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(72) EXPO 404-606

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(74)
:

(54)

10 ~ 40nm

가

가

가

가

가

가

- 1. 가
- 2. A B h
- 3.
- 4a. 가 $z_{\uparrow} \left(= \frac{1}{2} \frac{d\phi}{dk} \right)$ ()
- 4b. 가 $z_{\downarrow} \left(= \frac{1}{2} \frac{d\phi}{dk} \right)$ ()
- 5a. ()
- 5b. ()
- 6.
- 7a. (: I(z))
- 7b. (: J(k)=FFT[I(z)])
- 8. 94nm VLSI (h=95.3nm)

가 , () 가 () (異種)

가 가 가 가 (同種) (異種)

가 , 가 (同種) 가 ()

가 2 (ambiguity) (μm) , 가 가 (st

ray diffraction)

가 (異種)

m) 가 (Phase Shifting Interferometry) 10 40 (n

가

가

(異種)

가

(Micheolson), (Mirau), (Linnik)
(NA)

$z_o :$

$z_m :$

$z_{env} :$

$z_{fringe} :$

가 $(z_{env} = z_m)$
 $(z_{fringe} = z_m - \phi_m / 2k_0)$

$z_\phi :$

$\phi_m :$

$h :$

$H :$

$h_1 : k_1$ (파장 λ_1)

$h_2 : k_2$ (파장 λ_2)

$\Delta z : h_2 - h_1$

$k_0 : (k_0 = 2\pi / \lambda_0)$

$k_1 : h_1 (k_1 = 2\pi / \lambda_1)$

$k_2 : h_2 (k_2 = 2\pi / \lambda_2)$

(NA)

z_o

z

(: G. Kino, S. Chim, "The Mirau correlation microscop

e," App.Opt, 29(26), 3775-3783 (1990))

$$I(z) = I_0 \int_{k_0 - \Delta k/2}^{k_0 + \Delta k/2} [1 + \gamma(k) \cos(2k(z-z_0) + \phi(k))] F(k) dk \quad (1)$$

(1) $\gamma(k)$, $\phi(k)$, $F(k)$, k_0 , Δk
 $(k_0 = 2\pi / \lambda_0, \lambda_0)$, Δk
 $\phi(k)$ (Fresnel Equation) 가

$$\gamma = \frac{n_i - n_t}{n_i + n_t} \quad (2)$$

(2) n_i, n_t
 $n_i = 1$

$$n_t = n - ik$$

ϕ

$$\tan \phi = \frac{2k}{n^2 + k^2 - 1} \quad (3)$$

$$I(z) = g(z - z_m) \cos(2k_0(z - z_m) + \phi_m) \quad (4)$$

(4) I_0 , $g(z - z_m)$ 가 (Envelope Function), ϕ_m (4) 1 (Envelope Peak) 가 $z_{env} = z_m$, $z_{fringe} = z_m - \phi_m / 2k_0$ (Fringe Peak) 2 A, B $(\phi^B - \phi^A) / 2k_0$ h

(T. Doi, K. Toyoda, Y. Tanimura, Effects of phase changes on reflection and their wavelength dependence in optical profilometry" App. Opt, 36, 71 57(1997))

$$\Phi(k) = \phi(k) + 2k(z - z_0) \quad (5)$$

$\phi(k)$ 가 z_{env} k (Edward D. Palik, Handbook of Optical Constants of Solids Vol I, Academic Press, (1985)). 3

$$\phi(k) \cong \phi(k_0) + (k - k_0) \frac{d\phi}{dk} \quad (6)$$

$$\Phi(k) \cong \phi(k_0) - k_0 \frac{d\phi}{dk} + 2k(z - (z_0 - \frac{1}{2} \frac{d\phi}{dk})) \quad (7)$$

$$F(k), \gamma(k) \text{ 가 } \Phi(k) \text{ 가 } z_m \quad (8)$$

$$z_m = z_0 - \frac{1}{2} \frac{d\phi}{dk} = z_0 - z_\phi \quad (8)$$

$$(d\phi^A / dk - d\phi^B / dk) / 2 \text{ 가 } A, B \text{ h } (d\phi^A / dk - d\phi^B / dk) / 2 \text{ 가 } 4(a) \text{ 가 } A, B \text{ k } 4(a) \text{ 가 } h$$

$$k_1 < k_2 \text{ 가 } k_1, k_2 \text{ (Wavenumber), } k = 2\pi/\lambda$$

$$h_1 = h - \frac{\phi_1^A - \phi_1^B}{k_1}, \quad h_2 = h - \frac{\phi_2^A - \phi_2^B}{k_2} \quad (9)$$

