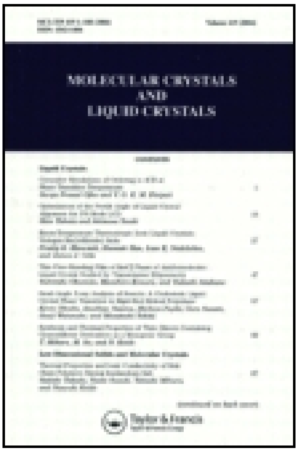

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Touch screen displays have been a subject of growing interest in recent years due to the significant usability benefits they provide for portable electronic devices ranging from mobile phones to tablet PCs. In this paper we report the preparation of index-matched ITO-PET films by depositing thin films of SiNx, SiOx and ITO on hard coated polyethylene terephthalate (PET) film utilizing roll-to-roll sputtering system.

Keywords Index Matching; ITO; Capacitive Touch Panel; ITO-PET film

Introduction

Touch screen displays have been a subject of growing interest in recent years due to the significant usability benefits they provide for portable electronic devices ranging from mobile phones to tablet PCs [1]. The principal sensing schemes include electrical resistance, ultrasonic waves, infrared ray, surface capacitive and projective capacitive type touch panels [2]. The projective capacitive type has become dominant in recent years due to its advantages in multi-finger user interfaces. This type has many conductive sensor elements in a grid pattern spanning the sensor area. Optical requirements arise because this non-homogeneous structure must appear to be homogeneous.

The current requirement of touch panels for visible light transmittance is 90% or better through the lens and all touch sensing layers. Most losses in touch panel system are due to reflections, and a small portion is lost to absorbance. The current state of transparent conductor, as embodied by ITO, is 88% T, <1% haze and reflectance less than 10% for the stack of all lens and sensor layers. The color requirement of ITO-PET film is b^*(less than 2) which is the measure of yellowness of the ITO thin layer deposited PET film. Depending on the type of capacitive sensing and operating frequencies, the conductive layers may be 50–300 Ohm/sq. Typically 99+% of the sensing area is covered with ITO, with insulating gaps of 20–30μm width. Though the contrast in reflected light intensity between the ITO

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and etched areas may be larger than >5%, the narrow gaps are difficult to see for most users. The gaps between traces may be 100–300 μm wide and would be easily visible if constructed of ITO directly on PET base film. The strong difference in reflectance between ITO layer and PET film can be reduced to invisible levels by use of index matching layers [3].

In this paper we report the preparation of index-matched ITO-PET films by depositing thin films of SiNx, SiOx and ITO on hard coated polyethylene terephthalate (PET) film utilizing roll-to-roll sputtering system.

Experimental

The schematic diagram of the roll-to-roll sputtering system is shown in Figure 1. First the degassing of PET film with hard coating on both sides was conducted in the roll-to-roll sputter for 24 hrs under the vacuum of 1×10^{-5} torr at 70°C with the illumination of mid-infrared lamp. It was found that the through degassing of PET film, especially the adsorbed moisture was very important in the subsequent thin film depositions, otherwise micro-cracking of deposited thin films would be formed.

The silicon nitride (SiNx) thin layer was deposited in the roll-to-roll system by reactive sputtering of Si target with argon(Ar) and nitrogen(N_2) gas (up to 50%) utilizing 100 kHz middle frequency pulsed DC power source. The silicon oxide (SiOx) thin film was also deposited by reactive sputtering with oxygen content up to 23%.

The ITO thin film on top of SiOx layer of PET film was deposited by using ITO target which had $In_2O_3 : SnO_2 = 97 : 3$ wt% composition with small amount of oxygen (0.6%) in the Ar gas flow system. The ITO/SiOx/SiNx multiple layers deposited PET film was annealed for 1 hr at 150°C in the convection oven for the crystallization of ITO layer and stabilization of the SiNx and SiOx index matching layers. The summary of the multiple layer deposition conditions are shown in Table 1.

