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Korea Astronomy & Space Science Institute

Application of extended MARI concept to SiC mirrors

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Korea Astronomy and Space Science Institute
NOAO
GREEN OPTICS

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1. BACKGROUND

- PROGRAM OVERVIEW

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1. Overview

- Collaboration between KASI and NOAO to develop SiC mirror polishing procedure and environmental testing since 2014[1,2]
- KASI was awarded a study program to develop ‘a basic research on ultra-lightweighted off-axis aspheric optical surfaces for space application’ from National Research Foundation (NRF) of Korea for 3 years from July 2018.
- KASI is extending research field toward polishability of ultra-lightweighted mirror materials such as SiC as well as testing for off-axis aspheric mirror surfaces.
- KASI will investigate the MARI (MAterial Removal Indicator) concept for the polishability of lightweighted materials.

[1]J.-Y. Han, et al., “Mirror polishing technology with Tool Influence Function (TIF) for SiC,” NASA Mirror Tech Days 2014.
[2]J.-Y. Han, et al., “International collaboration for Silicon Carbide mirror polishing and development,” Pub. Of the Korean Astronomical Society, 30, 687~690 (2015).

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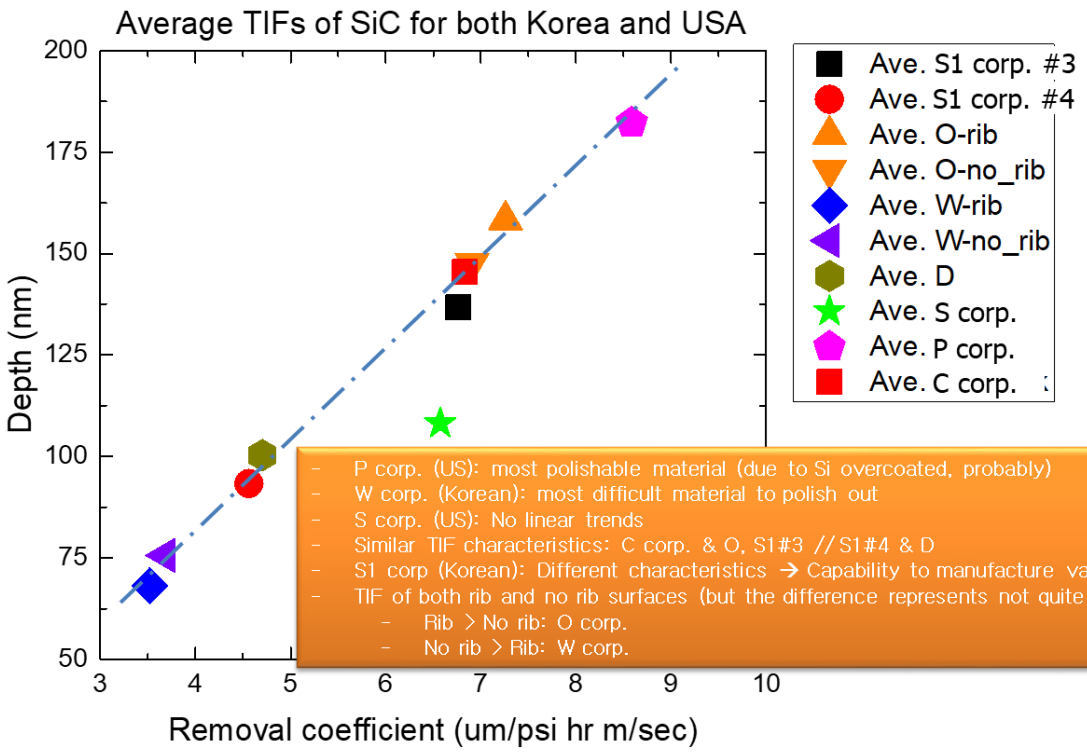
1. Overview - MARI

- Used SiC materials
  - US 3 vendors and Korean 4 vendors
- Tool Influence Function(TIF) values are obtained by 27 different input conditions composed of pressure, dwell time and rotation speed.
- TIF depth and material removal coefficient is obtained.



