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A TRADE OFF STUDY OF LIGHTWEIGHT PRIMARY MIRROR FOR SPACEBORNE TELESCOPE

Haeng-Bok LEE† and Se-Chol Choi
Agency for Defense Development, P.O Box 35-5, Yuseong, Daejeon 305-600, Korea
E-mail: lhb2000@hanafos.com, sechol77@kornet.net

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ABSTRACT

High-resolution telescope from space comprises electro-optical imagery with a ground resolution lying within the range of 1 to 5 meters. According to information documented in the literature up to now, most primary mirrors verified and flown in optical space missions have been lightweighted made from Zerodur, ULE, beryllium, SiC or aluminium. A trade off study was performed to determine as a "lightweighted" by factors like backside cell pattern, rib thickness, face thickness, mirror fixation device location and material and so on based on structural performance for primary mirror in submeter class spaceborne telescope.

Keywords: lightweight primary mirror, spaceborne telescope, SiC

1. INTRODUCTION

A trend in spaceborne telescopes has been an increase in collection area and in resolution. Both of these demands in performance require larger primary mirror aperture sizes. Since the primary mirror often dominates the mass budget of the telescope, either of these options imply larger mass for the overall system. Technologies that enable lighter primary mirror will enable lower mass telescopes with larger apertures to reduce the launch costs of these missions. Areal density is often limited by the stiffness to weight ratio of the primary mirror. Two key factors drive these criteria: telescope structural characteristics and fabrication requirements. Major efforts in spaceborne telescopes have inspired research in lightweight primary mirror. This paper describes a conceptual design trade studies that explores the structural views for the lightweight primary mirror.

2. TELESCOPE SYSTEM PARAMETERS AND OPTICS

Most system parameters and design requirements used in this study are documented in Kim (2003). This telescope will orbit the Earth during 5 years on a quasi-circular Sun-synchronous orbit of 675 km altitude with 8 km swath width. Mirror shape main characteristics are given in Table 1.

† corresponding author

Table 1. Mirror shape main characteristics.

	Primary Mirror	Secondary Mirror	Tertiary Mirror
Radius of Curvature [mm]	−1509.814	−358.8512	−470.7351
Conic Constant	−0.990020	−1.879236	−0.679735
Useful Aperture [mm]	700	160	
Lightweight [%]	> 80		
Natural frequency [Hz]	> 1000		

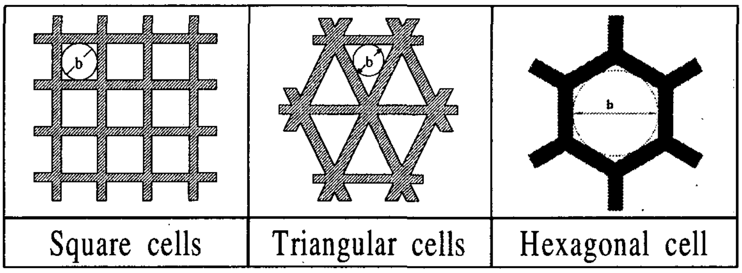

Figure 1. Regular cell pattern.

3. PRIMARY MIRROR DESIGN

3.1. Materials

The most important properties of materials used in lightweight, rugged optical systems are those determining structural efficiency, temporal stability, thermal stability, and polishability. Stiffness and density strongly influence the weight of an optomechanical structure. The figures of merit can be used to help select the mirror material. Figures of merit are derived from two or more properties to define a desirable trait not provided by a first order property.

3.2 Lightweight parameters

- Cell patterns

As shown in Yoder (1992), the cells are sized with the quilting parameter for their width. The height of the cells is consistent with gravity analysis. We will only consider three shapes of cells: square, triangular and Hexagonal pattern, as shown Figure 1.

- Quilting amplitude

During polishing, the face plate of the mirror deflects under polishing pressure. This deflection causes a permanent periodic deformation of the mirror surface, corresponding with the cell location. To ensure compliance with a WFE allocation of 7 nm for quilting with sufficient margins, the thickness of the mirror facesheet must be greater than 3 mm should be taken.

