MURA Detection Method using a Slit-Beam-Profile Ellipsometer

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Abstract

We developed a new ellipsometer for MURA detection. This ellipsometer can measure MURA along the slit line on the sample with high sensitivity, because this ellipsometer irradiates a slit beam onto the sample but can reject the reflected light from the back surface of the substrate. This ellipsometer is suitable for measuring MURA of the surface of sample with high sensitivity.

1. Introduction

Recently, higher sensitive inspection is required, because the quality of display device is coming important more and more. MURA inspection is important in the manufacturing process of LCD. MURA is a Japanese term, which means non-uniformity of film thickness, rubbing and so on.

The measuring method of rubbing state using an ellipsometer is proposed [1] [2]. This method is high sensitive, however, this method cannot measure MURA because of measuring only one spot area. We must move a sample in order to measure the MURA. Therefore, sensitivity of this method changes because of movement of measurement conditions caused by the stages.

The method of quantifying MURA using CCD camera is proposed [3]. However, this method is not sensitive, because this ellipsometer detects not only the reflected light from the surface but also the reflected light from the back surface which has the undesirable information about glass substrate (Fig.1).

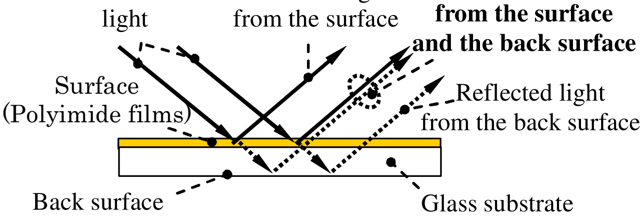


Fig. 1 The figure of reflected light from the surface/back surface

In this paper, we propose MURA detection method with high sensitivity using a-slit-beam-profile ellipsometer. This ellipsometer can measure MURA along the slit line without detecting the reflected light from the back surface.

First, in Section 2 the simulation of the reflected light from rubbed polyimide film is briefly recalled. The influence of reflected light from the back surface is discussed in Section 3. Section 4 introduces the optical system of a slit-beam-profile ellipsometer, and experimental results of measuring rubbed polyimide film are in Section 5.

2. Calculated Polarization of Reflected Light from Rubbed Polyimide Film

Reflection ellipsometry is a non-contact and non-destruction optical technique for characterization of thin film. An ellipsometer measures the reflected light's polarization (ρ) by quantifying the amplitude ratio (ψ) and the phase (Δ) induced by reflected light from the sample. ρ is related as follows[4]:

$$\rho = \tan\varphi \exp(i\Delta) = \frac{E_{ip}/E_{is}}{E_{rp}/E_{rs}} \qquad (1)$$

Here, E_{ip}、 E_{is}、 E_{rp} and E_{rs} are the electric fields of light, where subscripts ip, is, rp and rs indicate the incident light with p- and s-polarized, reflected light with p- and s-polarized, respectively.

ρ from rubbed polyimide film can be solved by Berreman matrix [4] [5]. Rubbed polyimide film has been considered as composition of an anisotropic upper layer and an isotropic lower layer. The upper layer can be approximated as an uniaxial medium [2] [6]. Then, the relation of incident, reflected and transmitted electromagnetic filed ψ_i, ψ_r, ψ_t can be expressed using Berreman matrices Π_{iso}, Π_{ani} and thickness d_{ani}, d_{iso} as

$$\psi_t = \exp(ik_0\Pi_{iso}d_{iso})\exp(ik_0\Pi_{ani}d_{ani})(\psi_i + \psi_r) \qquad (2)$$

For uniaxial medium, the Berreman matrix Π [4] is given by

$$\Pi = \begin{pmatrix} \Pi_{11} & \Pi_{12} & \Pi_{13} & 0 \\ \Pi_{21} & \Pi_{11} & \Pi_{23} & 0 \\ 0 & 0 & 0 & 1 \\ \Pi_{23} & \Pi_{13} & \Pi_{43} & 0 \end{pmatrix} \qquad (3)$$

where

$D\varepsilon = \varepsilon_e - \varepsilon_o, \quad \eta = 1/\left(\varepsilon_o + D\varepsilon\cos^2\theta\right), \quad \xi = \tilde{n}_o \sin\phi_o = \tilde{n}_1 \sin\phi_1$

$\Pi_{11} = -\eta D\varepsilon \sin\theta\cos\theta\cos\varphi\xi, \quad \Pi_{12} = 1 - \eta\xi$

$\Pi_{13} = -\eta D\varepsilon \sin\theta\cos\theta\sin\varphi\xi, \quad \Pi_{21} = \varepsilon_0\eta\left(\varepsilon_e - D\varepsilon\sin^2\theta\sin^2\varphi\right)$

$\Pi_{23} = \eta D\varepsilon\varepsilon_0 \sin^2\theta\sin\varphi\cos\varphi, \quad \Pi_{43} = \eta\varepsilon_0\left(\varepsilon_e - D\varepsilon\sin^2\theta\cos^2\varphi\right) - \xi^2$

ρ is given by Eq. (2) and the boundary conditions of each layers.