(9) A, B k_1, k_2 A, B $\phi_1^A, \phi_1^B, \phi_2^A, \phi_2^B$, 1 2

$$h_1, h_2, h$$

가

H

H

,

(8) 가

z_ϕ

$$z_\phi \equiv \frac{1}{2} \frac{d\phi}{dk} \approx \frac{1}{2} \frac{\phi_2 - \phi_1}{k_2 - k_1} \quad (10)$$

(10) 가 z_ϕ , 가 z_{mz} A, B H

$$H = h - \frac{1}{2} \frac{(\phi_2^A - \phi_1^A) - (\phi_2^B - \phi_1^B)}{k_2 - k_1} \quad (11)$$

h_1, h_2

(9) Δh

$$\Delta h = h_2 - h_1 \cong -\frac{1}{k_c} [(\phi_2^A - \phi_1^A) - (\phi_2^B - \phi_1^B)] \quad (12)$$

(12) k_1, k_2 k_c , 가

$$h = H - \frac{1}{2} \frac{k_c(h_2 - h_1)}{k_2 - k_1} \quad (13)$$

(13) H h_1, h_2 가 4(b)

$$k_1, k_2 \quad (\phi_1^A - \phi_1^B)/k_1, (\phi_2^A - \phi_2^B)/k_2 \quad -\frac{1}{2} (d\phi^A/dk - d\phi^B/dk)$$

가

가

3

1

가

(Fringe Peak)

ϕ_{mz}

가

가

Δk

(1)

Δk

$\phi(k)$ 가

Δk

5

$\phi(k_1), \phi(k_2)$

(13)

k_1, k_2

h_1, h_2

1 가

b) (13) 가

h

5(

6

6

λ_1, λ_2

60)

(100)(110)

(120)

(130)

(1

(160)

(140)

(190)

(140)

(160)

(170)

(180)

$$\lambda_1 = 650nm, \lambda_2 = 550nm, \Delta\lambda = 70nm$$

$$\lambda_1 = 650nm, \lambda_2 = 550nm$$

(P. Sandoz, "Wavelet transform as a processing tool in white-light interferometry," Opt. Lett, 22, 1065 (1997) ; P. Groot, L. Deck, "Three-dimensional imaging by sub-Nyquist sampling of white-light interferograms" Opt. Lett, 18, 1462 (1993))가 (Fourier Transform) (Frequency Domain Analysis) I(z) J(k)=FFT[I(z)]

