Development of Low Thermal Expansion Material and CTE measurement tool for EUVL

Asahi Glass Co., Ltd. *1
ASET *2

Yasutomi Iwahashi*1, Mitsuhiro Kawata*1
Shinya Kikugawa*1
Yoshimasa Takeichi*2, Iwao Nishiyama*2

contact : yasutomi-iwahashi@agc.co.jp

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Outline

CTE measurement tool

- Principle of measurement (Optical heterodyne interferometer)
- Reproducibility of measurements
- Accuracy of measurements

CTE properties of AZ

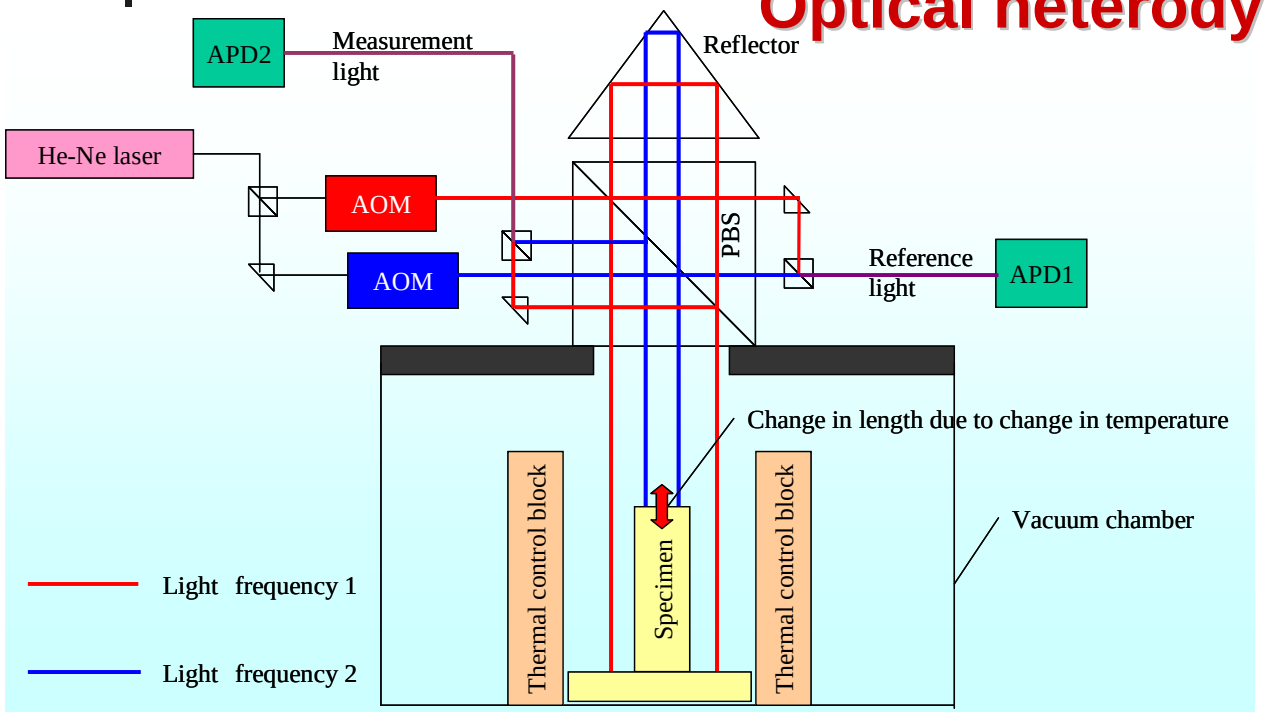
(= Asahi Zero-expansion glass)

- Dependence of CTE on temperature
- Dependence of CTE on TiO_2 concentration in AZ
- CTE variation within a substrate and among lots
- Various kinds of properties

CTE measurement tool (1)