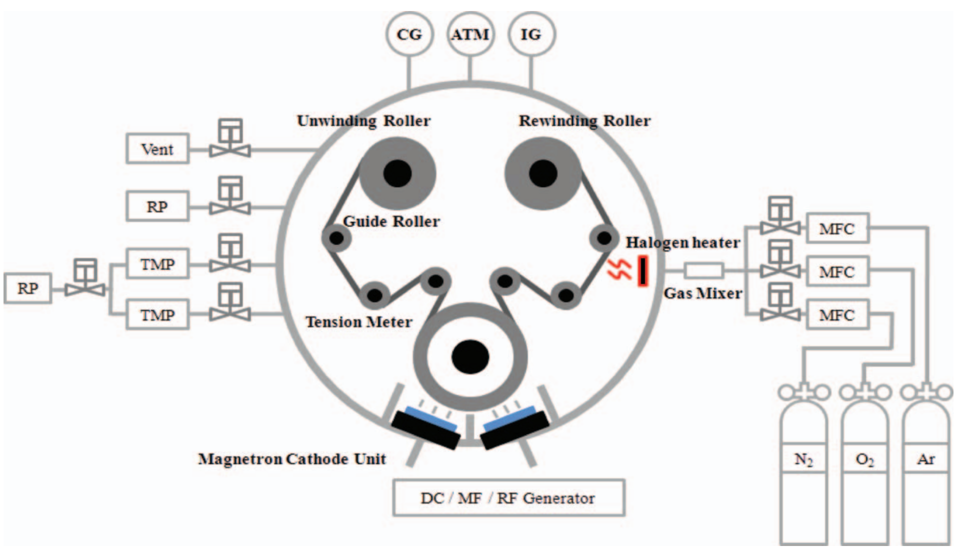

Figure 1. Schematic diagram of roll-to-roll sputtering system.

Table 1. Deposition conditions of the SiNx, SiOx and ITO thin layers on PET film

Parameters/Thin films	SiNx	SiOx	ITO
Power	MF 630 W		DC 400 W
Target	Si (99.99%)		$In_2O_3 : SnO_2 = 97 : 3$ (wt%)
Base pressure	under 1E-05 torr		
Working pressure	3 ∼ 6 m torr (depending on gas flow)		
Ar gas flow	30 sccm	30 sccm	50 sccm
Additive gas	0 ∼ 30 sccm	1 ∼ 9 sccm	0.3 sccm

The optical properties of the multiple thin layers such as refractive index(n), extinction coefficient(k), thicknes(d) were measured with the ellipsometer (Ellipso. Technology Co., Korea). The sheet resistances of the ITO-PET films were measured by four point porbe meter (MCP-T610 Changmin Tech., Korea). The simulation of multiple layers was carried out by using Macleod software for the index matching between the ITO and ITO etched layers of the ITO-PET films. The optical properties of the index matched ITO-PET films was measured with UV-vis spectrophotometer (Minolta CM-3600d, Japan) and compared with the simulation values.

Results and Discussion

Multiple Thin Film Deposition and Optical Simulation

First the silicon nitride (SiNx) and silicon oxide (SiOx) thin films were deposited separately as high and low refractive index layer, respectively, on top of the PET film with hard coating layer by reactive sputtering method utilizing roll-to-roll sputtering system [4]. In case of ITO thin film on top of the SiOx/SiNx thin layers the deposition was carried out by varying the O_2 gas flow rates in the DC magnetron sputtering. As shown in Figure 2 the optimum flow rate of O_2 was obtained at about 0.3 sccm while Ar gas flow rate was fixed at 50 sccm. Under this condition a low sheet resistance and large increase of transmittance could be obtained after thermal annealing of ITO layer [5].

In order to get refractive index matched ITO/SiOx/SiNx on PET (ITO-PET) film the optical parameters such as refractive index(n) and extinction coefficient(k) as well as the

Table 2. Simulation data of ΔR_{21} before and after etching of ITO layer on the ITO/SiOx/SiNx/PET films

Simulation of ΔR21 values (380 ∼ 740 nm)		Thickness of SiOx thin film				
		0 nm	20 nm	40 nm	60 nm	80 nm
Thickness of SiNx thin film	0 nm	3.51	3.77	3.42	2.74	2.16
	10 nm	3.98	3.49	2.65	1.99	1.85
	20 nm	4.05	2.90	**2.47**	**1.42**	1.81
	30 nm	3.74	2.12	**1.06**	**1.13**	2.03
	40 nm	3.13	1.29	**0.52**	**1.12**	2.40

