

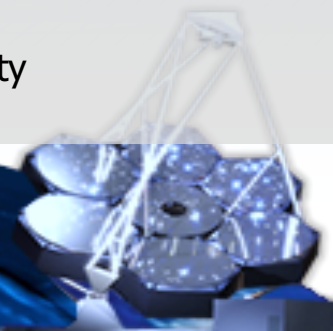


# TIF and material removal characteristics of SiC mirror materials


2016. 11. 01.

**Jeong-Yeol Han**, Myung Cho, Gary Poczulp, Dong-Kyun Kim, Hyoung Kwon Lee, Jinho Kim, Hyunju Seo, Sehyun Seong, Sug-Whan Kim, Min-Gab Gog, Jong-Su Jeon, Jihun Kim, Young-Soo Kim, Ukwon Nam, Gun Hee Kim, Sang Won Hyun, Minwoo Jeon

Korea Astronomy and Space Science Institute (KASI)  
National Optical Astronomy Observatory (NOAO)  
Green Optics Co., Ltd., YoonSeul Co., Ltd, Yonsei University  
Korea Basic Science Institute (KBSI)



# Contents

- 
- Introduction
  - TIF analysis
  - Preparation of thermal test setup
  - Conclusion

# INTRODUCTION

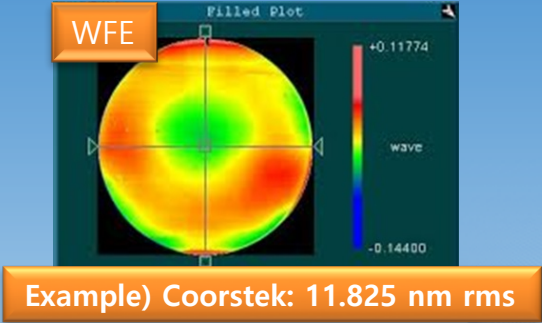
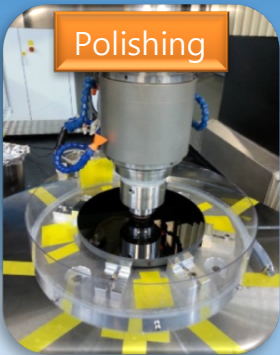
# 1. Collaboration plan overview

- Collaboration partners: NOAO, KASI, GO
- Objectives
  - Develop polishing and testing procedures for SiC lightweight blanks
    - For 300 mm flat blanks
    - Polishable surfaces (Si CVD, or SiC CVD over-coated)
  - Test of optical and mechanical characteristics
    - Optical surface WFE maps
    - Environmental tests (Thermal tests)
  - Optical surface characterizations
    - Surface figuring
    - Structure function
    - Surface micro-roughness
- Deliverables
  - Three SiC polished mirrors
  - Final report of SiC mirror polishing and tests

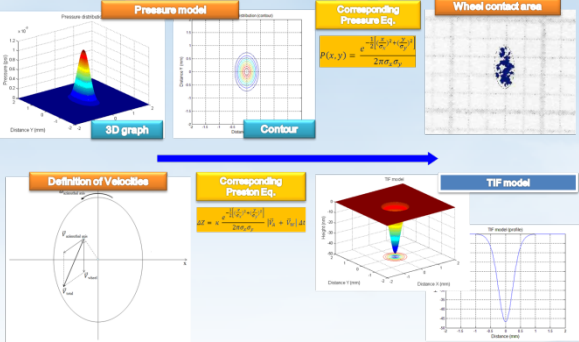


# 1.1 WFE acquisition and TIF study

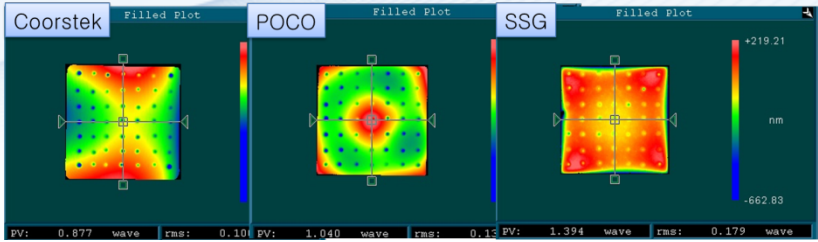
## WFE acquisition



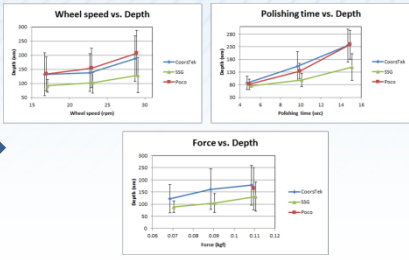
## TIF study



TIF Modeling



TIF acquisition



TIF analysis

# 1.1 Structure function

- Definition

**Structure function of random variable,  $P(r)$**

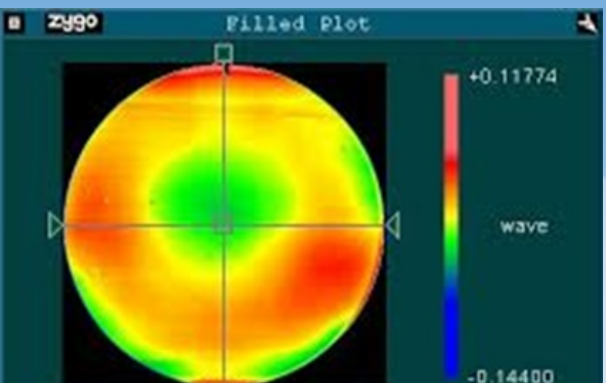
$$D(\rho) = \langle | P(r+\rho) - P(r) |^2 \rangle$$

- Structure function is related to RMS WFE at various spatial separations measured on the optical surface
- $P(r)$ : WFE at position,  $r$
- $\rho$ : separation

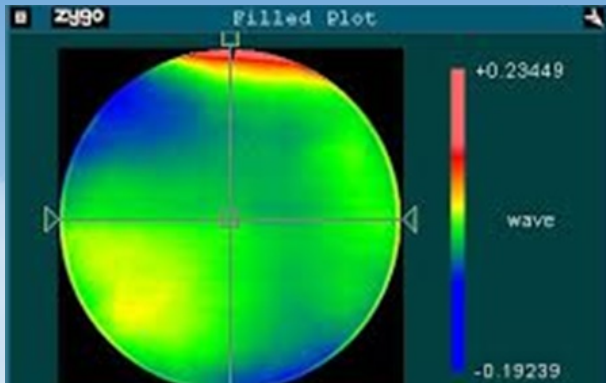
# 1.1 $\Phi$ 300 mm SiC polishing – surface figure

Mirror Tech 2015

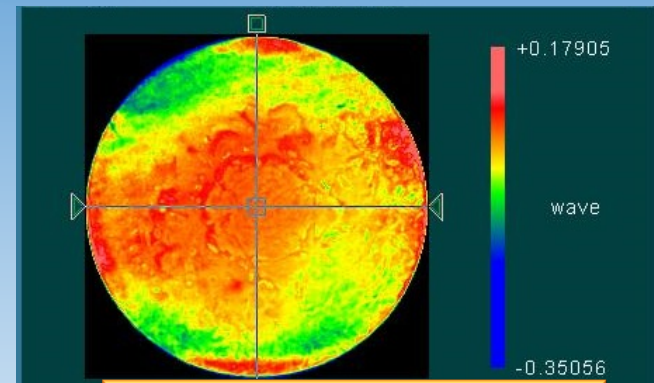
- Polished optical surfaces (work in progress for SSG)
  - Coorstek, POCO, SSG (requirement:  $< 20$  nm rms)