Principle of measurement

Optical heterodyne interferometry



Electric field intensity

$$E_1 = a_1 \cos(2\pi f_1 t + \phi_1)$$

$$E_2 = a_2 \cos(2\pi f_2 t + \phi_2)$$

Intensity of superimposed light

$$I = \left\langle |E_1 + E_2|^2 \right\rangle$$

$$= \frac{a_1^2 + a_2^2}{2} + 2a_1 a_2 \cos\{2\pi(f_1 - f_2)t + (\phi_1 - \phi_2)\}$$

$$= \frac{a_1^2 + a_2^2}{2} + 2a_1 a_2 \cos\{2\pi f_b t + \Delta\phi\}$$

Phase difference between APD1 and APD2 at T_1 : $(\varphi_{APD2} - \varphi_{APD1})_{T1}$

Phase difference between APD1 and APD2 at T_2 : $(\varphi_{APD2} - \varphi_{APD1})_{T2}$

Change in phase difference between T_1 and T_2 : $\Delta(\phi_{APD2} - \phi_{APD1}) = \dfrac{2\pi\Delta L}{\lambda}$

ΔL : Change in length

(Quadruple - sensitivity)

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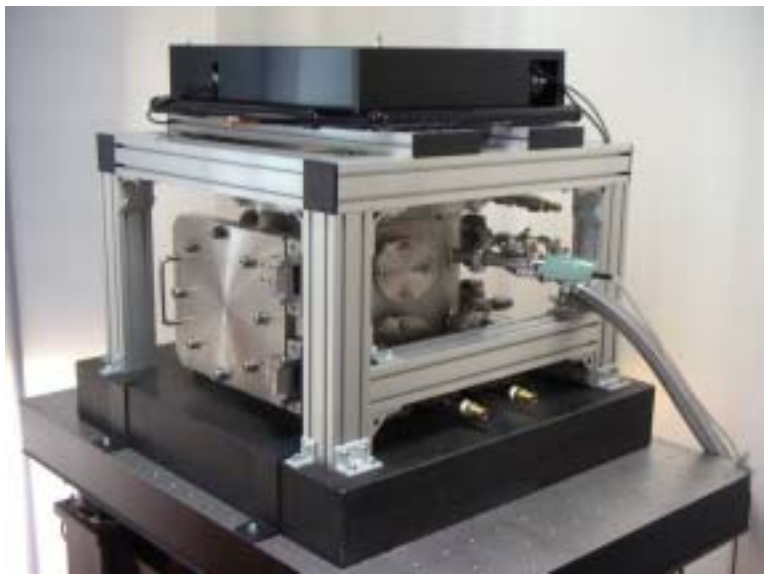
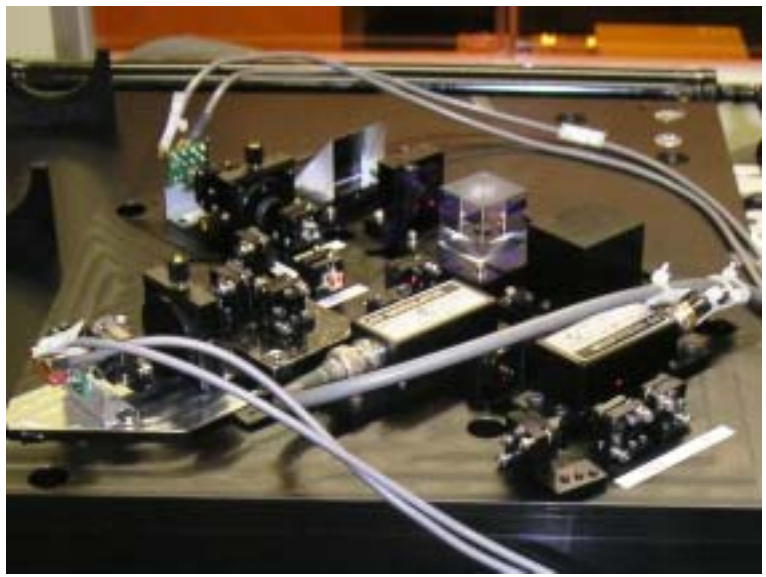
CTE measurement tool (2)