$$\angle J(k) = \phi(k) - 2(k - k_0)z_m \quad (14)$$

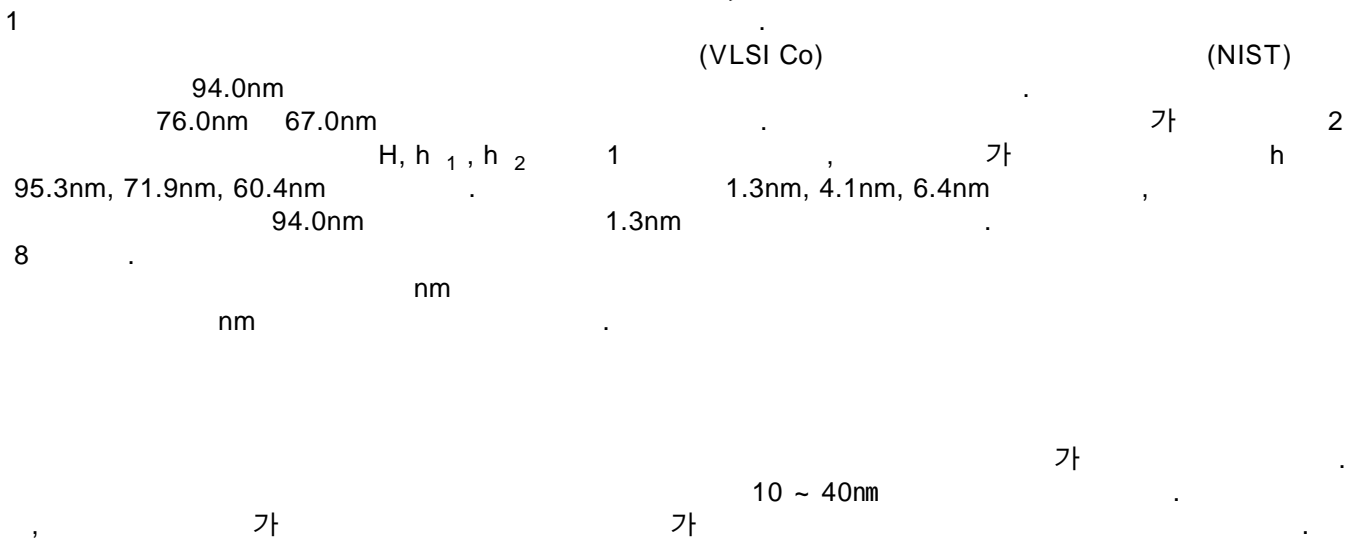
(14) 가 z_m k k_1, k_2 ϕ_1, ϕ_2 $k_1(=2\pi/\lambda_1), k_2(=2\pi/\lambda_2)$ $\phi(k_1), \phi(k_2)$ 2 가

$$h_1, h_2, H, h$$

[1]

	h_1 (nm)	h_2 (nm)	H (nm)	h (nm)
94nm Step Height (VLSI Co)	45.5	68.2	162.9	95.3
76nm Step Height (Chromium doped on Glass Substrate)	50.3	46.7	61.0	71.9
67nm Step Height (Gold doped on Glass Substrate)	39.1	31.1	36.6	60.4

표 1 두과장 백색광 간섭법에 의한 단차 측정 결과;
 h_1, h_2 : 위상 정점에 의한 측정 결과($\lambda_1=650nm, \lambda_2=550nm$),
 H: 가시도 정점에 의한 측정결과, h: 보상결과



가 가 , 가 가
 가 가 , 가 가
 ±2 (nm),

(57)

1. (h)

h
 H
 h₁ k₁ (파장 λ₁)
 h₂ k₂ (파장 λ₂)
 , (h) (H); k₁ (파장 λ₁)
 (h₁); k₂ (파장 λ₂)
 (h₂);

2.

1
 (h)
$$h = H - \frac{1}{2} \frac{k_c(h_2 - h_1)}{k_2 - k_1}$$

 {
 H:
 h₁: k₁ (파장 λ₁)
 h₂: k₂ (파장 λ₂)
 k₀: (k₀ = 2π/λ₁)
 k₁: h₁ (k₁ = 2π/λ₁)
 k₂: h₂ (k₂ = 2π/λ₂) }
 }

3.

1 2
 H:
 h₁: k₁ (파장 λ₁)
 h₂: k₂ (파장 λ₂)
 가 k₁ (파장 λ₁) (H) 1 ;
 ; (h₁) 2
 ; 가 k₂ (파장 λ₂) (h₂) 3
 ;

4.

1 2
 (H)
 (h₁) k₁ (파장 λ₁)
 (h₂) k₂ (파장 λ₂)
 k₁ (파장 λ₁) k₂ (파장 λ₂)

5.