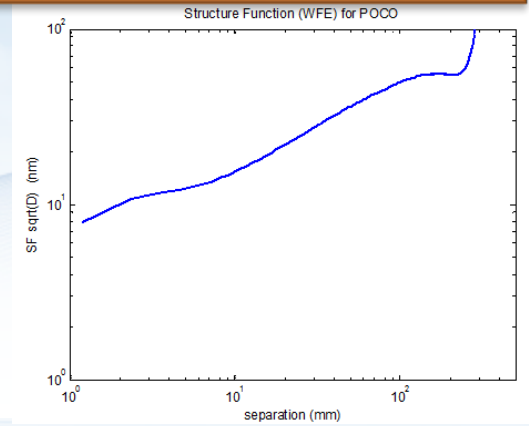
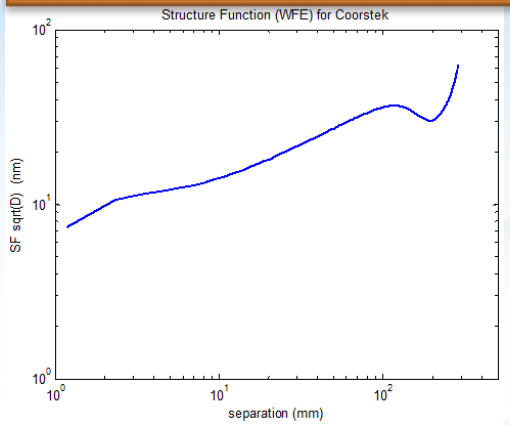
Coorstek: 11.825 nm rms



POCO: 18.161 nm rms



SSG: 28.884 nm rms

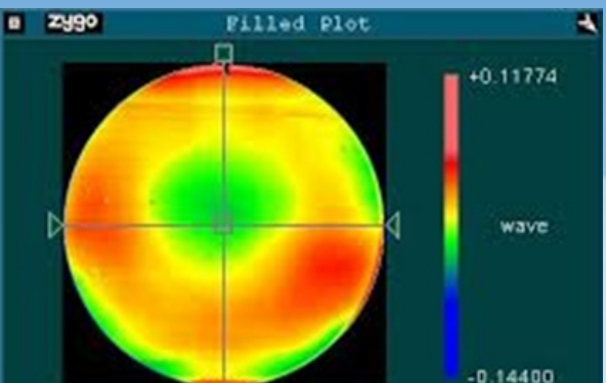




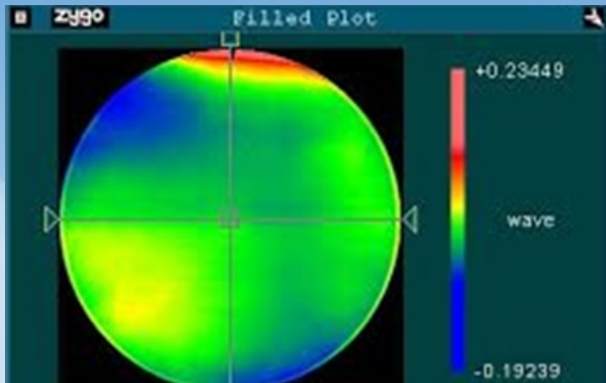
# 1.1 $\Phi$ 300 mm SiC polishing – surface figure

Met requirements

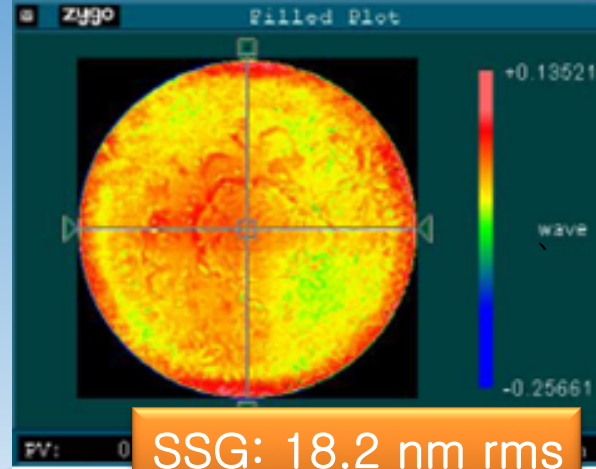
- Polished optical surfaces
  - Coorstek, POCO, SSG (requirement:  $< 20$  nm rms)



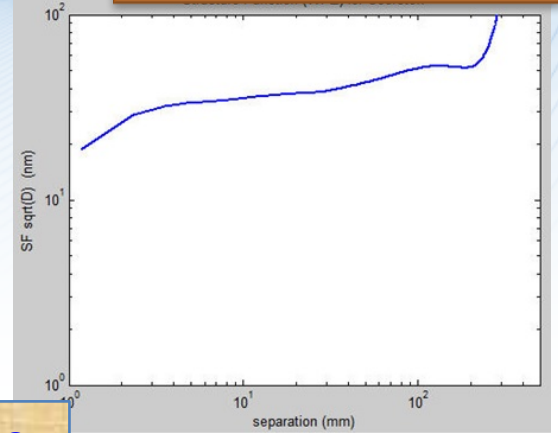
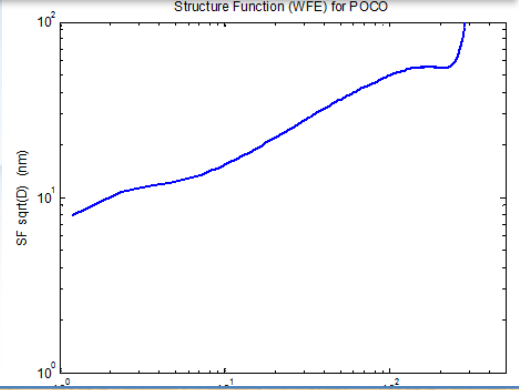
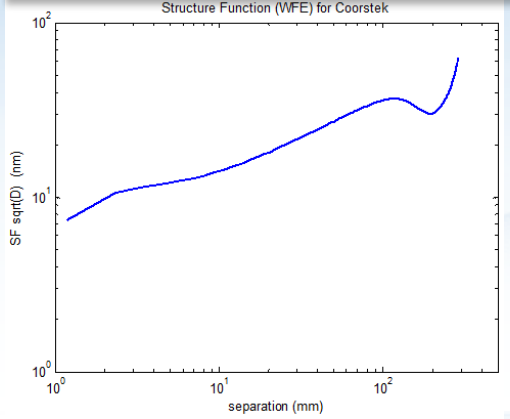
Coorstek: 11.825 nm rms