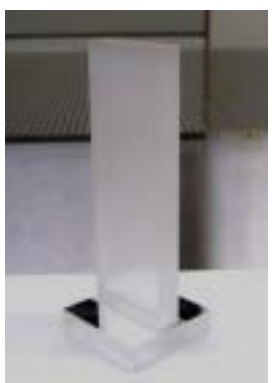
Practical Dilatometer, Sample

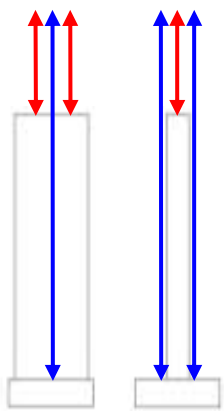
CTE-01

Equipment supplier: uniopt





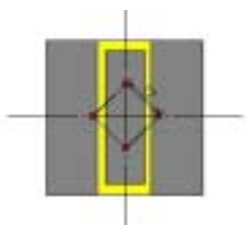




Optical path

Reference

Displacement



Arrangement of laser spot

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CTE measurement tool (3)

Reproducibility of Measurements

Sample: LTEM (Ti-doped silica glass)

Fig. Change in sample temperature

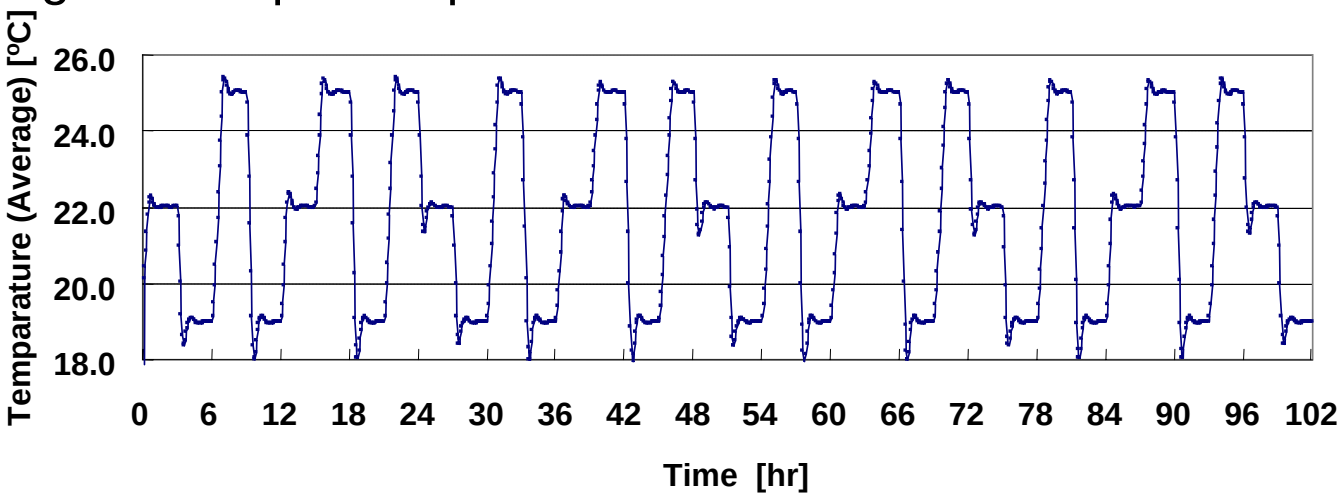
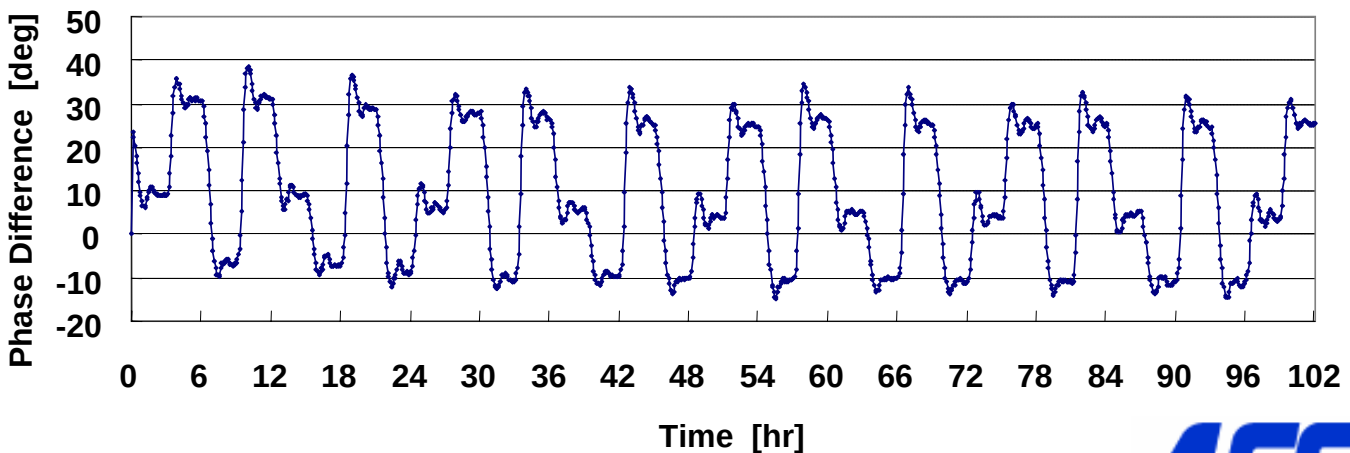


