Polished Substrate, Silicon Input Test Mass (ITM), 40m Mariner

Authors	Date	Document Change Notice, Release or Approval
R Adhikari, N Vaidya, C Wipf		See DCC record

1 Applicable Documents

LIGO-D21xxxxx-v1	Mirror Substrate Drawing, Silicon End Test Mass (ITM), 40m Mariner
LIGO-D21xxxxx-v1	Mirror Blank Drawing, Silicon Test Mass (ETM/ITM), 40m Mariner
LIGO-E2100300-v1	Specification: Blank Material, Silicon Test Mass (ETM/ITM), 40m Mariner
ASTM F523	Practice for Unaided Visual Inspection of Polished Silicon Wafer Surfaces

2 Requirements

2.1 Physical Configuration

LIGO-D21xxxxx Mirror Substrate Drawing, Silicon End Test Mass (ITM), 40m Mariner

2.2 Starting Materials

LIGO-D21xxxxx	Mirror Blank Drawing, Silicon Test Mass (ETM/ITM), 40m Mariner
LIGO-E2100300	Specification: Blank Material, Silicon Test Mass (ETM/ITM), 40m Mariner

2.3 Registration Marks

Registration marks shall be etched, ground, or sandblasted, and located per LIGO-D21xxxxx

2.4 Serial Number

Serial number “ITMXX” shall be etched, ground, or sandblasted on the barrel of the optic per D21xxxxx, where XX is sequential starting with 01.

2.5 Bevel

Bevel for safety per LIGO-D21xxxxx

2.6 Surface, Side, and Bevel Polish

All surfaces, sides, and bevels shall be polished using a progression of smaller grit sizes. The last step before final polish shall be equal to or less than a five micrometer grit finish. Surfaces, sides, and bevels shall appear uniform, with no scuffs or scratches visible to the naked eye when viewed in normal room light.

Polished Substrate, Silicon Input Test Mass (ITM), 40m Mariner

2.7 Surface Quality

Inspect surfaces 1 and 2 using the following methods:

1. The surface is examined visually by two observers independently, applying ASTM F523 procedures for *Front-Surface Inspection, High-Intensity Light Source* and *Front-Surface Inspection, Diffuse Light*. A 100% inspection of the surface is carried out. Any scratches, sleeks, or other defects that are detected will be measured using a calibrated eyepiece.
2. Further inspection will be done with a minimum 6X eyeglass using the same illumination conditions, again with two observers. The surface will be scanned along one or two chords from center to edge, then at ten positions around the edge, and ten to fifteen positions near the center.
3. An inspection is then carried out with a microscope with 5X objective, at four positions at each of the following locations:
   a. Within 10 mm of the center of the surface.
   b. Equally spaced along the circumference of a centered, 20 mm diameter circle.

Surface 1
Zero defects within the central 20 mm diameter. The total area of defects within the central 30 mm diameter shall not exceed 3 square micrometers, when weighted per *Appendix A, Defect Analysis*. The total area of defects outside the central 30 mm diameter shall not exceed 20 000 square micrometers.

Surface 2
The total area of defects within the central 30 mm diameter shall not exceed 5 square micrometers, when weighted per *Appendix A, Defect Analysis*. The total area of defects outside the central 30 mm diameter shall not exceed 20 000 square micrometers.

2.8 Surface Figure

Measure over the central 30 mm diameter.

Surface 1
Flat. Radius of curvature > 10 000 m in absolute value

Surface 2
Flat. Radius of curvature > 10 000 m in absolute value

Polished Substrate, Silicon Input Test Mass (ITM), 40m Mariner

2.9 Surface Error

2.9.1 *Low Spatial Frequency*

The low spatial frequency band includes the range from the measurement aperture to 1 mm^{-1}

The following root mean square standard deviation (σ_{rms}) values are calculated from the phase maps which are to be provided with each optic. For this calculation, the amplitudes for the best fit Zernike terms $Z_{0,0}$, $Z_{1,1}$ and $Z_{2,0}$ (or corresponding Seidel aberrations) are subtracted from the phase map. Known bad pixels may be excluded from this calculation.

Measure over the central 40 mm diameter.

Surface 1
Low spatial frequency error σ_{rms} < 1 nanometer (0.5 nanometer goal)

Surface 2
Low spatial frequency error σ_{rms} < 1 nanometer

2.9.2 *High Spatial Frequency*

The high spatial frequency band includes the range above 1 mm^{-1}

Measure at the following locations:
1. Within 2 mm of the center of the surface.
2. Four positions equally spaced along the circumference of a centered, 20 mm diameter circle.

Surface 1
High spatial frequency error σ_{rms} < 1 nanometer (0.1 nanometer goal)

Surface 2
High spatial frequency error σ_{rms} < 1 nanometer (0.5 nanometer goal)

3 Inspection

Specification	Test method & frequency	Data delivered
Dimensions	Measurement, 100%	Measurement results
Surface quality (methods 1 and 2)	Visual inspection, 100%	Hand sketch noting defect dimensions
Surface quality (method 3)	Visual inspection, 100%	Digital image of each inspection site
Surface figure	Interferometry, 100%	Surface phase maps
Surface error (low spatial frequency)	Interferometry, 100%	Surface phase maps
Surface error (high spatial frequency)	Interferometry, 100%	Surface phase maps

Orientation: For the purpose of full surface phase maps, the data shall be oriented such that the substrate registration mark is at the top center of the data.

Format: All data shall be delivered in electronic format. Electronic data of the phase maps shall be delivered in either ASCII or .dat format.

Polished Substrate, Silicon Input Test Mass (ITM), 40m Mariner

4 Appendix A, Defect Analysis

Surface defects in weighted areas are to be evaluated as follows:

1. Measure the area of the defect in square micrometers, and its distance from the center of the optic
2. Find the weighting factor for the radius measured in step 1, from the table below.
3. Multiply the measured area found in step 1 with the weighting factor found in step 2.
4. Sum all weighted defects found within the analysis zone.

	Position-dependent defect weighting factor	
Radius (mm)	Surface 1	Surface 2
1	None allowed	3.22E-02
2	None allowed	3.22E-02
3	None allowed	3.22E-02
4	None allowed	3.22E-02
5	None allowed	3.22E-02
6	None allowed	3.22E-02
7	None allowed	3.22E-02
8	None allowed	3.22E-02
9	None allowed	3.22E-02
10	None allowed	3.22E-02
11	None allowed	3.22E-02
12	None allowed	2.29E-02
13	None allowed	1.30E-02
14	None allowed	5.88E-03
15	None allowed	2.12E-03
16	None allowed	6.09E-04
17	None allowed	1.40E-04
18	None allowed	2.55E-05
19	None allowed	3.71E-06
20	None allowed	4.30E-07
21	3.98E-08	3.98E-08
22	2.93E-09	2.93E-09
23	1.72E-10	1.72E-10
24	8.06E-12	8.06E-12
25	3.01E-13	3.01E-13
26	8.95E-15	8.95E-15
27	2.12E-16	2.12E-16
28	4.02E-18	4.02E-18
29	6.05E-20	6.05E-20
30	7.27E-22	7.27E-22