POCO: 18.161 nm rms



SSG: 18.2 nm rms

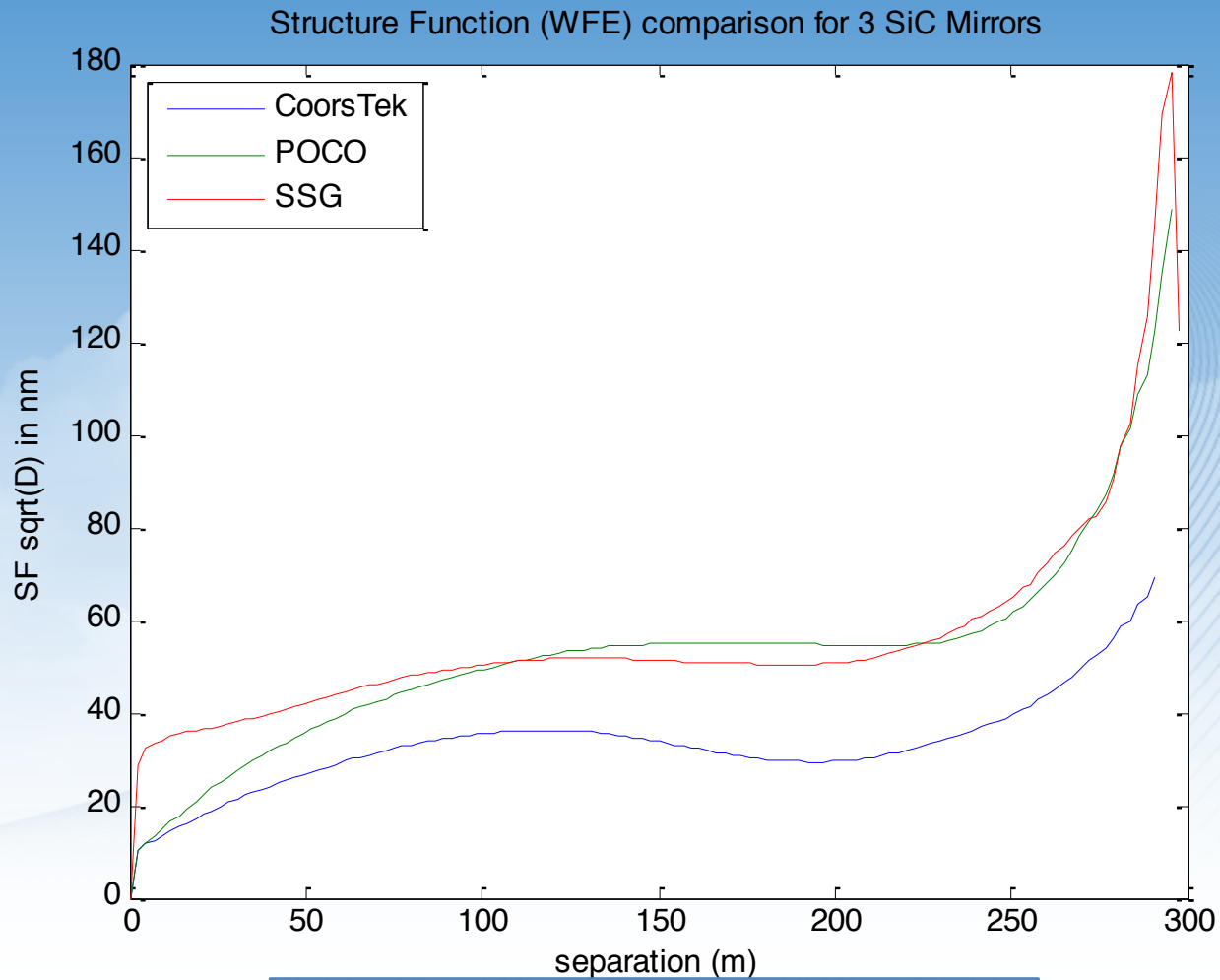
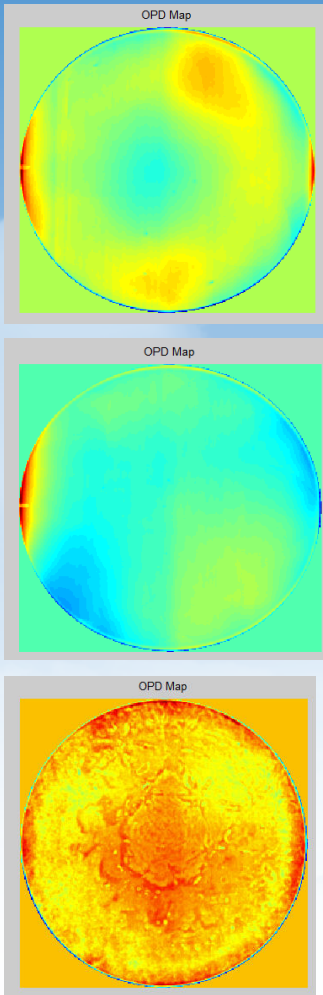


Structure functions in log-log scale

jhan@kasi.re.kr

# 1.1 $\Phi$ 300 mm SiC polishing – structure function comparison

Structure functions show strong edge effects (turn-up, turn-down)



Structure functions in linear scale

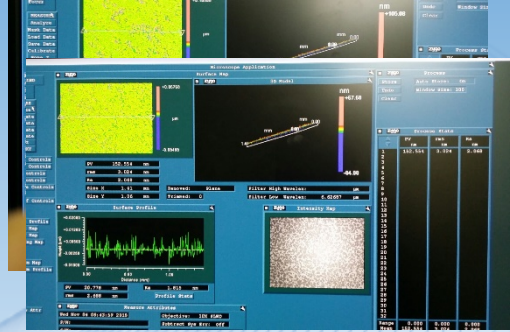
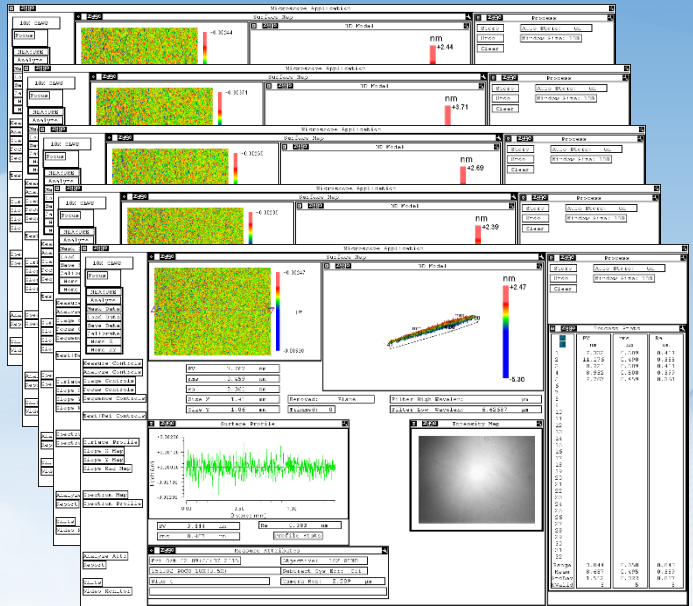
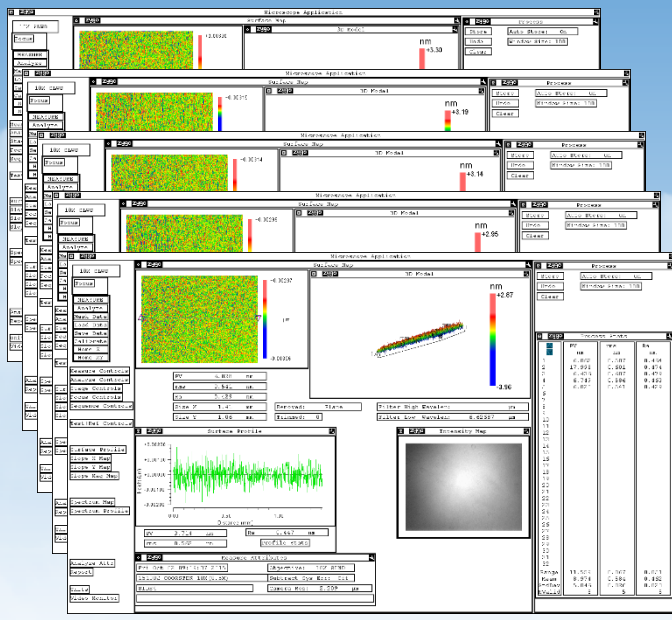
jhan@kasi.re.kr