Fig. Change in phase difference



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CTE measurement tool (4)

Reproducibility of Measurements

Table Reproducibility of measurements [ppb/°C]

Test No.	No.1 (n=16)	No.2 (n=12)	No.3 (n=16)
σ	0.80	0.68	0.70
2σ	1.60	1.37	1.39
3σ	2.40	2.05	2.09
Average.	-26.8	-25.6	-27.3

Repeatability *1

σ: 0.80 ppb/°C

Resetability *2

ΔCTE: +/- 0.85 ppb/°C

***1** Repeatability (Static) :
reproducibility obtainable from measurements of the same sample without moving it .

***2** Resetability (Dynamic) :
reproducibility obtainable from measurements involves changing the sample.

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CTE measurement tool (5)

Accuracy of Measurements

Sample: LTEM (Ti-doped silica glass)

Table Comparison with AIST Measurement.

[ppb/^{o}C]

Sample	ASET	AIST	**Difference**
LTEM	4.0	2.3	**1.7**

19-25 ^{o}C, ΔT: 6 ^{o}C

➢ ASET is investigating the root-cause of difference, and considering the improvement for the dilatometer.

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CTE properties of AZ (1)

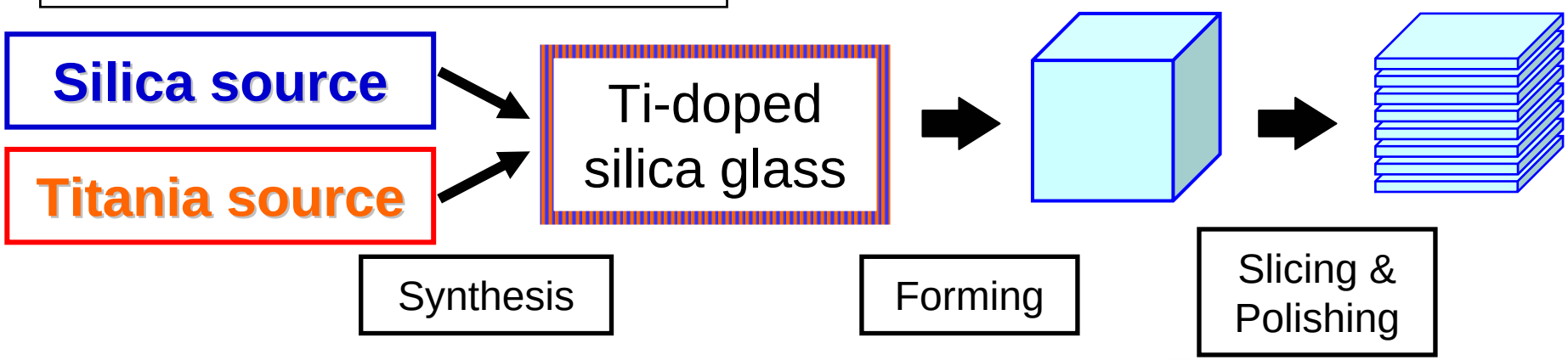
Development of AZ (LTEM)

➢ AGC has been developing Low Thermal Expansion Material produced by the method which is similar to "Asahi silica glass producing method".

