to 300°C in air or in vacuum or inert gas, to decompose the low residue, environmentally friendly binder, which converts to CO_2 & H_2O . While fragile, singularity coatings can be field repaired with a brush and heat gun.





Singularity™ Black, Properties

Cleanliness

The coatings are cleanable using gaseous nitrogen at low to medium pressure (5 to 50 psi). The process removes stray fibers and dust, but not the coating. Once cleaned, the coatings were measured with a Clemex particle counter.

Typical optical instruments have a requirement of Level 400 per Institute of Environmental Sciences and Technology (IEST) STD-CC1246E.

Assemblies with slits or pinholes require Level 200. Painted hardware typically has a particle levels higher than 500. The IEST equivalent for the Singularity sample was 127.

Total Particles	266	Total Area Counted				2.813E+09
Background Particles	0	(μm^2)				1.848E+04
		Area of Particles (μm^2)				6.571E-04
		Percent Area Covered (PAC)				0.000E+00
Particles Analyzed (total - background)	266	Background PAC				6.571E-04
		PAC (total - background)				
Particles Analyzed (total - background) per 0.1m²	9457	PAC rate				
		Equivalent IEST Level*				127

Particle Size μm	ALLOWABLE PARTICLES per 0.1m ² BY IEST CONTAMINATION LEVEL					Number of Others per 0.1m ²	Number of Fibers per 0.1m ²	Total Particles per 0.1m ²
	100	200	300	400	500			
>25	78.4	1230	7450	28800	86300	284	36	320
>50	10.7	169	1020	3950	11800	142	36	178
>100	1	15.8	95	367	1090	36	36	71
>200		1	6	23.3	69.6	0	36	36
>300			1	3.9	11.6	0	0	0
>400				1	3	0	0	0
>500					1	0	0	0

Outgassing

One sample was vacuum baked for 24 hours at 100°C and the outgassing rate was measured using a Thermal Quartz Crystal Microbalance. The final outgassing rate was 3.95e-15 g/cm²-sec. This rate is considered very low and is typical of metal hardware.

Thermal Data

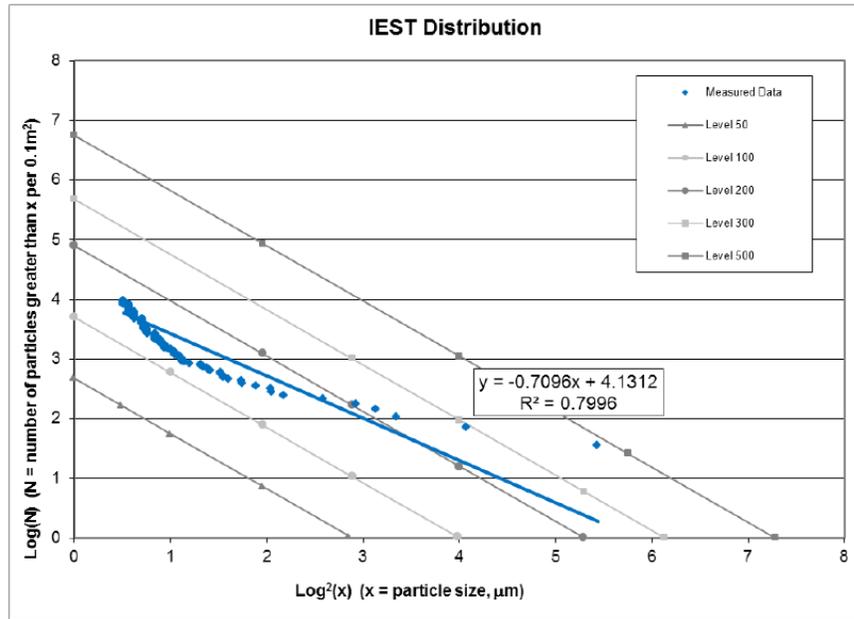
Samples were thermal cycled three times between -60°C and 85°C at a ramp rate of 10°C/minute, with 30

minute dwells at the extremes, in a nitrogen atmosphere. No damage or loss of particulate was noted. Also, thermal vacuum conditions, <1e⁻⁶ torr at 100°C, did not affect the coating. Safe upper operational limits for the coating is 450°C in air, 1200°C in vacuum, and safe lower operational limits for the coating are -200°C in vacuum.

The autogenous autoignition temperature for the coating is 600°C in air. Combustion products may include CO, CO₂.

Other

Odor-none, Immersion tests: No Visible Reaction to immersion 2hrs in 25C water, or ethanol.





Singularity Black Technical Data Sheet



Vibration

The Singularity coated panels successfully passed vibration testing. The GEVS vibration level is a low level input of 14.1 Grms that comes from a widely accepted government document called "General Environmental and Verification Specification for STS and ELV Payloads, Subsystems and Components", GEVS-SE, June 1996, Table 2.4-4. The BPL test is from a Ball Aerospace Structural Guideline and the vibs levels (also called Power Spectral Density or PSD) are fairly high to account for design cases where responses cannot be predicted. It includes a combination of vibs levels that account for acoustic vibration, random vibration, and quasi-static loading. This level is higher than most flight applications. No visible particles were removed during these tests. Some particles were generated by the vibration testing, and characterized using the Clemex particle analyzer.