# 1.1 $\Phi$ 300 mm SiC polishing – surface roughness

Mirror Tech 2015

- Surface roughness (work in progress for SSG)
  - Coorstek, POCO, SSG (requirement:  $< 2$  nm rms)



Coorstek surfaces  
 $0.58 \pm 0.03$  nm rms  
(Data taken by 5 different positions)

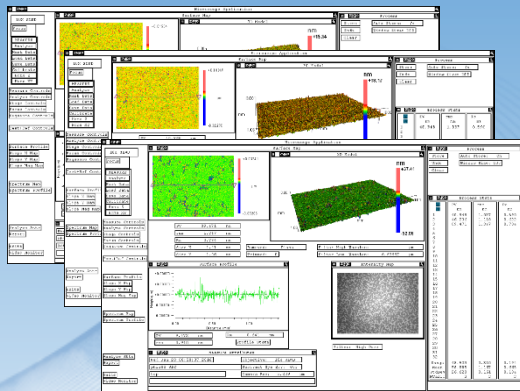
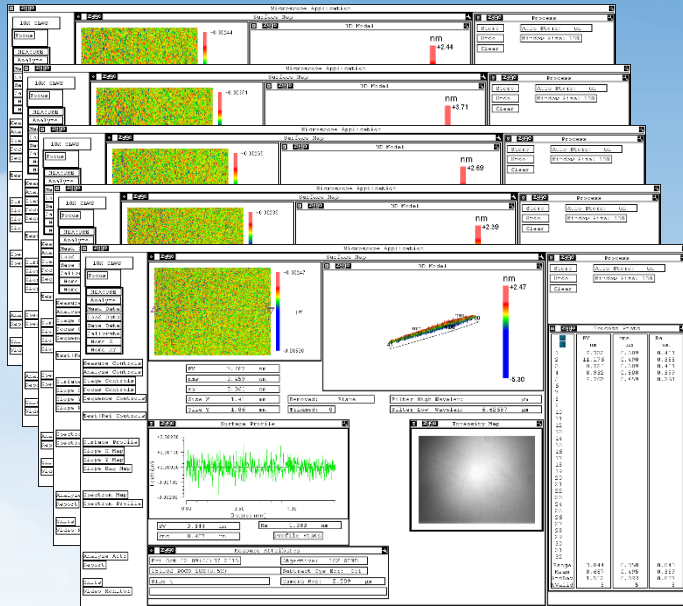
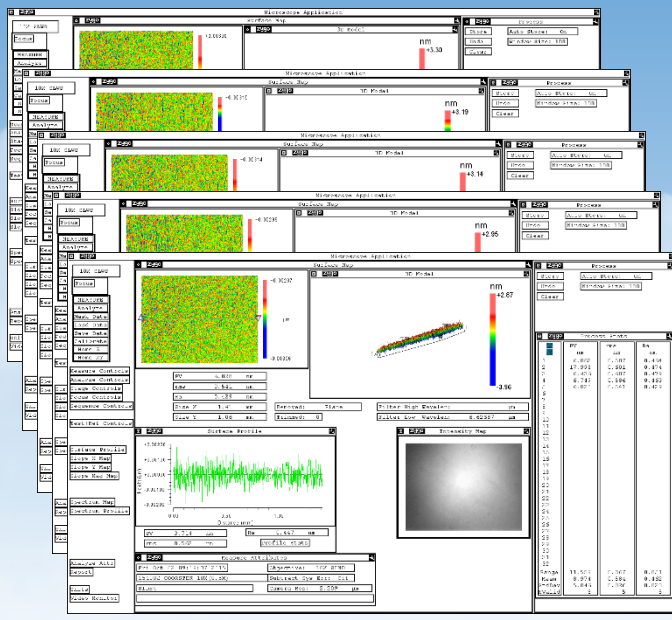
POCO surfaces  
 $0.50 \pm 0.02$  nm rms  
(Data taken by 5 different positions)

SSG surfaces  
 $2.72 \pm 0.46$  nm rms  
(Data taken by 2 different positions)

# 1.1 $\Phi$ 300 mm SiC polishing – surface roughness

Met requirements

- Polished optical surfaces
  - Coorstek, POCO, SSG (requirement:  $< 2$  nm rms)



Coorstek surfaces  
 $0.58 \pm 0.03$  nm rms  
(Data taken by 5 different positions)

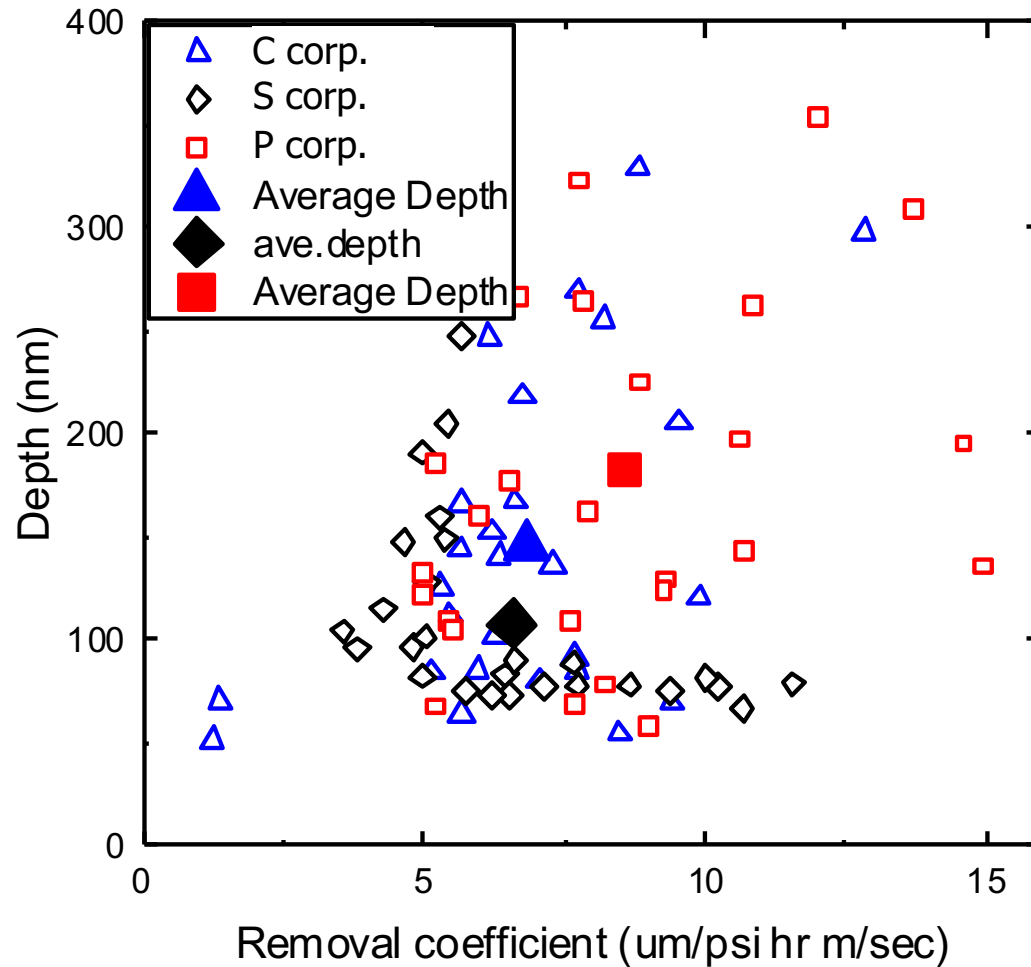
POCO surfaces  
 $0.50 \pm 0.02$  nm rms  
(Data taken by 5 different positions)