Fig. 2 shows the orientational dependence Δ of the reflected light from rubbed polyimide film. This calculated line has two local maximum at 30°, 190° and has two local minimums at 100°, 290°. Asymmetric orientational dependence Δ caused by anisotropy of rubbed polyimide film is clearly observed.

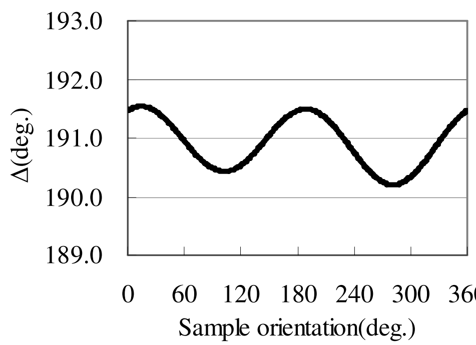


Fig. 2 Calculated orientational dependence Δ of reflected light from rubbed polyimide film.

3. Observed Polarization of Reflected Light from Rubbed Polyimide Film with/without the Back Surface

Next, we observed the influence of reflected light from the back surface using ellipsometer. Sample is prepared on 0.7-mm-thickness glass substrate. Polyimide is coated on glass substrate. The surface of polyimide is rubbed using a roller.

Fig. 3 shows the results of orientational dependence Δ of reflected light from rubbed polyimide film with/without the back surface. Dot line is the reflected light without the back surface, and solid line is the reflected light with the back surface

From Fig. 3, Asymmetric orientational dependence Δ of dot line is clearly observed, but asymmetric orientational dependence Δ of solid line is not clearly observed. Moreover, the difference between maximums and minimums of Δ of solid line is smaller than the difference of dot line. Thus, we think that reflected light from the back surface is the undesirable information in order to detect MURA with sensitivity.

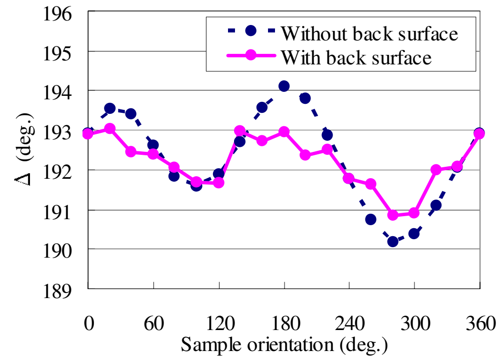
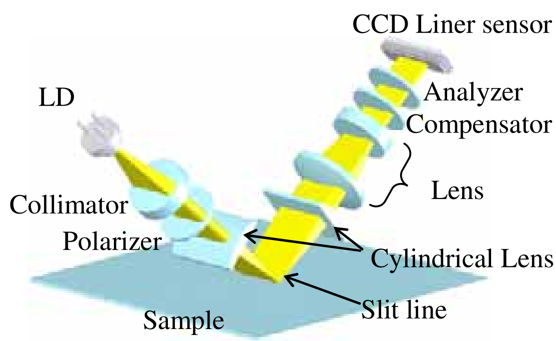


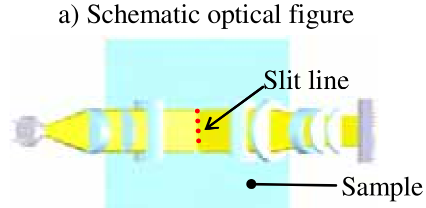
Fig. 3 Observed orientational dependence Δ of reflected light from rubbed polyimide film.

4, A Slit-Beam-Profile Ellipsometer

The optical system of a-slit-beam ellipsometer is shown in Fig. 4. This ellipsometer can measure MURA along the slit line without detecting the reflected light from the back surface.



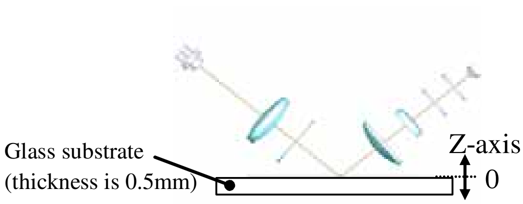
a) Schematic optical figure



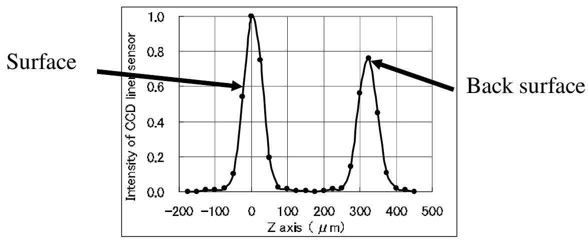
b) Top view

Fig. 4 Optical system

The slit beam generated by cylindrical lens is irradiated to the sample. The length of the slit line is about 30mm. The reflected light from the sample passes the lens, and is detected by CCD liner sensor.



a) Side view of optical system



b) The separation of intensity

Fig. 5 Separation of the reflected light from the surface and the back surface of a glass substrate

Fig. 5b) is the result of the intensity on CCD liner sensor. Horizontal axis is Z-axis as shown by Fig. 5a). Z-axis is defined in the direction where the glass substrate moves up and down. Fig. 5b) shows the separation of the reflected light. Moreover, the full width at half maximum of the reflected light from the surface is about ±50μm. If the surface of sample is adjusted at the position of 0 at Z axis, this ellipsometer detects only the reflected light from about ±50μm area of the surface of sample without detecting the reflected light from the back surface of the substrate.