→ MARI concept* can be used to characterize various SiC materials

*J.-Y. Han, et al., "TIF and material removal characteristics of SiC mirror materials," NASA Mirror Tech Days 2016.

1. Overview – NRF program

Objectives

- To improve prediction of accuracy for deterministic polishing of lightweighted mirror materials
- To study of quantitative measurement method and of definition for an off-axis aspheric surfaces

Schedule and budget

- Schedule: July 2018 ~ June 2021 (3 years)
- Budget: 350 M Won (~300,000 USD)

Deliverables

- TIF experiments and analysis
- Characterization of off-axis aspheric surfaces and measurement of physical property for off-axis aspheric mirror surfaces
- All academic achievements will be encouraged to publish to journal or international conferences.

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2. EXPERIMENTAL PLAN

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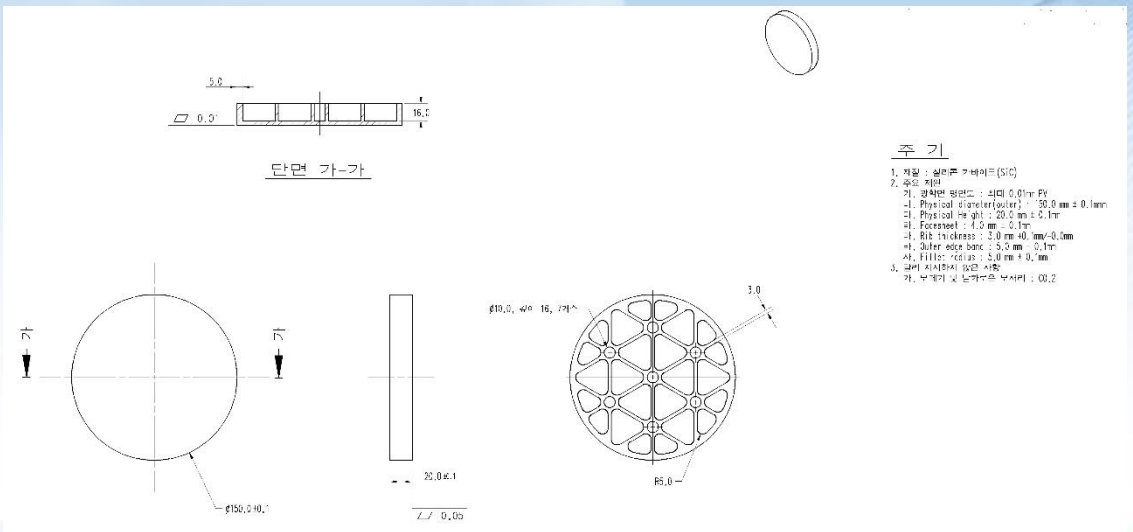
2. MARI experiment plan

- Materials
  - SiC: RB, Sintered, Conversion, and Hybrid SiCs
  - Other ultra-lightweighted materials
- Size and drawing of Sample
  - Size: 150 mm in diameter x 2ea, lightweighted
    - TIF patterns engraving: 81 TIFs (=27 input variables x 3 redundancies),

      TIF on Rib and Ron-rib surfaces
  - Drawing (not fixed)
    - Vendor may suggest optimized drawing incorporated with their own manufacturing process



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2. MARI experiment plan

- Polishing head
  - Orthogonal Velocity Tool (OVT)[1,2] in KASI
  - Simple configuration with two rotation axes and High repeatability of about 90%

OVT (Orthogonal Velocity Tool)

Items		Detailed items	Ranges / Spec.
Req.	TIF shape		Gaussian shape
Spec.	Wheel	Rotation speed	15~1000 rpm
		Contact width	3.8 ~ 3.9 mm
		Contact area	6.0 ~ 6.5 mm^2
	Rotational axis (Radial direction)	Rotation speed	4~60 rpm
		Motion control item	Rotation angle Dwell time
	Load cell	Measurement ranges	Min.: 0.1 psi Max.: 10 psi
Development		KASI, SphereDyne, YoonSeul	

TIF polishing head

- Input variables: Pressure(P), Rotation speed(V), Dwell time(T)
- Outcomes: TIF depth and volume

[1]H.Seo, et al., "Novel Orthogonal velocity polishing tool and its material removal characteristics from CVD SiC mirror surfaces," Opt. Express., 24, 12349 (2016).