SSG surfaces  
 $1.16 \pm 0.17$  nm rms  
(Data taken by 3 different positions)

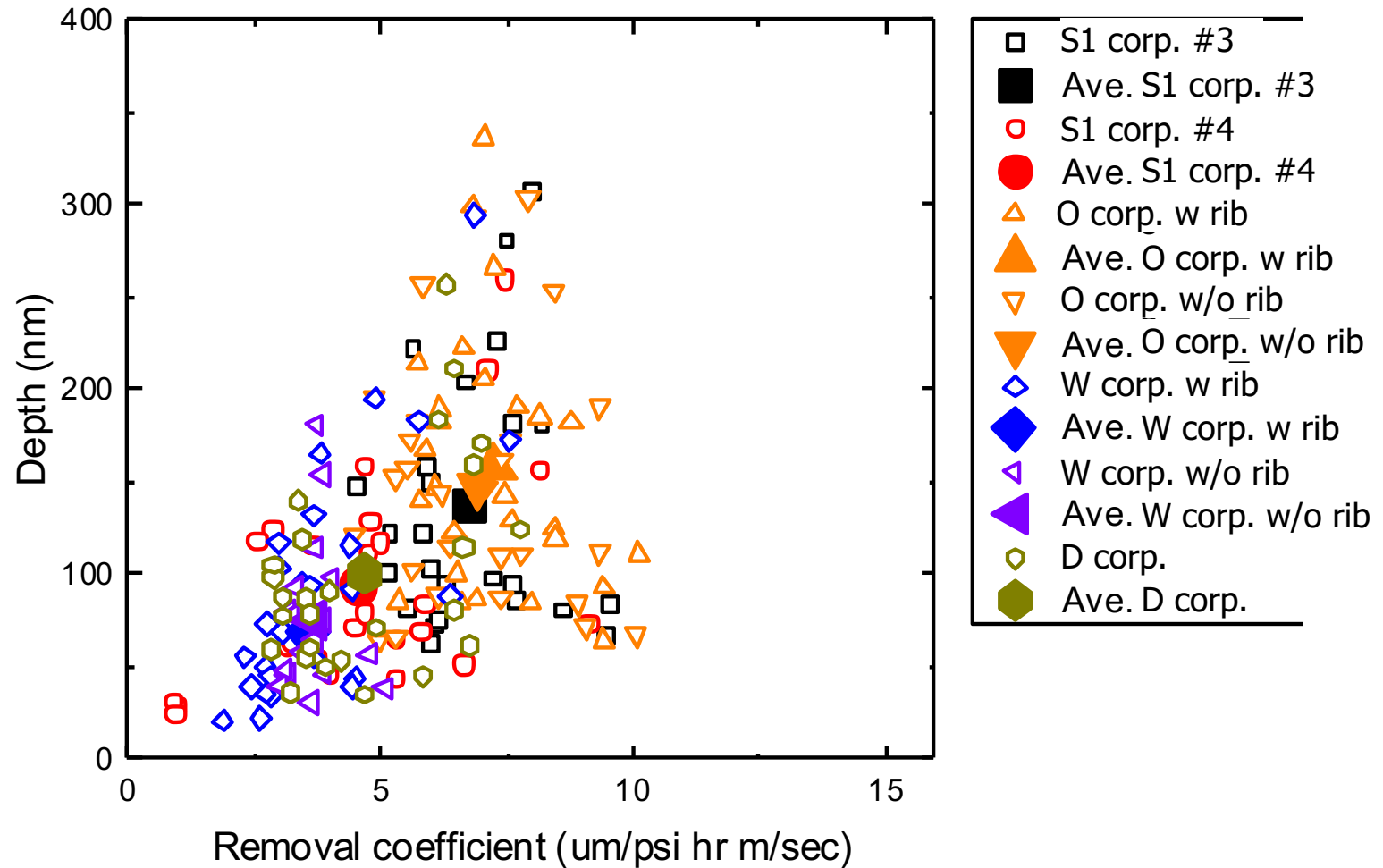
# TIF ANALYSIS

## 2. TIF analysis – MARI

Suggest below relationship as a MARI (MAterial Removal Indicator) for SiC mirrors