- Techniques for supporting mirror

Normal mode analysis were performed with changing the radius located MFD. The frequency at r = 213 mm is better than others, the results from r = 133 mm to r = 293 mm range have shown very small difference. As a consequence, the selected MFD location radius is 213 mm. The mirror is axial supported in three points by isostatic conditions (4 degrees of freedom:1 radial translation and 3 rotations are released in each of those fixation points.)

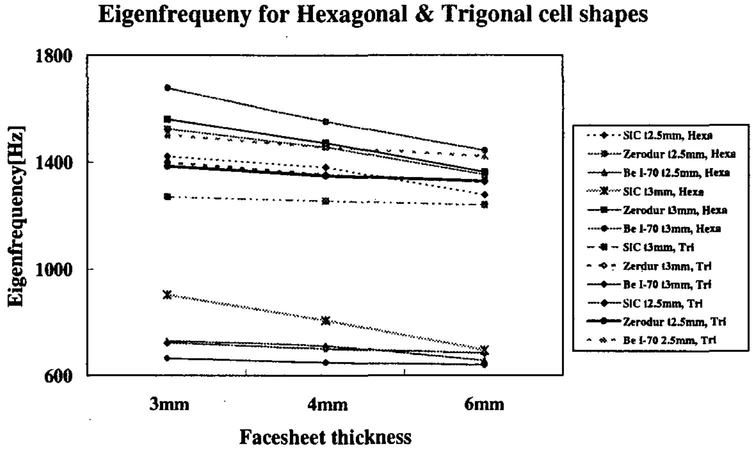

Figure 2. Frequency for cell shape, facesheet thicknesses and mirror materials.

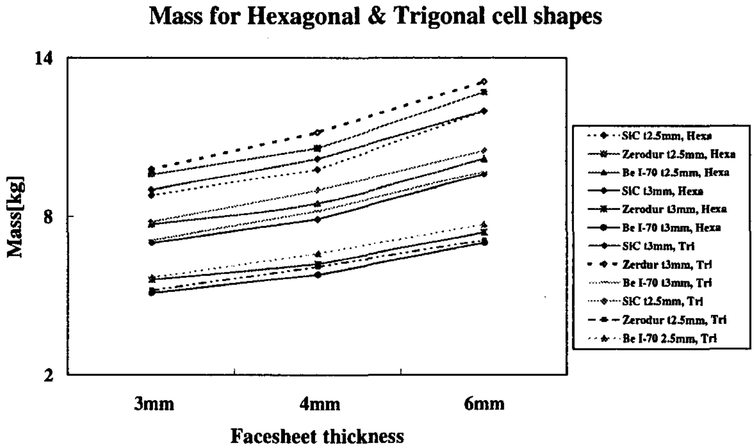

Figure 3. Mass for cell shape, facesheet thicknesses and mirror materials.

- Gravity deformation

The deformation is the sizing parameter of the mirror; it involves selecting a bipod shape MFD, whose crossing point converges at the center of gravity in conformance with accessibility wrt mirror face sheet. The WFE is minimized when the bipods cross at CoG location, which is around 5 mm distance from the face sheet. Stiffeners at 50 mm thickness gives 3 nm at 7 mm supporting point distance, the specified value of 7nm is easily reached over ±5 mm range for a mass of 11 kg maximum.

- Frequency and mass of lightweight primary mirror for changing parameters

Figure 2, 3 show the 36 cases analysis results were performed with changing parameters for mass and frequency. As shown Figure 2, 3, trigonal cell is better than hexagonal cell for both stiffness and mass. The 3 mm facesheet thickness is the best stiffness value for both trigonal cell and hexagonal cell.

Table 2. Optimum resulting primary design.

Design factors	Result
Outer/Inner Diameter	ϕ710 mm / ϕ160 mm
Overall Thickness	60 mm
Face Thickness	4 mm
MFD location	r = 213 mm
Material	SiC
Weight/Lightweight	10.6 kg / 91%
Frequency	1457 Hz
Quilting Amplitude	6.6 nm
Aerial Density	24 kg/m^2
Cell Web Thickness/Diameter	3 mm / 46 mm

4. CONCLUSION

Considering mass, natural frequency, quilting, and gravity deformation, the triangular cell with optical surfaces made with SiC material has been selected. The optimum resulting design as shown Table 2.

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