Material : AZ (TiO_2-SiO_2 glass)

Highly homogeneous
Mass-producible
} fused silica glass,
AGC has been commercializing since 1985.

In the case of Ti-doped silica glass



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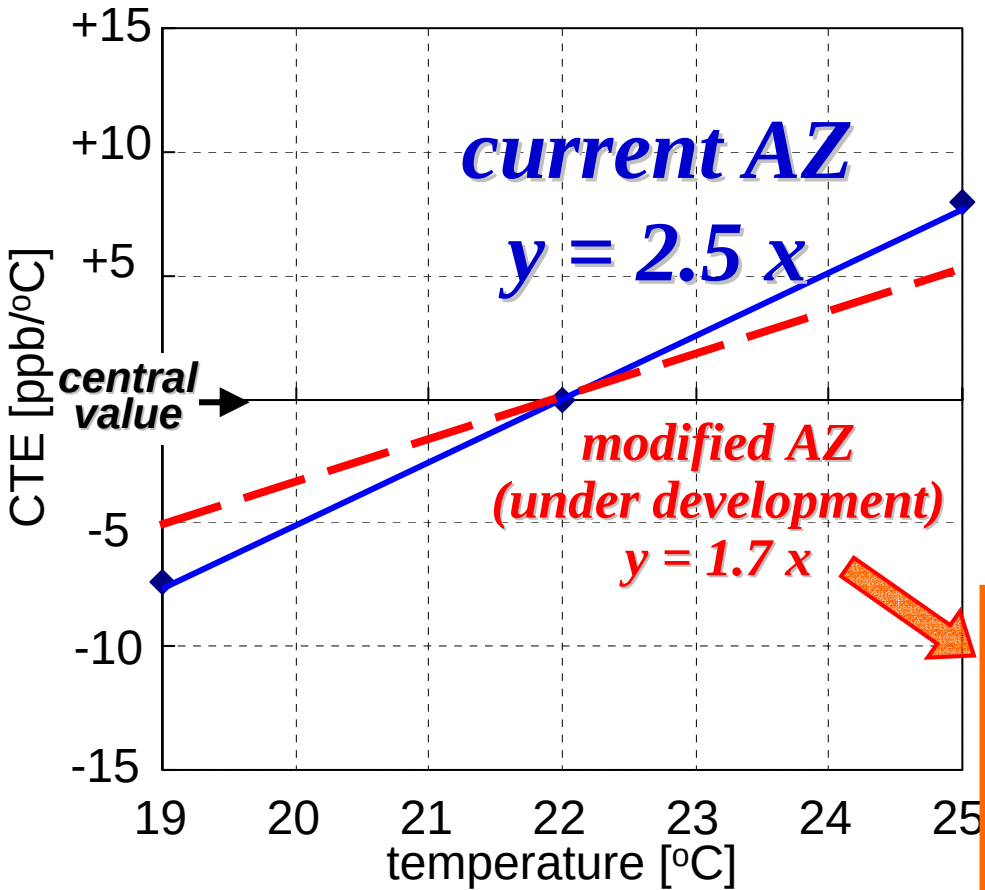
CTE properties of AZ (2)

Dependence of CTE on Temperature

- AGC have investigated the relationship between CTE of AZ and temperature.



CTE : measured by ASET's dilatometer

	CTE @ 19°C	CTE @ 22°C	CTE @ 25°C
measurement temperature [°C]	18 - 20	21 - 23	24 - 26
ΔT [°C]	2	2	2

AGC will start sample delivery of "modified-AZ" substrate for EUVL application from 2007.

CTE of AZ is in proportion to temperature within 19-25°C.