[2]J.-Y. Han, et al., "Tool Influence Function (TIF) Characteristics of SiC mirrors," NASA Mirror Tech Days 2015.

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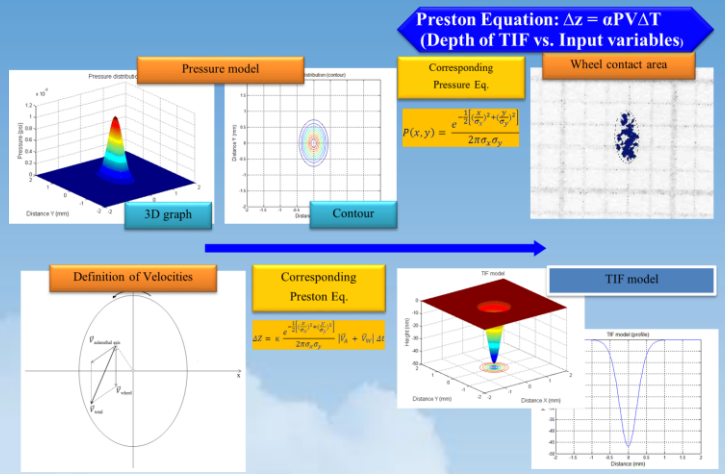
2. MARI experiment plan

- TIF model: Analytical and empirical model[1,2]
  - Basic relationship between input and output variables: Preston equation



- Collaboration
  - NOAO: Oversight for the SiC and ultra-lightweighted materials and applications
  - Green Optics(GO): Polishing the mirror surfaces
  - Material providers: KASI welcomes a mirror sample provider to have a novel and excellent physical property to check polishability. Please let me know if you have an interesting to check.

[1]H.Seo, et al., "Novel Orthogonal velocity polishing tool and its material removal characteristics from CVD SiC mirror surfaces," Opt. Express., 24, 12349 (2016).

[2]J.-Y. Han, et al., "Tool Influence Function (TIF) Characteristics of SiC mirrors," NASA Mirror Tech Days 2015.

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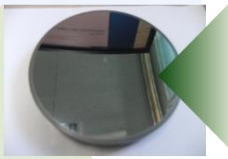
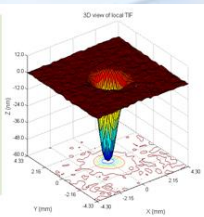
2. MARI experiment plan - Summary

- Materials: 150 mm in diameter
  - SiC: RB, Sintered, Conversion, and Hybrid SiCs
  - Other ultra-lightweighted materials
- Polishing head: Orthogonal Velocity Tool (OVT) in KASI
- Input variables: Pressure, Dwell time, Rotation speed
- Outcomes: TIF depth and volume
- TIF model: Analytical and Empirical model
- Collaboration
  - NOAO, GO and material providers

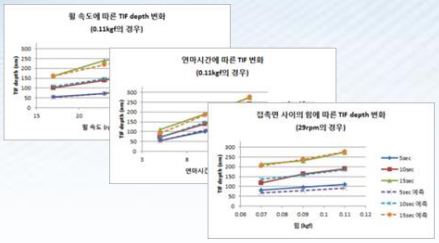
OVT
polishing tool



Ultra-lightweighted
material



TIF
generation



TIF analysis
→ Apply to MARI concept

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3. FABRICATION EXAMPLE OF OFF-AXIS ASPHERIC SURFACES

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3. Fabrication of off-axis aspheric optical surfaces (1/2)

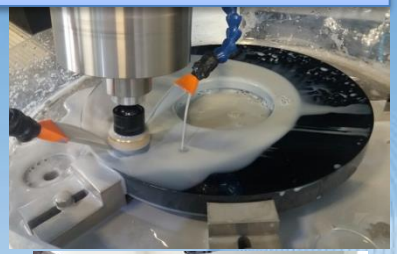
- Objectives
  - i) To fabricate SiC mirror and ii) to develop a metrology to measure an off-axis aspheric surfaces
- Fabrication for SiC