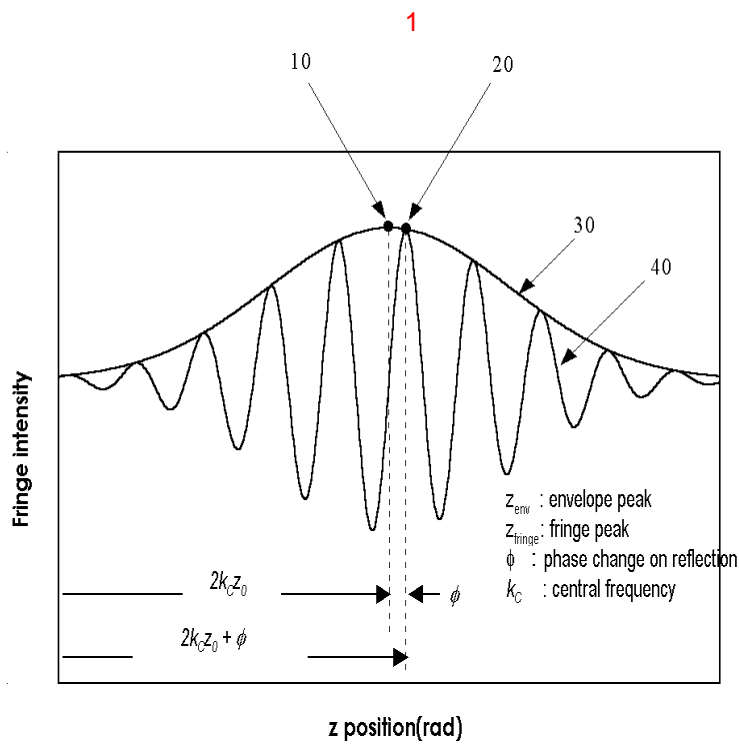
1 2

k_2 (파장 λ_2) (H) , k_1 (파장 λ_1) (h₁)
 (h₂)

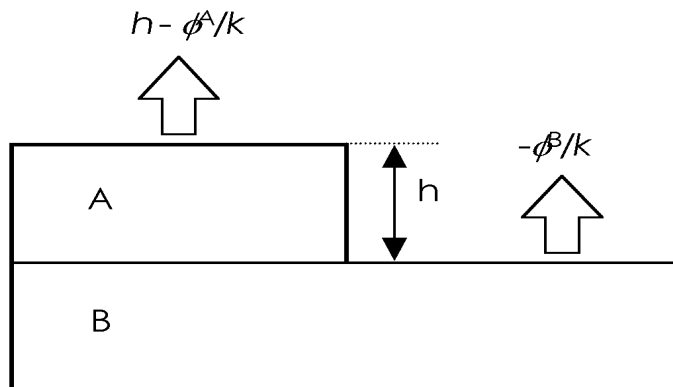
6.

5

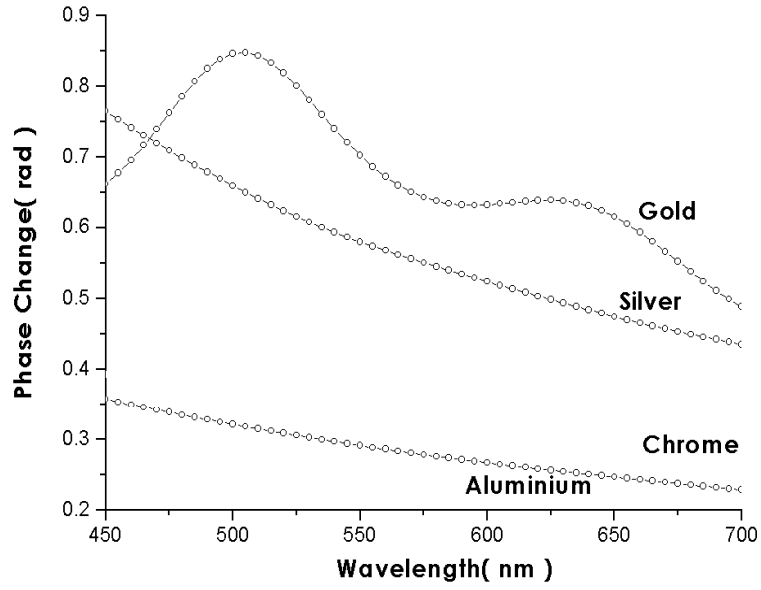
k_1 (파장 λ_1) k_2 (파장 λ_2) (120);
 (160); (160) (130); (190) (140);
 (140) (170) (180)



