Korea Research Institute of Standards and Science
267 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea
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CERTIFICATE OF REFERENCE MATERIAL

· CRM Description: Certified reference material for the thickness of a thin film layer of silicon nitride grown on silicon

· CRM No.: 207-03-535 · Serial No.: CTN-12-120-01

· Specification: Nominal thickness of silicon nitride film layer 120 nm, Diameter of wafer 300 mm

· Producer: Korea Research Institute of Standards and Science, 267 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea

This thickness certified reference material(CRM) of thin film layer is a silicon nitride thin film layer grown on a single crystal silicon wafer.

Description of Certification

- Intended Use: The CRM is used to calibrate optical instruments such as ellipsometers which have a capability to measure the thickness of a film.
- Instructions for Storage and Use: This CRM can be easily contaminated, so please be careful when storing and using it. Measure the CRM after washing it with high-purity isopropyl alcohol, washing it with ultra-pure water, drying it by blowing with high-purity nitrogen gas, and letting it settle in the air for (20-30) min.
- Method(s) of Certification: Refer to the “Detailed Information” on the next page(s).
- Certified Reference Values and Uncertainties: Refer to the “Detailed Information” on the next page(s).
- Metrological Traceability: Refer to the “Detailed Information” on the next page(s).

Safety Information: Material Safety Data Sheet(MSDS) is not required.

Date of Certification: *dd mm yyyy* Valid until: 60 Months From Date Of Certification

This is to certify that the above CRM(Certified Reference Material) is traceable to the national measurement standards in accordance with the provision of Article 13 of the Framework Act on National Standards.

- **Date of Issue :** *dd mm yyyy*
- **Approved by :** Chegal, Won Sign

President of KRISS Seal

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DETAILED INFORMATION

Used Instrument for Certification

- Description : KRISS Reference Spectroscopic Ellipsometer
- Manufacturer & model : KRISS & RTSE-VA-VSH-UV~NIR-1000

Certification Method

- Preparation and certification of reference materials used for optical measurement of thickness of a silicon nitride layer on silicon [R-207-018]

Certification Traceability of Used Instrument

- These certified results have traceability to the definition of the base unit of the international system (SI) of units, through the calibrated KRISS reference spectroscopic ellipsometer.

Conditions on Measurement and Analysis

- Measurement conditions (level of confidence: 68 %, coverage factor: κ =1)
  - Measurement wavelength(λ) : (229.5~989.5) nm ± 0.5 nm
  - Angle of incidence(ϕ) : (65.000, 70.000, 75.000)° ± 0.006°
  - Measurement position : Inside a 2.5 cm x 2.5 cm square area centered on the sample
- Analysis model structure : (Air)/(silicon nitride film layer)/(single crystal silicon substrate)

Certification Results

- Average value of the observed spectrum of ellipsometric transfer quantitities(ETQs)
  - Structure of the attached observed data file: 0000-00000-000_Certified Values of ETQs.dat

1st Column	2nd Column	3rd Column	4th Column	5th Column	6th Column
λ / nm	ϕ / °	Average of N_m values	Type A standard uncertainty of $\overline{N}_m$	Type B standard uncertainty of $\overline{N}_m$	Combined standard uncertainty of $\overline{N}_m$
7th Column	8th Column	9th Column	10th Column	11th Column	12th Column
Average of C_m values	Type A standard uncertainty of $\overline{C}_m$	Type A standard uncertainty of $\overline{C}_m$	Combined standard uncertainty of $\overline{C}_m$	Average of Ψ values / °	Type A standard uncertainty of $\overline{\Psi}$ / °
13th Column	14th Column	15th Column	16th Column	17th Column	18th Column
Type B standard uncertainty of $\overline{\Psi}$ / °	Combined standard uncertainty of $\overline{\Psi}$ / °	Average of Δ values / °	Type A standard uncertainty of $\overline{\Delta}$ / °	Type B standard uncertainty of $\overline{\Delta}$ / °	Combined standard uncertainty of $\overline{\Delta}$ / °

☞ Ellipsometric Transfer Quantity(ETQ): $\{N_m[=\cos(2\Psi)], C_m[=\sin(2\Psi)\cos\Delta]\}$ or $\{\Psi, \Delta\}$.