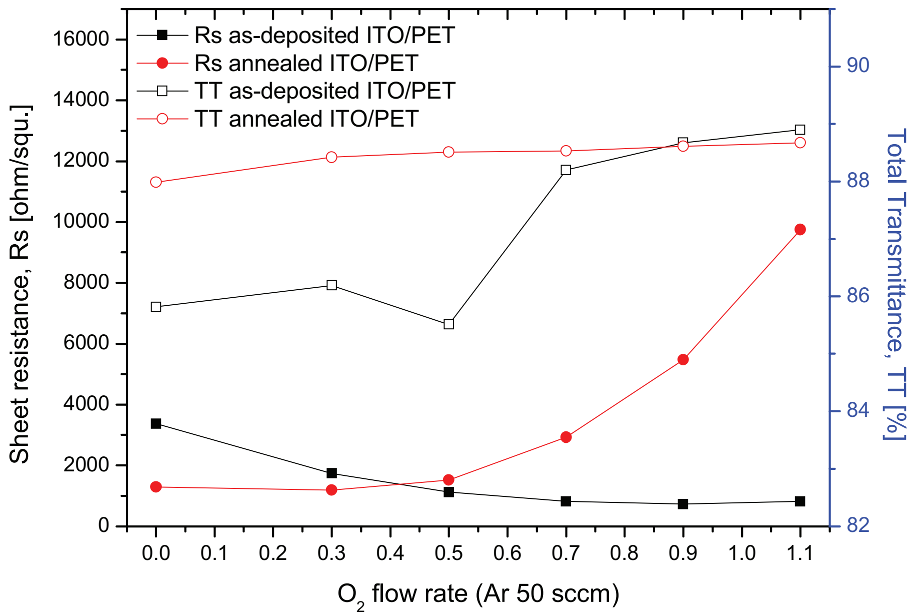

Figure 2. The sheet resistance and transmittance of ITO on PET film with O_2 flow rate.

thickness of the thin films were measured with ellipsometer and analyzed by fitting to model while varying the wavelength [6]. The six refractive indices and two extinction coefficients (PET and ITO thin film) data are plotted according to the wavelengths in Figure 3.

These optical parameters were used for the simulation of refractive index matched ITO-PET films utilizing Macleod software. If the refractive indices of the ITO/SiOx/SiNx/PET

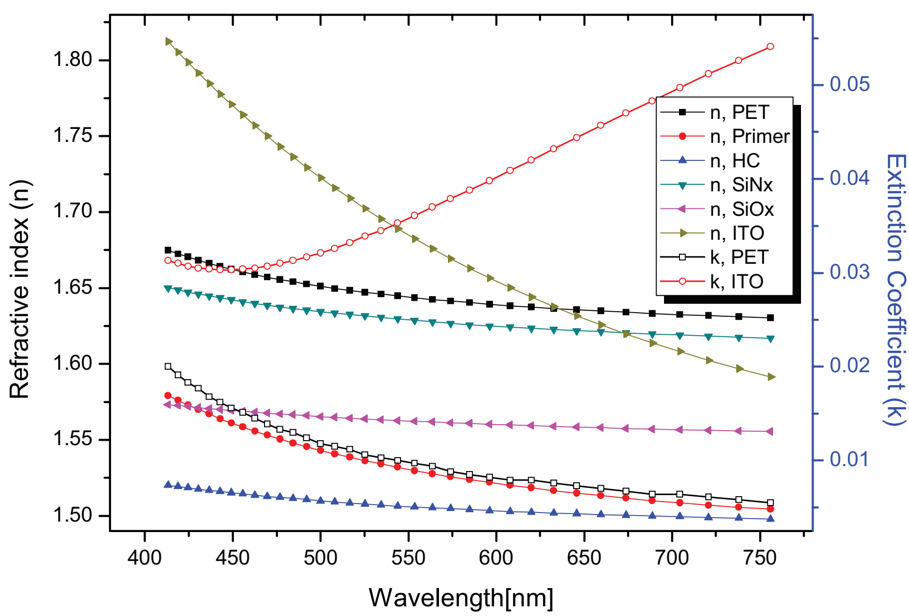

Figure 3. The refractive index(n) and extinction coefficient(k) of 6 layers on PET film.