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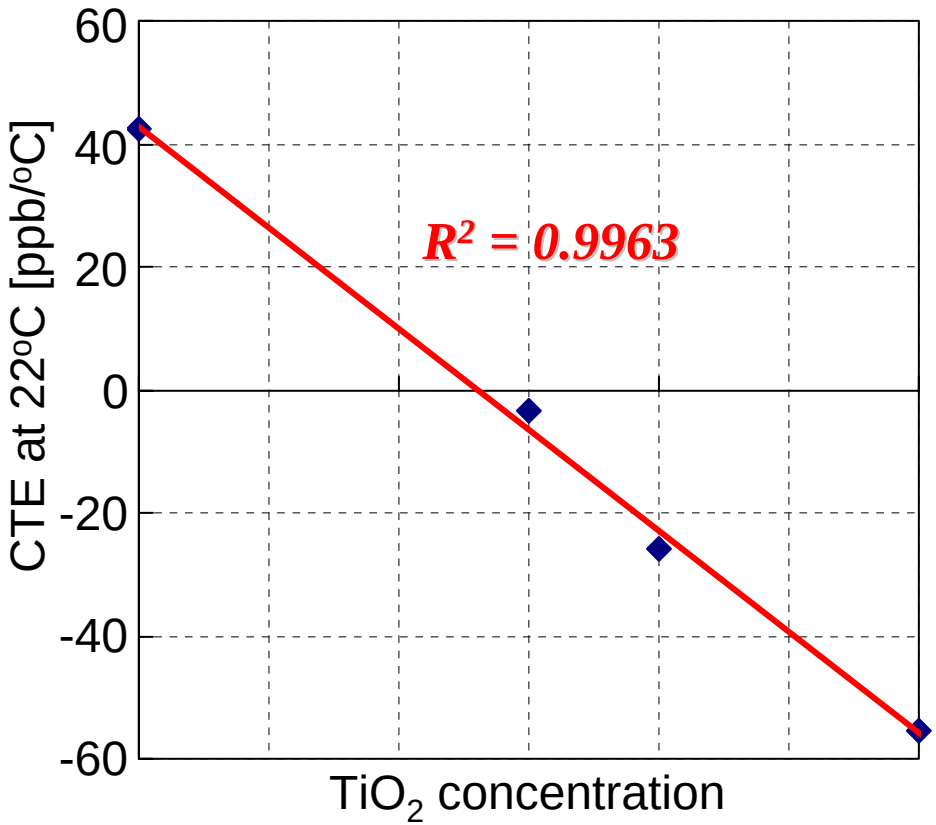
CTE properties of AZ (3)

Dependence of CTE on TiO_2 conc.

- AGC have investigated the relationship between CTE at 22ºC and TiO_2conc. in AZ.



CTE : measured by ASET's dilatometer

	CTE @ 22ºC
measurement temperature [ºC]	19 - 25
ΔT [ºC]	6

TiO_2 conc. : measured by XRF(X -ray Fluorescence Analysis)

CTE is in proportion to TiO_2 conc. in AZ.

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CTE properties of AZ (4)

CTE Optimization to Zero

- CTE of AZ can be optimized to zero
  using the linear correlation between CTE and TiO_2 conc.

Table CTE measurement result of AZ

CTE measurement Temperature [°C]	Measurement range			CTE [ppb/°C]
	T1[°C]	T2[°C]	ΔT[°C]	
22	19	25	6	**1.09**

AZ adjusted TiO_2 concentration showed nearly zero CTE at 22°C.

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CTE properties of AZ (5)

CTE Difference in Measurement Temp.

- The difference of CTE@22ºC between the measurement temp. range 6ºC(19-25ºC) and 2ºC(21-23ºC) have been investigated in AZ.

AZ Sample	CTE measurement temperature [ºC]	Measurement range			CTE@22ºC [ppb/ºC]	Difference [ppb/ºC]
		T1 [ºC]	T2 [ºC]	ΔT [ºC]		
A	22	19	25	6	-25.1	1.4
	22	21	23	2	-26.5	
B	22	19	25	6	-56.6	0.7
	22	21	23	2	-57.3	
C	22	19	25	6	42.3	0.7
	22	21	23	2	43.0	
D	22	19	25	6	1.1	1.8
	22	21	23	2	-0.7	

measured by ASET's dilatometer

In the case of AZ,

the difference of CTE@22ºC caused by the measurement range is very little.