☞ Example) Certified average value of each ETQ observed at a measurement wavelength of (250.3±0.5) nm and an incident angle of (65.000±0.006)°, [level of confidence: 95 %, coverage factor: κ=2].

- $\overline{N}_m$ = 0.4522 ± 0.0035
- $\overline{C}_m$ = −0.5195 ± 0.0228
- $\overline{\Psi}$ = (31.56 ± 0.11)°
- $\overline{\Delta}$ = (125.56 ± 1.73)°

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- Analyzed results of thin film layer thickness and complex refractive indices of each layer.
  - Thickness of thin film layer : (118.18 ± 0.28) nm (level of confidence: 95 %, coverage factor: κ=2)
  - Structure of the attached analyzed data file: 0000-00000-000_Certified Values of Complex Refractive Indices.dat (level of confidence: 68 %, coverage factor: κ=1)

1st Column	2nd Column	3rd Column	4th Column	5th Column
WL / nm	Refractive index of thin film layer	Extinction coefficient of thin film layer	Combined standard uncertaity of refractive index of thin film layer	Combined standard uncertaity of extinction coefficient of thin film layer
6th Column	7th Column	8th Column	9th Column	
Refractive index of c-Si substrate	Extinction coefficient of c-Si substrate	Combined standard uncertaity of refractive index of c-Si substrate	Combined standard uncertaity of extinction coefficient of c-Si substrate	

☞ In the complex refractive index, which is a complex number, the real part is the refractive index [$n(\lambda)$], and the imaginary part is the extinction coefficient [$k(\lambda)$].

☞ Example) Analyzed results of complex refractive index of each layer at a measurement wavelength of (250.3±0.5) nm (level of confidence: 68 %, coverage factor: κ=1)

- Refractive index of thin film layer(n_f) : 2.655 ± 0.097
- Extinction coefficient of thin film layer(k_f): 0.028 ± 0.009
- Refractive index of c-Si Substrate(n_s) : 1.631 ± 0.020
- Extinction coefficient of c-Si Substrate(k_s): 3.689 ± 0.044

- The thickness of the thin film layer was determined from the ellipsometiric transfer quantity spectrum observed when fixed input values for the complex refractive indices of each layer were adopted as the reference values below in the analysis model.
  - Thickness of thin film layer : (118.18 ± 1.44) nm (level of confidence: 95 %, coverage factor: κ=2)

☞ The complex refractive index ($\tilde{N}_f = n_f - ik_f$) value of the thin film layer is obtained using the relation of $\tilde{N}_f = \sqrt{\epsilon_f}$ from the Tacu-Lorentz dispersion function ($\epsilon_f = \epsilon_{f,1} - i\epsilon_{f,2}$) below.

$$\epsilon_{f,1}(E) = \epsilon_\infty + \frac{2}{\pi}\int_{E_g}^{\infty}\frac{\xi\epsilon_{f,2}(\xi)}{\xi^2 - E^2}d\xi, \quad \epsilon_{f,2}(E) = \begin{cases} \dfrac{A_m C E_0 (E-E_g)^2}{(E^2-E_g^2)^2 + C^2E^2}\dfrac{1}{E}, & (E > E_g) \\ 0, & (E \le E_g) \end{cases}$$

☞ The reference value of the refractive index of the thin film is fixed as a result calculated using the values of the parameters of the Tauc-Lorentz dispersion function below obtained from the silicon nitride thin film thickness certification standard(level of confidence: 68 %, coverage factor: κ=1).

- ϵ_∞ = 1.437 ± 0.258
- A_m = (80.83 ± 8.73) eV
- C = (2.420 ± 0.356) eV
- E_0 = (8.617 ± 0.353) eV
- E_g = (3.753 ± 0.038) eV

☞ The attached certified data were used as fixed input data for the complex refractive indices ($\tilde{N}_s = n_s - ik_s$) of the silicon substrate layer in the analysis model(level of confidence: 68 %, coverage factor: κ=1).

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