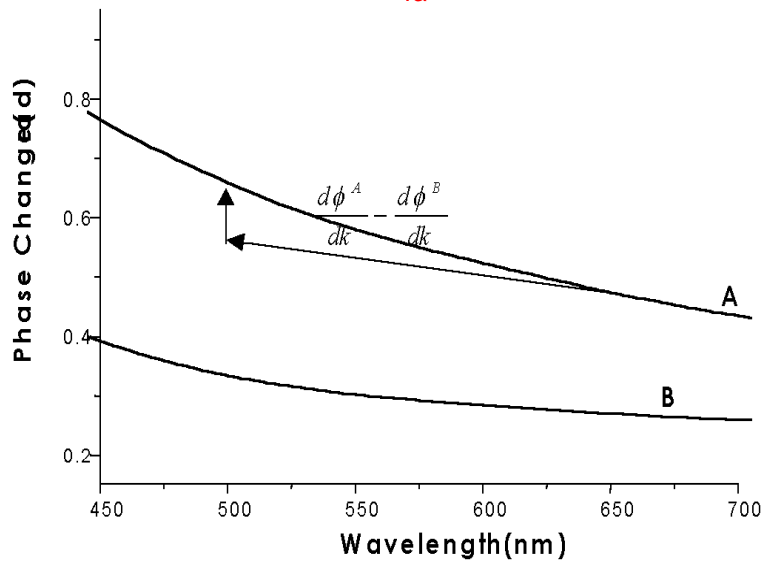
2



3

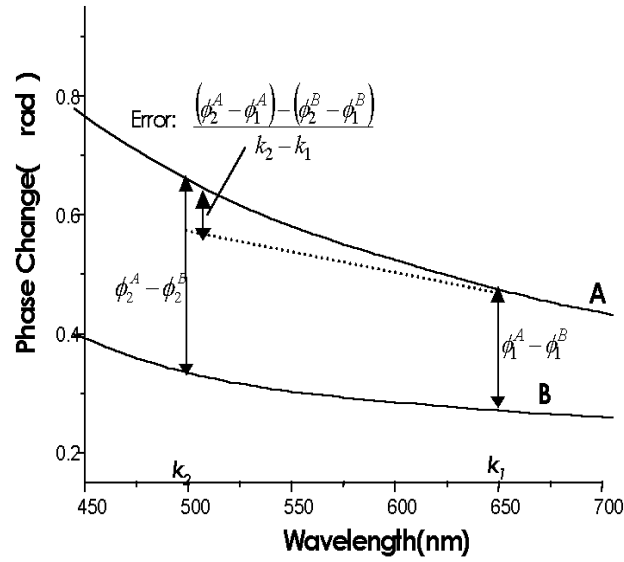


4a



입의의 두 금속 A, B 에 의한 위상변화율 오차 : $\frac{d\phi^A}{dk} - \frac{d\phi^B}{dk}$

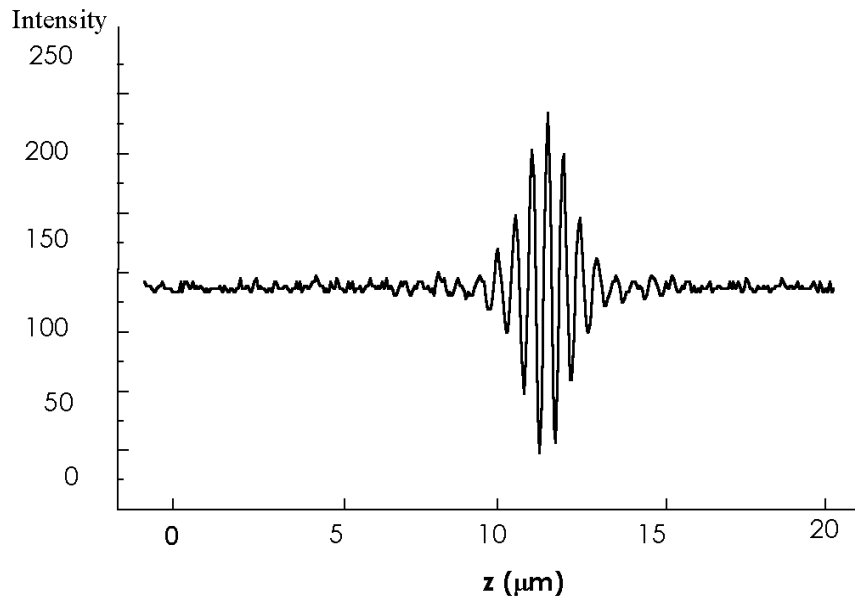
4b



단색광 간섭법의 측정오차를 이용한 위상변화율 오차의 계산 ($k_1=2\pi/\lambda_1$, $k_2=2\pi/\lambda_2$)