Table 3. The thickness of ITO/SiOx/SiNx thin layer on PET film

Thin Films/ITO-PET Film Sample Num.	Thickness of ITO/SiOx/SiNx layers [nm]			
	ITO-PET/1	ITO-PET/2	ITO-PET/3	ITO-PET/4
ITO	40			
SiOx	50	63	50	63
SiNx	16	16	33	33

film and SiOx/SiNx/PET film in which the conductive ITO layer was etched out were designated to be R_1 and R_2, the difference ($\Delta R_{21} = |R_2\text{-}R_1|$) should be less than 1% for the invisibility before and after patterning of ITO-PET film. As shown in Table 2, the simulation of ΔR_{21} data in the 380–740 nm wavelength range showed that ΔR_{21} values were lower in the shaded area than other area which corresponds to 40 nm ITO layer on 40–60 nm SiOx/20–40 nm SiNx multiple layers on PET film.

Fabrication and Properties of Index matched ITO-PET Films

The reactive sputtering of ITO/SiOx/SiNx/PET films were carried out utilizing the roll-to-roll sputtering system while adjusting the thickness of the ITO, SiOx and SiNx thin layers as shown in Table 3.

The measured transmittance(T), reflectance(R), sheet resistance(Rs) and index matching data of the ITO/SiOx/SiNx/PET films are shown in Table 4. From Table 4 it was found that ITO-PET/3 sample film exhibited lowest ΔR_{21} of 0.63% and Δb^* of 1.17. It was noted that the ΔR21 (0.63%) of ITO-PET/3 film with geometry of ITO/SiOx/SiNx = 40/50/33 nm on PET film was close enough to the simulation value ΔR21 of ITO/SiOx/SiNx = 40/50/35 nm (0.78%).

Table 4. The measured T, R, Rs and ΔR_{21} (Δb^*) values of the ITO/SiOx/SiNx/PET films

Properties/Sample Num.		ITO-PET/1	ITO-PET/2	ITO-PET/3	ITO-PET/4
Transmittance, T [%]		86.80	87.30	88.31	88.82
Reflectance, R [%]		11.00	10.44	9.68	8.88
b*		2.61	2.99	1.71	2.90
Annealed T [%]		87.83	88.25	89.19	89.70
Annealed R [%]		11.13	10.63	9.94	9.07
Annealed b*		2.46	2.84	1.56	2.65
Rs [ohm/sq.]		459	428	491	485
Annealed Rs [ohm/sq.]		357	347	340	335
Index	ΔT_{21}	2.56	2.53	0.10	0.02
matching	ΔR_{21}	1.91	1.75	0.63	0.87
values	Δb^*	1.81	2.41	1.17	2.71

Conclusions

In order to get refractive index matched ITO-PET film the optical parameters such as refractive index(n) and extinction coefficient(k) as well as the thickness of the thin films were measured with ellipsometer and analyzed by fitting to model while varying the wavelength. It was noted that the ΔR21 (0.63%) of ITO-PET film fabricated with ITO/SiOx/SiNx = 40/50/33 nm on PET film was lower than the required value ΔR21 (1.00%) accepted in the industry.

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References

[1] Brown, C. *"In Cell Touch Panels : A Review of Technologies and Applications"*, IDW'10.
[2] Liu, C-J., Hu, G-R., Chen, Y-J., Tsai, C-J., Wang, M-H., Wang, P-H., Chiang, W-J., Kung, C-P., Ho, J-C., & Lee, C-C. *"Low Cost and Easy Manufacturing Flexible Projective Capacitive Touch Sensing Film"*, IDW'10.
[3] Mackey, B. "Trends and Materials in Touch Sensing", SID 11 DIGEST, 43.1.
[4] Milton Ohring (1991, 2002). The Materials Science of Thin Films., Academic Press, Inc., New York.
[5] Guillen, C. & Herrero, J. (2007). *J. Applied. Phys.* 101. 073514
[6] R. M. A. Azzam & N. M. Bashara, Ellipsometry and Polarized Light, (1997). Elsevier Science Publishers B. V.