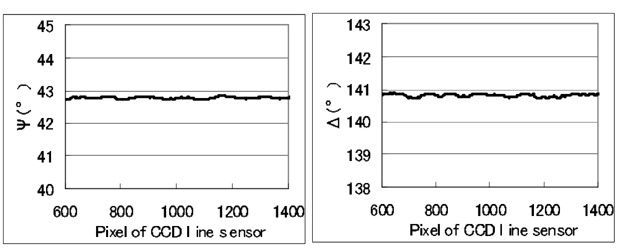
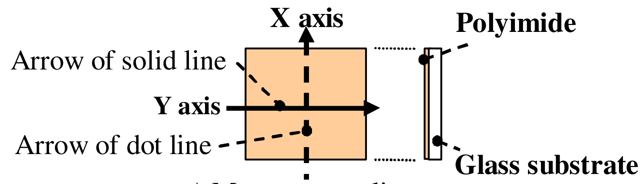


Fig. 6 Uniformity of a slit line

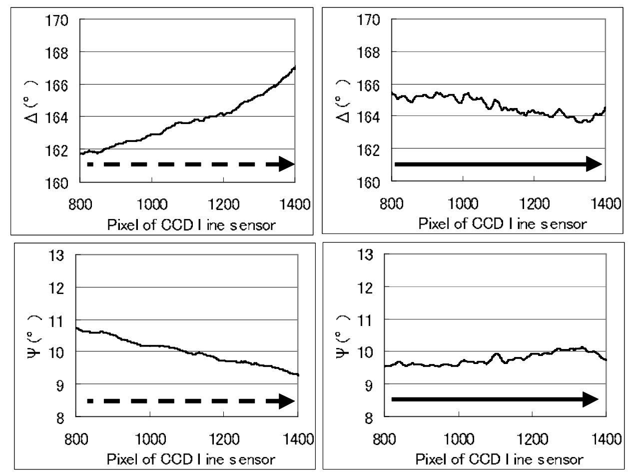
We measured the uniformity of a slit line in a-slit-beam ellipsometer. Fig. 6 shows the results of measuring SiO_2 film (the thickness is about 100nm) on the silicon substrate. Uniformity along slit line is Ψ=±0.05, Δ=±0.05 or less.

5, Experimental results and Discussion

We prepared the polyimide film without/with rubbing. It is said that the thickness and the state of rubbing of polyimide film affect the quality of the display device and it is related to reflection light's polarization ρ [2] [6].



a) Measurement line



b) X axis c) Y axis

Fig. 7 Thickness distribution of polyimide film without rubbing

Fig. 7 shows the measurement result along the slit line of polyimide film without rubbing sample. Fig. 7b) shows the result on the arrow of dot line in Fig. 7a). Fig. 7c) shows the result on the arrow of solid line in Fig. 7a). From Fig. 7b) c), the value of Δ and ψ change about several degrees. The amount of the change of Δ and ψ is converted into the film thickness (refractive index of polyimide film is 1.68 at wavelength 650 nm.). The change of thickness along the arrow is about 2nm in Fig. 7b) and about 4nm in Fig. 7c) [2]. We think that thickness MURA of polyimide film can be detected.

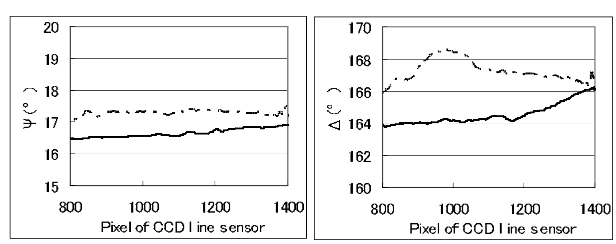


Fig. 8 The difference of Δ and Ψ with/without rubbing sample

Next, The change of Δ and ψ with/without rubbing sample is shown in Fig. 8. Solid line of Fig. 8 is the result of without rubbing sample and dot line is the result of with rubbing sample. The difference of profile between solid line and dot line are caused by rubbing. We thick that rubbing MURA of polyimide film can be detected

6. Conclusion

We developed a slit-beam-profile ellipsometer. This ellipsometer can measure MURA along the slit line on sample with high sensitivity. We proposed new MURA detection method of polyimide film using this ellipsometer. We expect this method will contribute the yield improvement in manufacturing LCD.

7. References

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