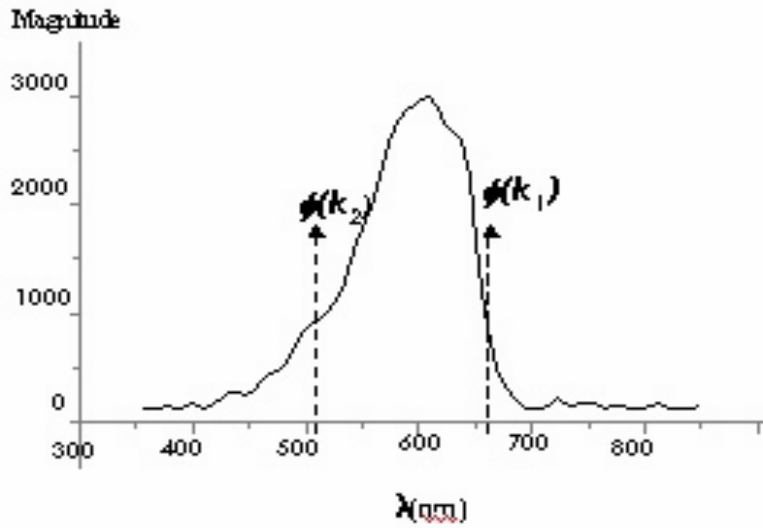
가시도 정점에 의한 오차 $z \left(= \frac{1}{2} \frac{d\phi}{dk} \right)$ 의 해석

