Advanced LIGO End Test Mass Coatings

AUTHOR:	CHECKED:	DATE	APPROVALS		
			DCN NO.	REV	DATE
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Name	**End Test Mass (ETM)**
Applicable Documents	
Blank Specification	E080047
Blank Drawing	D080055
Polish Specification	E080512-v2
Polish Drawing	D080658-A
Coating Specification	E0900068-v1
Fabricate From	D080055
Surface Quality (Scratch Total Area)	
Max Scratches Surface 1 inside 120mm diameter (units of um^2)	20000
Max Scratches Surface 1 outside 120mm to 160 mm diameter (units of um^2)	500000
Max Scratches Surface 2 inside 120mm diameter (units of um^2)	1000000
Surface Quality (Total Defect Number)	
Max Point Defects Surface 1 inside 120mm diameter	10

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Max Point Defect Density Surface 1 inside 120 mm diameter	1 per 4 mm^2
Max Point Defects Surface 1 outside 120 mm to 160 mm diameter	100
Max Point Defects Surface 2 inside 120 mm diameter	100
General to All Surfaces	
Coating Thickness Uniformity	Fractional Change <0.001 over 160 mm diameter. If the physical thickness variation of the coating cannot be measured with a profilometer or inferred interferometrically, it may be inferred from the wavelength shift of the coating as a function of position.
Coating Relative Wavelength Uniformity	Fractional Change <0.001 over 160 mm diameter.
Coating Area	To Bevel
Witness Sample Durability Testing	Once Witness Piece Per Run: Coating to resist adhesion test per MIL-C-48497A 4.5.3.1 Adhesion (snap tape). MIL-C-4.5.3.2 Humidity (120F 95% RH for 24 hours), combined with before/after spectrophotometer scan from 400 - 2500 nm, marking the specimen ensure the same area is scanned. There should be no measureable spectral shift. MIL-C-4.5.3.3 Moderate Abrasion (cheesecloth rub).
Surface 1	**NOTE: ARROWS ON OPTIC SIDE POINT TO SURFACE 1**
Coating Type	High Reflection

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Angle of Incidence	Normal
Transmission at 1064 nm	< 6 ppm requirement
Transmission Matching Between Parts at 1064 nm	N/A
Transmission at 532 nm	0.01 - 0.15, goal of 0.05
Thermal Stability at 532 nm	2 |(T1-T2)/(T1+T2)| < 0.1 for T1=25 °C to T2=40 °C
Thermal Stability at 1064 nm	3 |(T1-T2)/(T1+T2)| < 0.01 for T1=25 °C to T2=40 °C
Coating Materials	The coating is comprised of silicon-dioxide layers alternating with layers tantalum pentoxide doped with 25% (by cation) titanium dioxide.
Surface Electric Field 1064 nm	E<0.01 V/m. Vendor must demonstrate through calculation using $E\ [V/m] = 27.46\ (T / Re\ (Y))^{0.5}$ with T being the transmittance and Y the admittance in free space units.

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Thermal Noise	< 4.1 10^{-21} m/√Hz at 100 Hz – This is to be calculated from the material layer thicknesses, other parameters provided by LIGO, and by a formula provided by LIGO. The requirement is that using the provided formula, the predicted thermal noise should be below this level, the goal is to get as low a thermal noise as possible. This is to be done on a best-effort basis with no warranty or guarantee of suitability of use for any application
Surface 2	
Coating Type	Antireflection
Angle of Incidence	Normal
Reflection at 1064 nm	< 500 ppm requirement
Reflection at 532 nm	< 100 pm requirement
Surface Electric Field	N/A
Scatter	N/A
Absorption	<1 ppm requirement.
Thermal Stability at 532 nm	N/A
Thermal Stability at 1064 nm	N/A
Coating Materials	N/A
Other	
Additional Deliverables	
1. Witness Samples	Ten 1-inch witness samples, provided by LIGO, from each coating run

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2. Measured and Design Layer Thicknesses	For all layers in the design, measured thickness data from the deposition for each run), designed thicknesses, and measured indices of refraction at both 1064 nm and 532 nm for both coating materials (based on individual layers).
3. Surface 1 Spectrophotometer Scans	On a representative witness piece for each run, spectrophotometer graphs of reflectance and transmission of Surface 1 (HR coating) from 350-2500 nm before it is coated, between Surface 1 and Surface 2 coating, and after coating is completed. LIGO's preference is to have all spectrophotometer data be provided in Excel spreadsheet format.
4. Surface 2 Spectrophotometer Scans	On a representative witness piece for each run, spectrophotometer graph of reflectance of Surface 2 (AR coating) from 350-2500 nm before it is coated, between Surface 1 and Surface 2 coating, and after coating is completed. LIGO's preference is to have all spectrophotometer data be provided in Excel spreadsheet format.
5. Scatter Maps.	Maps of scatter, absorption, and transmission over central 160 mm diameter with optic orientation specified. Scatter should be measured accurately to ± 1 ppm, absorption to ± 0.1 ppm, and transmission to ± 0.001.

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6. Scratches & Point Defects Methods 1&2 (Hand Sketch).	**METHOD 1.** The surface is examined visually by two observers independently. The examination is done against a dark background using a fiber optic illumination system of at least 200 W total power. A 100% inspection of the surface is carried out. Pits and scratches down to 2 micrometers in width can be detected using this method of inspection. Any scratches or sleeks that are detected will be measured using a calibrated eyepiece. **METHOD 2.** Further inspection will be done with a minimum 6X eyeglass using the same illumination conditions, again with two observers. Sleeks down to 0.5 micrometers wide can be detected using this method. The surface will be scanned along one or two chords from centre to edge, then at ten positions around the edge, and ten to fifteen positions near the centre.
7. Scratches & Point Defects Method 3 (Digital Images).	**METHOD 3.** An inspection is then carried out with a dark or bright field microscope, with 5x objective at four positions at each of the following locations: a) Within 10mm of the center of the surface. b) Equally spaced along the circumference of a centered, 60 mm diameter circle. c) Equally spaced along the circumference of a centered, 120 mm diameter circle.
8. Durability Test Data & Samples.	All samples from the durability tests and data, including spectrophotometer scans of the representative coating on each side in an Excel spreadsheet.

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