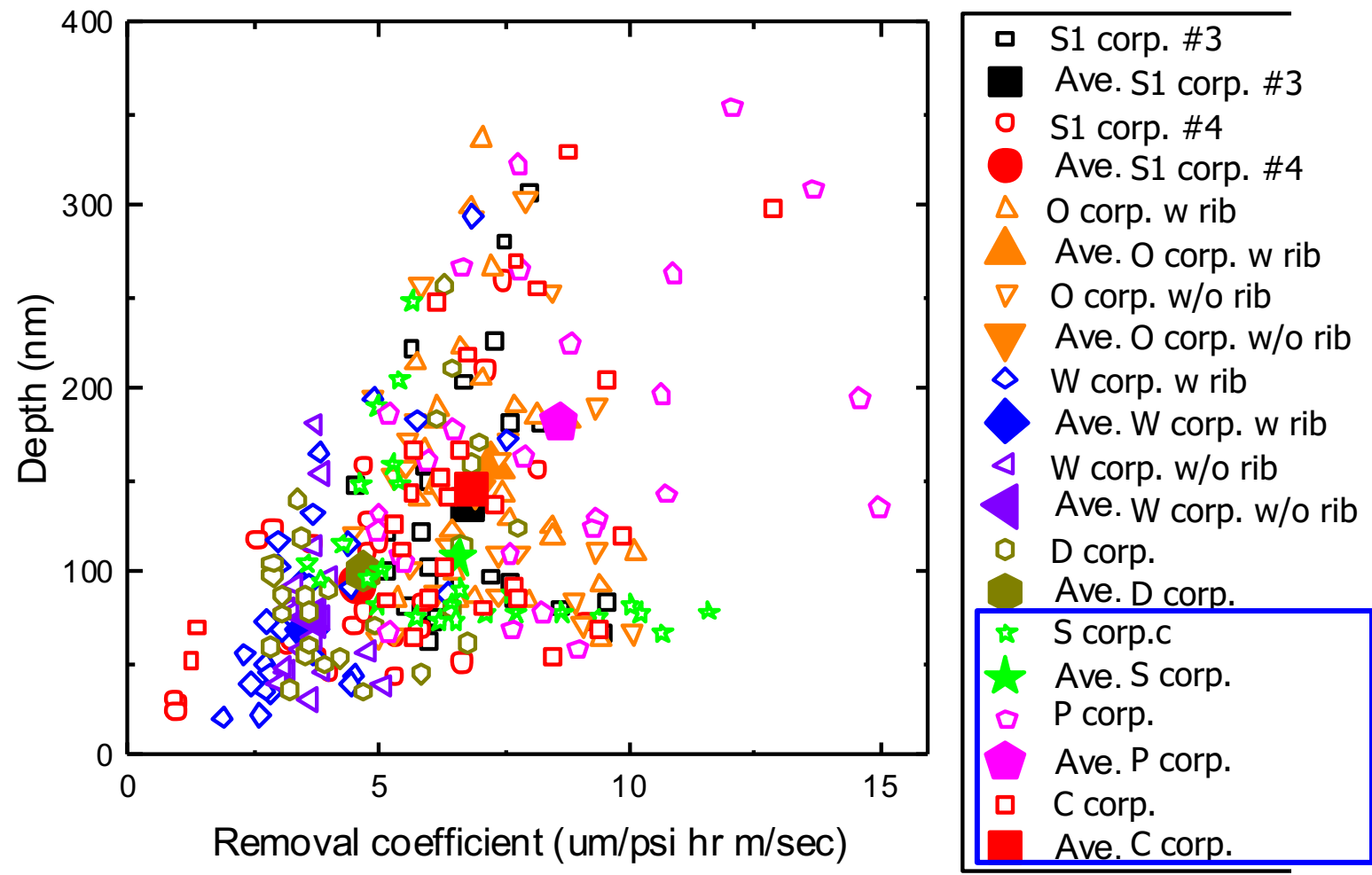


## 2. TIF analysis – MARI Korea

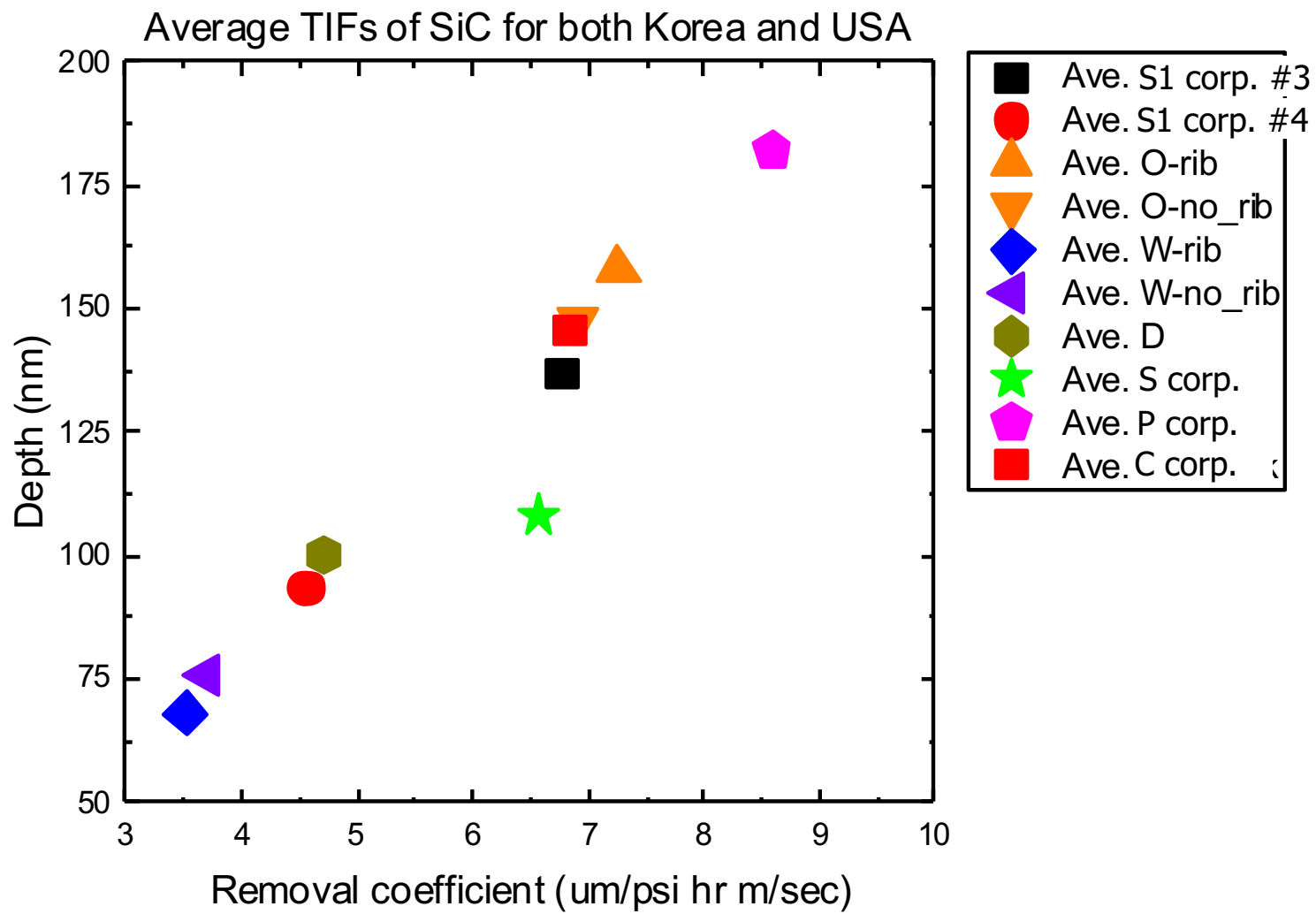




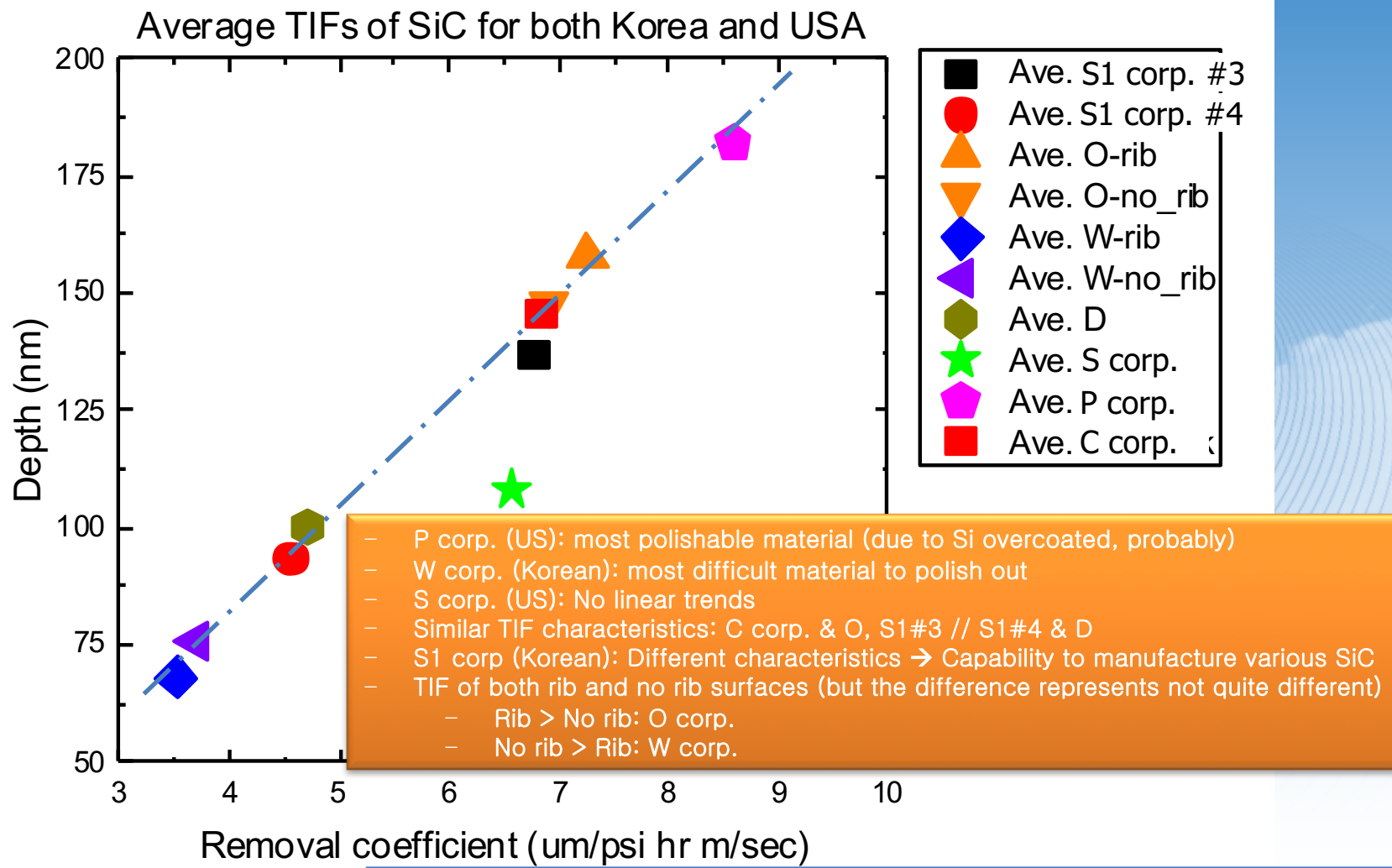
# 2. TIF analysis – MARI Korea & USA



# 2. TIF analysis – MARI comparison with average plot



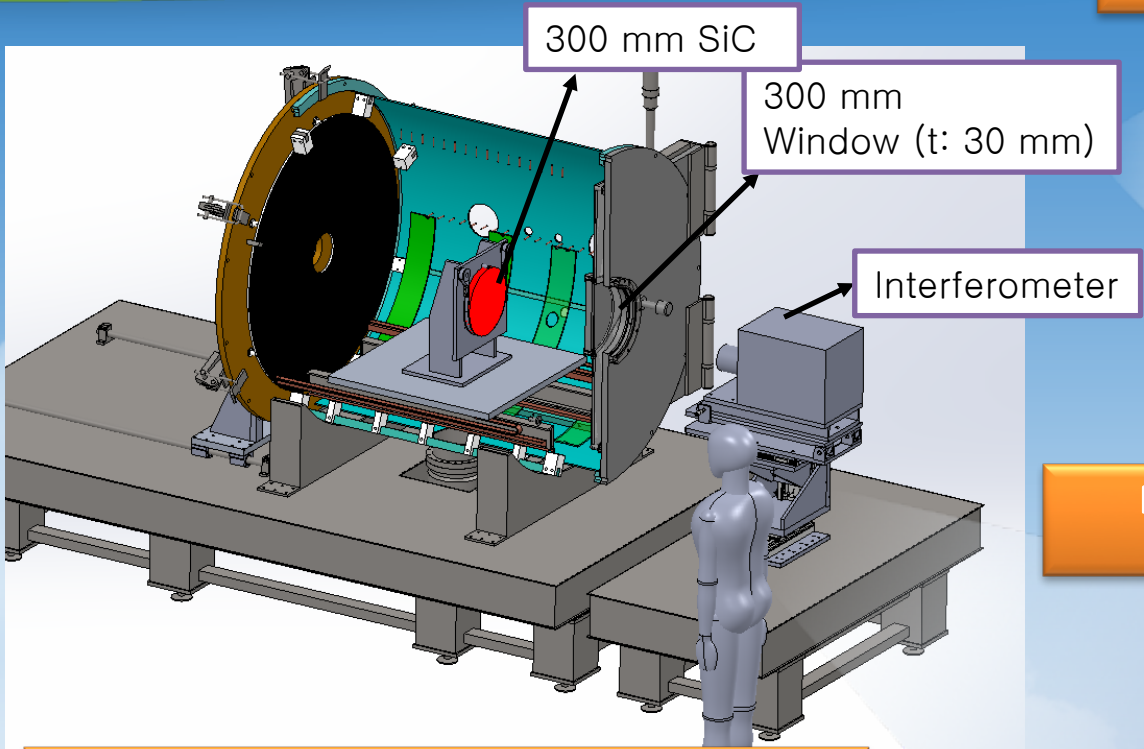
# 2. TIF analysis – MARI comparison with average plot



MARI concept can be used to characterize various SiC materials

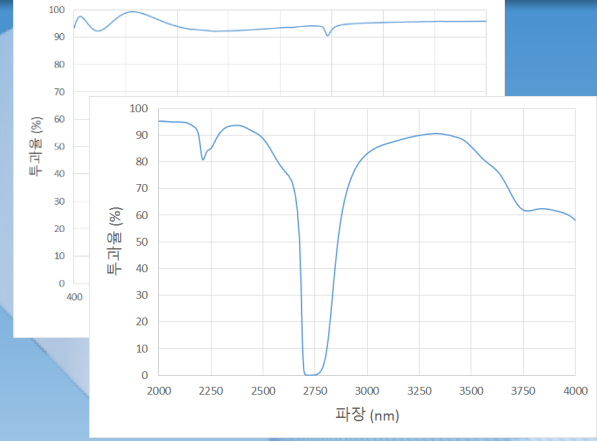