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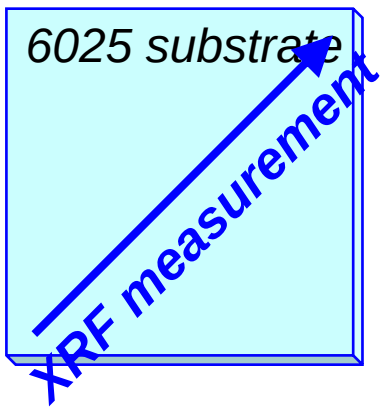
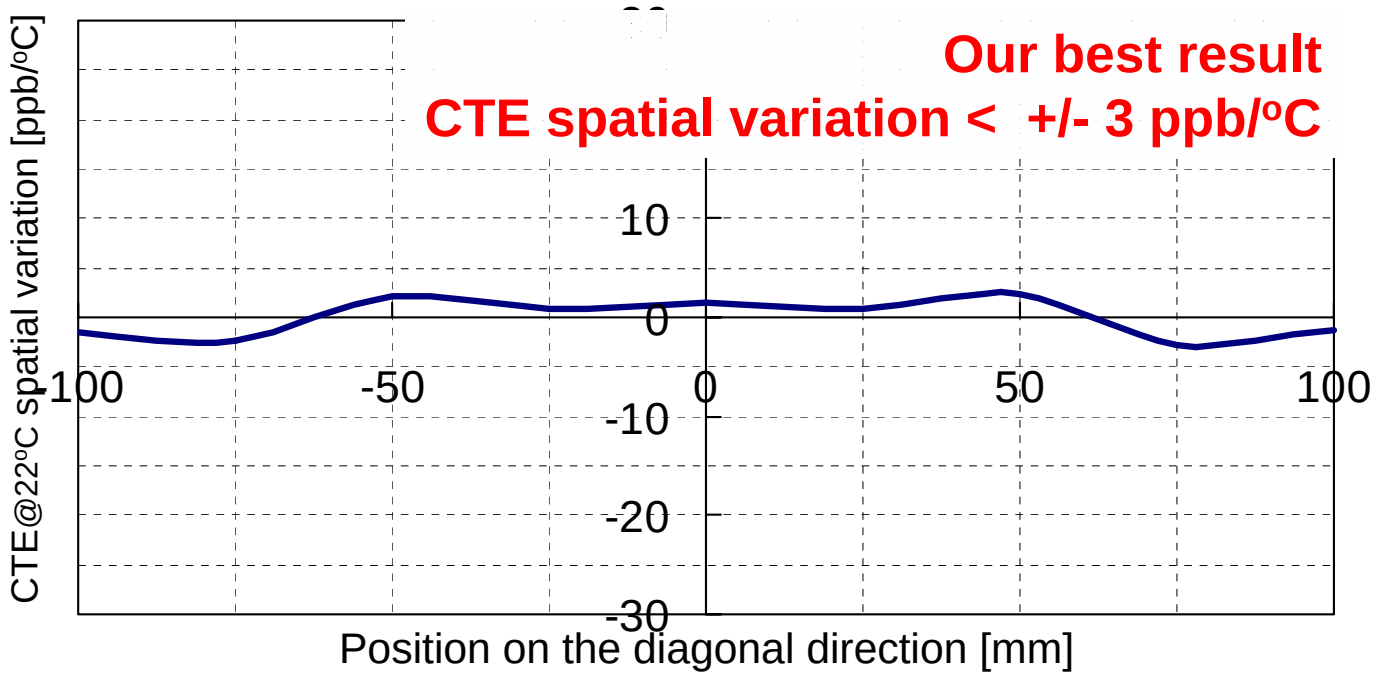
CTE properties of AZ (6)

CTE variation within a substrate

- CTE@22°C spatial variation within a AZ-substrate can be evaluated using the spatial variation of TiO_2 conc. measured by XRF, since CTE has the linear correlation with TiO_2 conc.