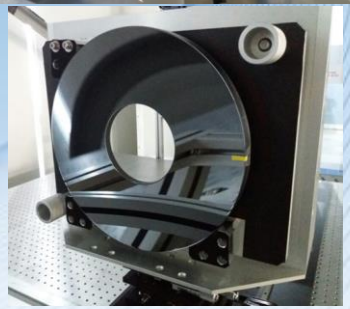
Material: SiC
R: 850.45 mm, K: −1.147
CA: 300 mm, Central hole: 128 mm

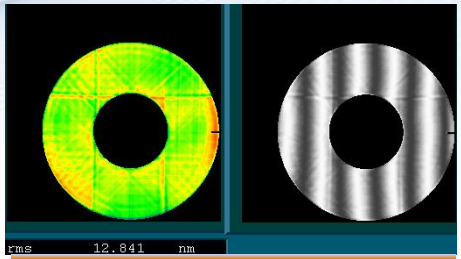
Material

Grinding

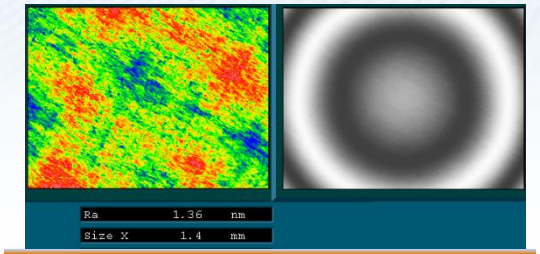
Polishing and measurement







Surface error: 12.8 nm



Surface roughness: 1.36 Ra

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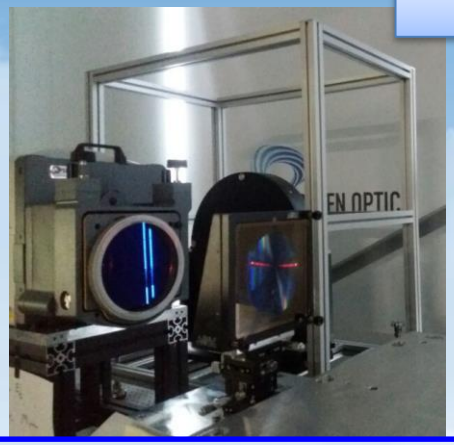
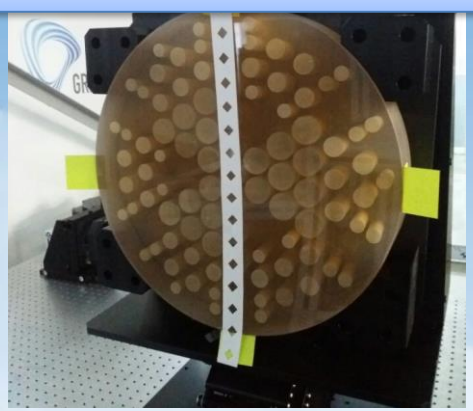
3. Fabrication of off-axis aspheric optical surfaces (2/2)

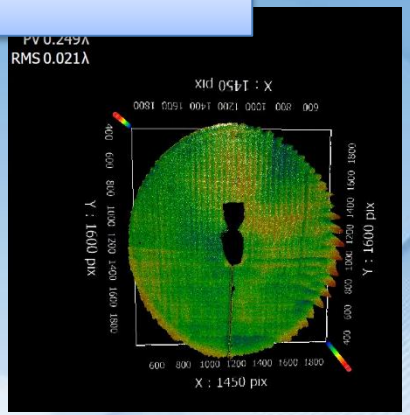
❖ Measurement of off-axis aspheric surfaces

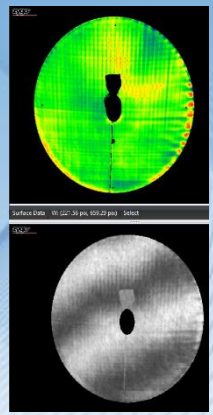
Material: Zerodur
R: 1670.106 mm, K: −1.0
CA: 400 mm, OAD: 340 mm