# PREPARATION FOR THERMAL TEST SETUP

# 3. Preparation of environmental testing chamber



Preliminary design for environmental testing (-40, -10, +20 degrees)

## Transmission curve on Chamber window



## Mechanical mounting specifications for interferometer movement

Parameters	Specifications
X Stroke	±90mm
Y Stroke (manual)	±5mm
Z Stroke	±90mm
Tilt (manual)	±3 (±5mm)
Load	100kgf
Accuracy	10μm
Repeatability	5μm
Speed	0.05~20mm/sec
Linearity	±0.07mm/190mm

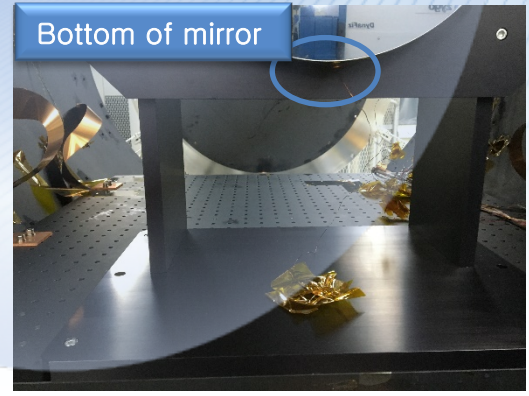
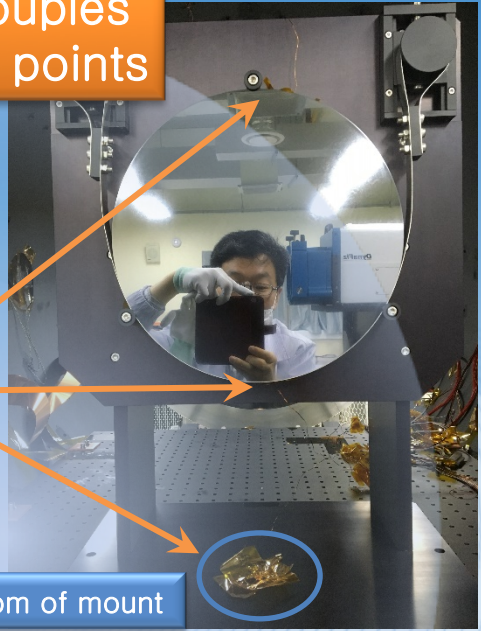