5a



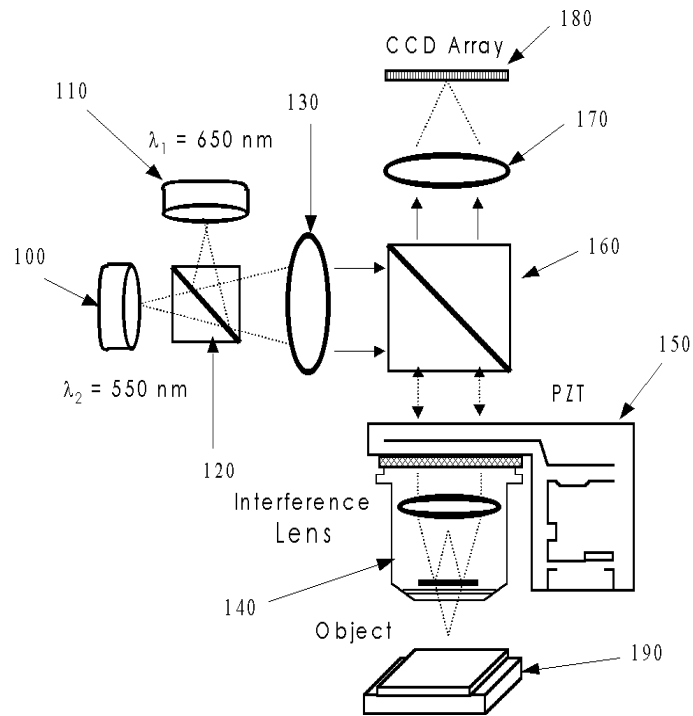
백색광 간섭무늬

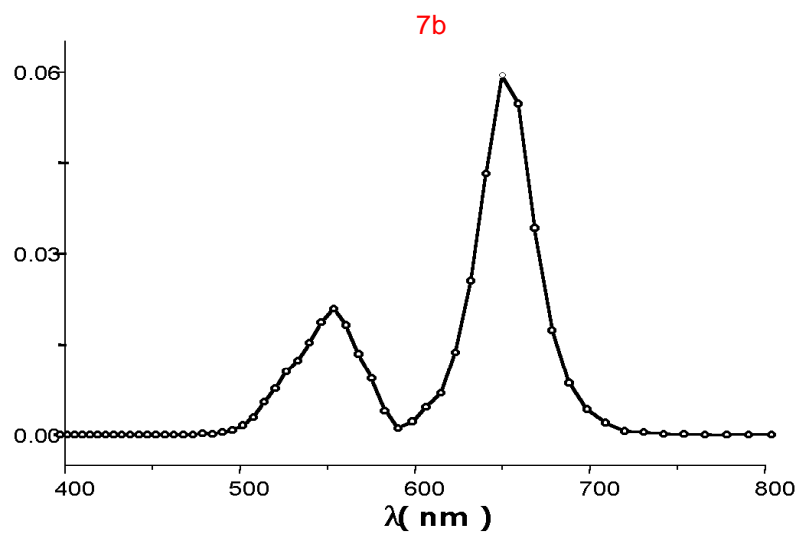
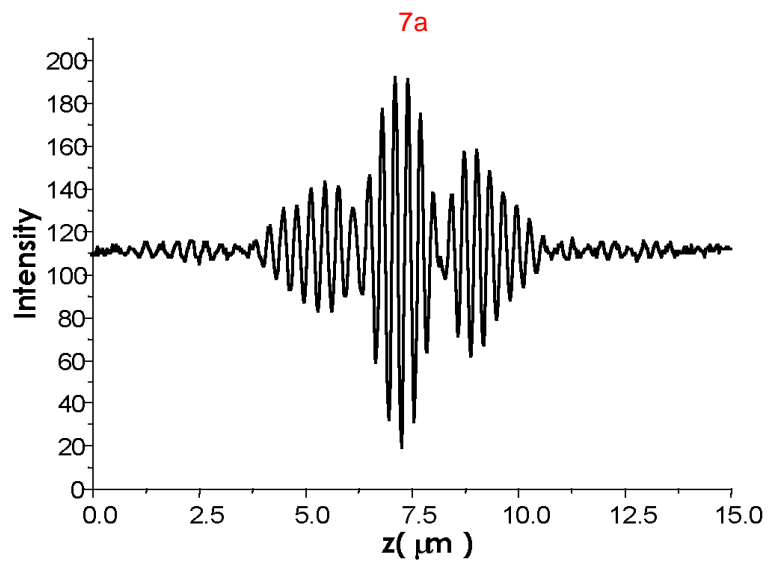
5b



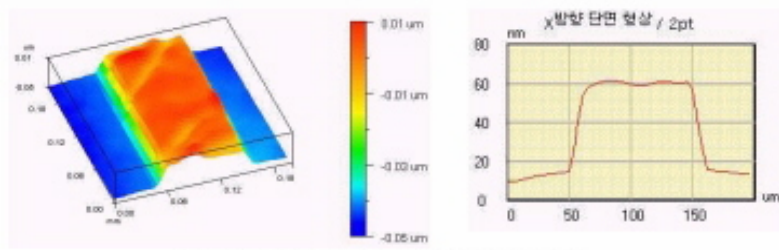
태색광 간섭무늬의 푸리에 변환결과

6

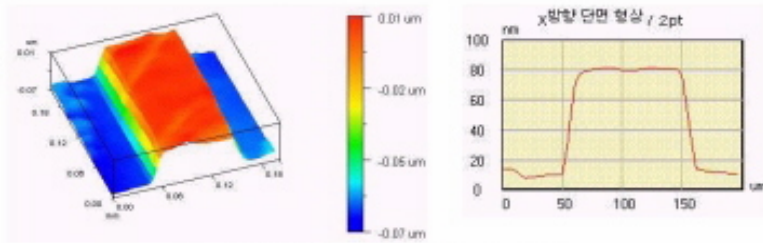




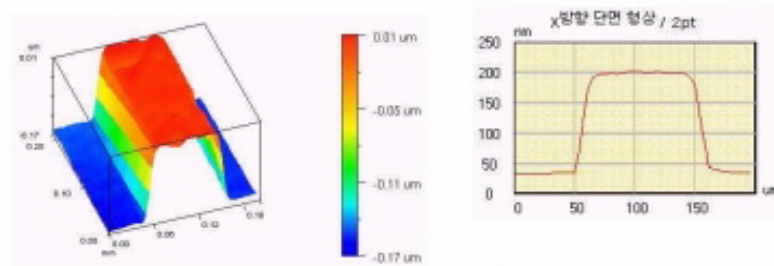
8



(a) 위상 검정 계산 결과, $\lambda = 650\text{nm}$, $h_1 = 45.5\mu\text{m}$



(b) 위상 검정 계산 결과, $\lambda = 550\text{nm}$, $h_1 = 68.2\mu\text{m}$



(c) 가시도 검정 계산 결과, $F\# = 162.9\text{mm}$