CTE@22°C spatial variation within 6025 substrate can be less than **+/- 3 ppb/°C.**

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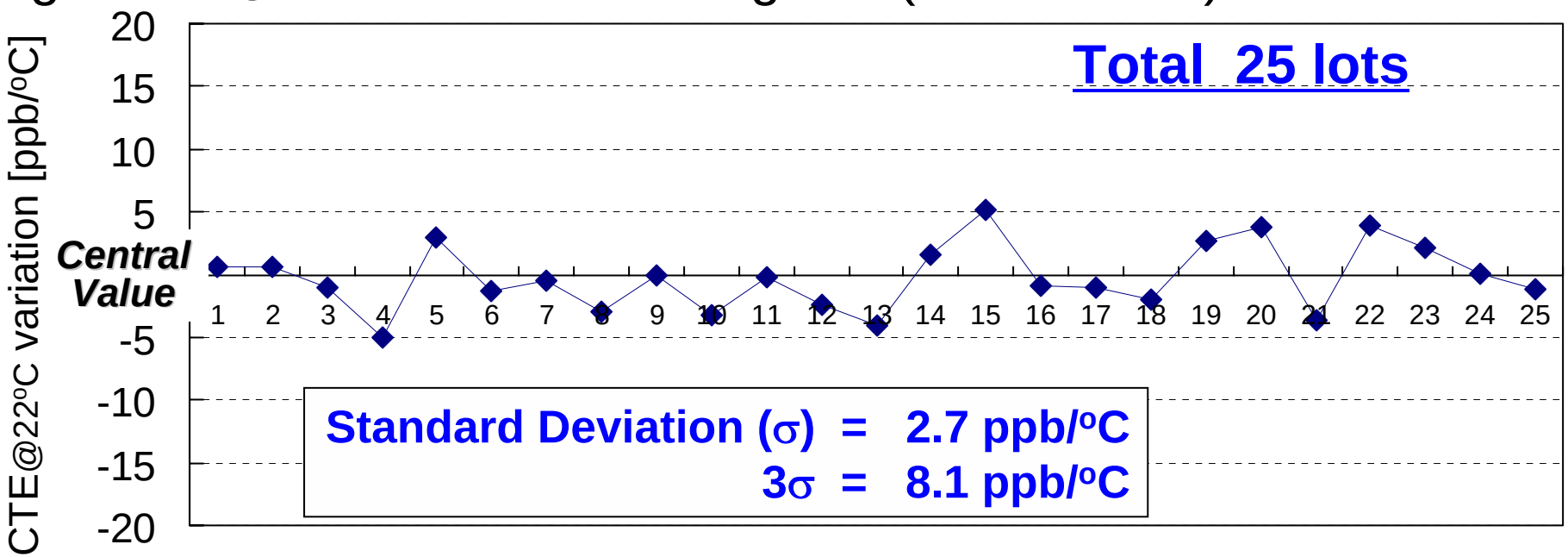
CTE properties of AZ (7)

CTE variation among lots

Fig. CTE@22°C variation among lots (Lot No.1-25)



- In order to monitor the trend of CTE variation, AGC have been measuring mean TiO_2 conc. every lot.
- Sigma(σ) of CTE@22°C variation among 25 lots is less than 3 ppb/°C.

Summary

CTE measurement tool

- Reproducibility of data

  Repeatability, σ<1ppb/^{o}C, Resetability, ΔCTE <+/- 1ppb/^{o}C

- Accuracy of data

  LTEM; <2ppb/^{o}C (under improving)

- ASET confirms that the CTE-01 will be useful for the precise measurement of the CTEs of EUVL-grade LTEMs.

CTE properties of AZ

- AGC have demonstrated

  the correlation between CTE and temperature (19-25^{o}C) and

  the correlation between CTE and TiO_2 conc. in AZ by ASET's dilatometer.

- AZ optimized TiO_2 conc. showed CTE =1.09 ppb/^{o}C at 22^{o}C

- CTE variation

  Spatial variation within a substrate, ΔCTE@22^{o}C < +/- 3ppb/^{o}C

  CTE@22^{o}C variation among 25 lots, σ< 3ppb/^{o}C

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