# 3. Preparation for thermal test setup (1/2)



Setting Thermocouples in 3 different points

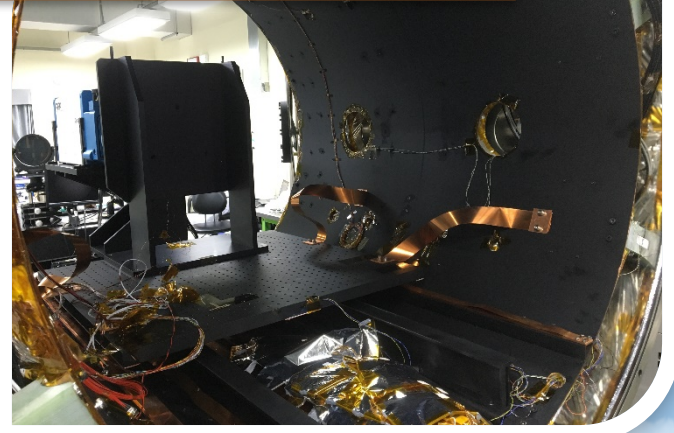
Location of 3 Thermocouples



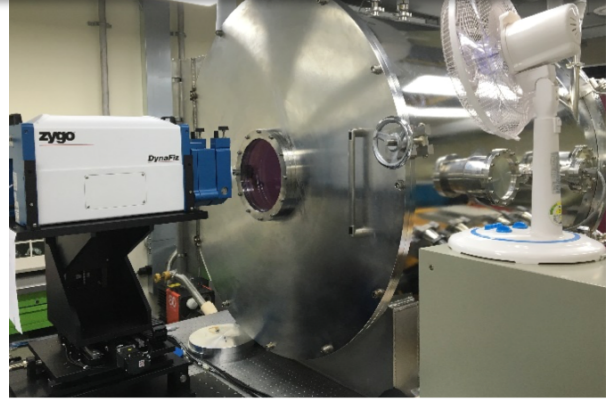


# 3. Preparation for thermal test setup (2/2)

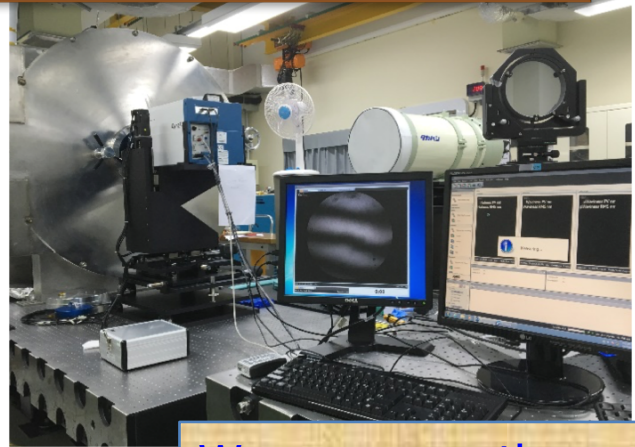
SiC setup in Chamber



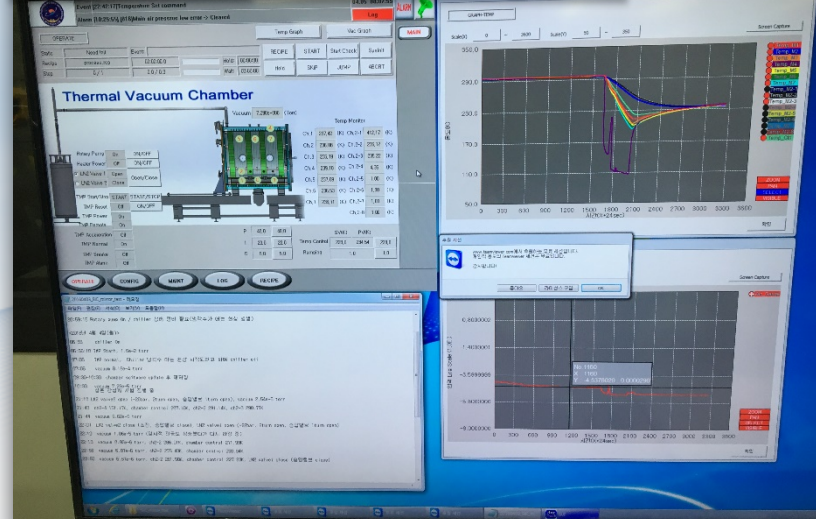
Chamber closed and measurement setup



WFE measurement while changing temperatures (+20C, -10C and -40C)



Control panel of Chamber



We are currently working on data acquisitions and post-processing

# CONCLUSION

## 4. Results and Implication

- ❖ Summary of polishing and environmental testing results for coupons and 300 mm SiC mirrors. We met all requirements including SSG SiC material.

		Coorstek	POCO	SSG
Coupons	Surface figure (nm rms)			12.3
	Roughness (nm rms)			0.092
300 mm	Surface figure (nm rms)	11.8	18.2	18.2
	Roughness (nm rms)	$0.58 \pm 0.03$	$0.50 \pm 0.02$	$1.16 \pm 0.17$
Preston coefficient (um/(psi·hour·m/sec))		6.83	8.59	6.57
Environmental testing (-40C, -10C, +20C)		Done (Obtain initial data)		

- ❖ Present the understandable TIF patterns
  - Established TIF characteristic maps for various SiC mirrors

## 4. Results and Implication

- ❖ It would be great to have a chance to get additional meaningful data during environmental testing at 2017 (plan)
  - Obtain a WFE pattern with different temperature
    - Fixed location of interferometer
- ❖ Preparation of Phase II planning by NOAO
  - Period: 2016~2018 (3 years)
  - Size: 500 mm in diameter
  - Shapes: Off-axis aspheric, Convex aspheric, Concave aspheric
  - Scope: Development of both polishing and material process



## 5. Conclusion

- TIF characteristics is presented under controlled machine parameters
- Preston Equation is applied to TIF characterization
- MARI is suggested as a MAterial Removal Indicator for SiC mirror substrates
  - The relationship between TIF and material removal coefficient of Preston Equation

# FUTURE WORKS

## – PREPARATION FOR PHASE II

# NOAO plan

## Plans for SiC Phase II (1/2)



### 1. Tasks (SOW for three years)

1. Develop a **competitive design** for SiC blank configuration
  - 500mm in diameter
  - on-axis aspheric blank (asphericity<1mm)
  - off-axis aspheric blank (off-axis<600mm)
  - double arch shape with depth > 60mm
  - Radius of curvature: 4000mm
  - Optimized lightweight mirror (<70%)
  - Polishable optical surface with SiC or Si overcoat
    - Over coating thickness (<300um)
2. Prepare a RFP for development of efficient **manufacturing** procedures.
3. Prepare a RFP for development of efficient **polishing** fabrication methods.
4. Award two/three contracts for development of SiC mirror **manufacturing and fabrication**.

# NOAO plan

## Plans for SiC Phase II (2/2)



### 1. Deliverables for Phase II

1. Multiple sets of SiC **blanks**
  - 2 sets of on-axis and off-axis blanks
2. 4 coupons per mirror blanks (5mmx5mm)
3. SiC mirror **blank testing data and** procedures
4. Multiple sets of SiC **polished mirrors**
5. SiC polished mirror **testing** data sheets and procedure
6. **Cost estimates** for SiC blank manufacturing and polishing

**KASI is welcoming potential contributors to join this program as a material provider, experiment contribution, for data analysis, expand MARI concept, or other common interests. Please contact Jeong-Yeol Han (jhan@kasi.re.kr)**



Thank you for attention