Measurement



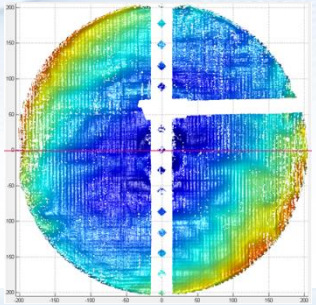






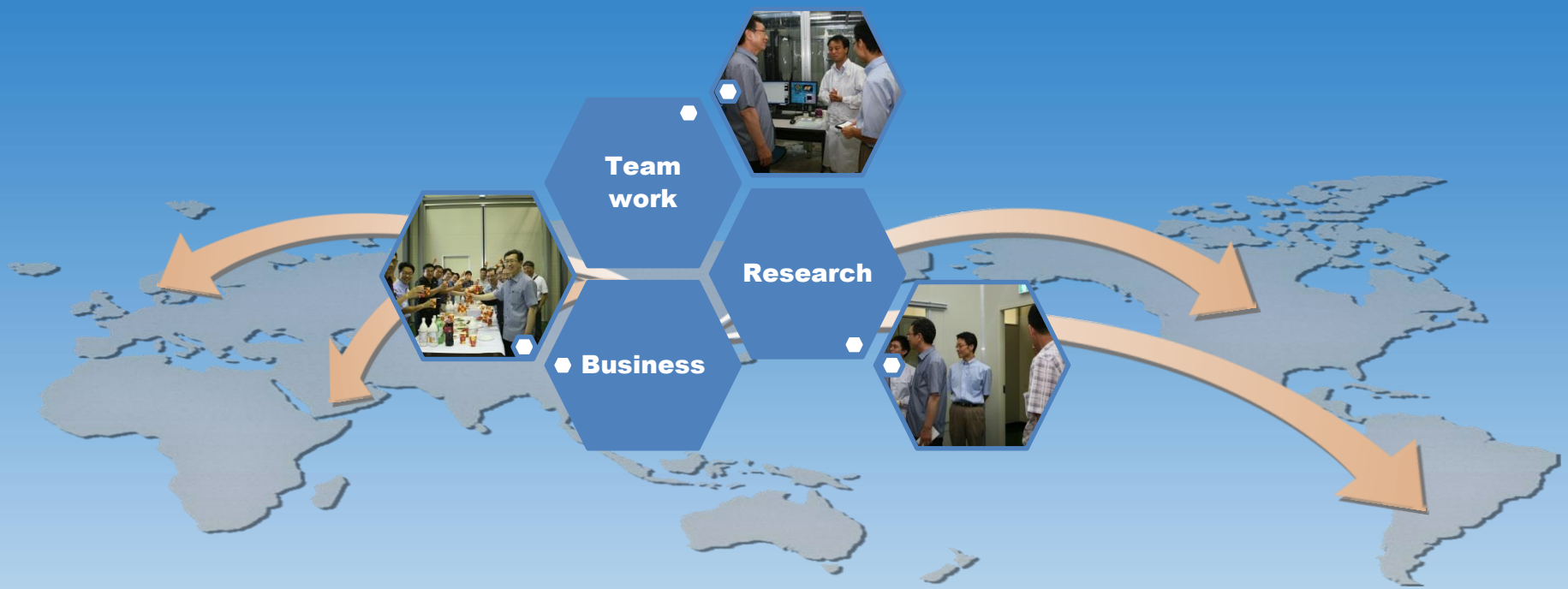
Surface error: 13.3 nm

Distortion correction



4. Conclusion

- KASI has plan to extend MARI concept for various SiC and ultra-lightweighted materials for three years with NOAO, GO, and material providers.
- In order to get TIF, KASI implemented OVT as a polishing head and TIF model.
- KASI and GO is developing deterministic fabrication and measurement processes for off-axis aspheric optical surfaces



Thank you for your attention

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