Vibe Level	GEVS				BPL			
Test Order	1	2	3	4	5	6	7	8
Sample	129-6	140-5	129-6	140-5	129-6	140-5	129-6	140-5
Axis	X	X	Z	Z	Z	Z	X	X
PC Test	15-0705	15-0708	15-0706	15-0707	15-0704	15-0703	15-0701	15-0702
micrometers	Particles per 0.1 m2							
>25	1201	426	543	659	504	465	1783	1473
>50	271	155	155	116	116	155	426	426
>100	0	116	0	78	0	116	310	194
>250	0	39	0	78	0	78	78	78
>500	0	0	0	78	0	78	78	39
Percent Area Covered (PAC)	2.86E-03	4.19E-03	1.19E-03	1.36E-02	1.19E-03	1.46E-02	2.53E-02	1.83E-02
IEST-CC-1246 Level	100	200	148	262	248	266	300	280
Comments	Dark	Dark	Mostly dark	Mostly black + 2 Blue	Mostly dark	Dark	None	Mostly black

Particle fallout levels during vibration testing were between IEST Levels 100 and 300, which are lower than what is observed for Martin Black and other black paints.

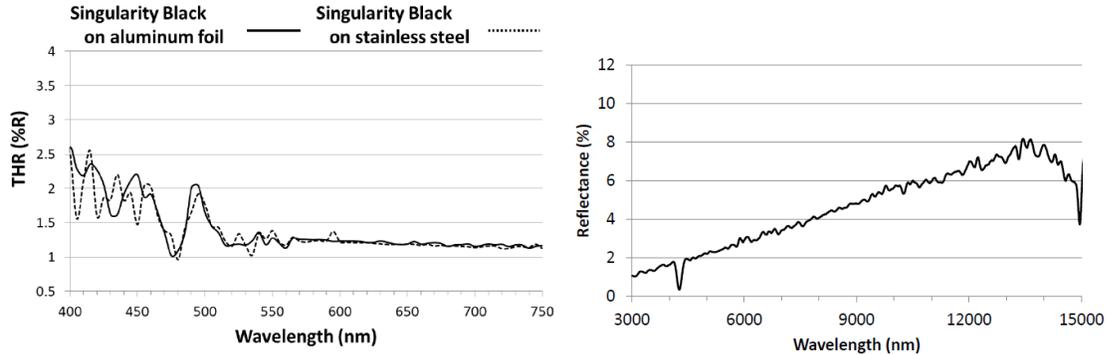
Singularity™ Black Optical and IR performance

Coatings had a measured absorptivity of 0.99, and emissivity of 0.86.



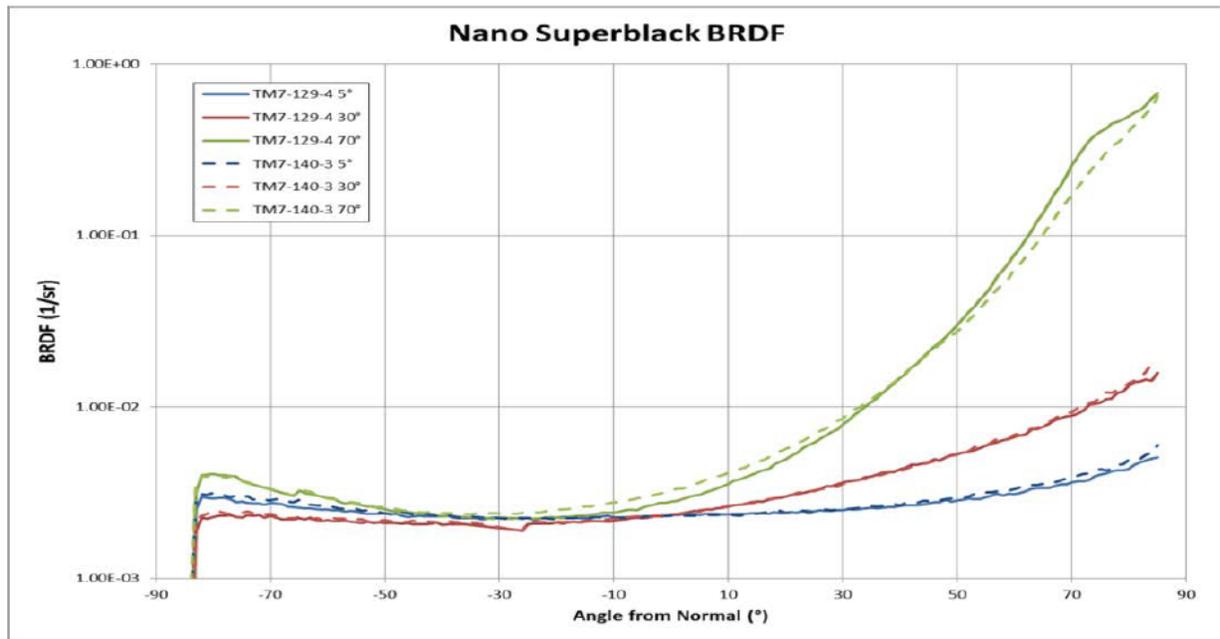
Total Hemispherical Reflectance (THR)

Samples were loaded into a PE I-19 UV-Vis-NIR spectrometer equipped with 60mm integrating sphere, and measured referenced to a Spectralon white sample.



BRDF

Reflectance measurements were taken using a Complete Angle Scatter Instrument (CASI) with the source at incidence angles of 5, 30, & 70 degrees. The detector scan radius covers the range +/- 90 degrees to the surface normal. The test wavelength was 633 nm.



Singularity™ Black Training & Packaging

For those interested in painting components, we offer a Singularity School where students will learn safety protocol, and application techniques to make the deepest blacks possible. These courses can be held at NanoLab, or at your facility. We sell Singularity Black in four sizes: 20ml, 250ml, 500ml & 1000ml. Coverage is ~1cm²/ml.

Singularity™ Black Coating Services and Contact Information

NanoLab provides coating services for baffles, telescope components, and other optical parts. Parts are handled in a class 100 clean space to prevent particulate contamination during the coating process. All work is done domestically, by US citizens in an ITAR compliant facility.