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The characteristics of AlNd thin film for TFT-LCD bus line

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TFT-LCD bus line용 AlNd 박막 특성에 관한 연구

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Abstact – The structural, electrical and etching characteristics of Al alloy thin film with low impurity concentrations AlNd deposited by using dc magnetron sputtering deposition are investigated for the applications as gate bus line in the TFT-LCD panel. And ITO thin film was deposited on AlNd, then the contact resistance was measured by Kelvin resistor. The deposited thin films show the decrease of resistivity and the increase of grain size after the RTA at 300°C for 20 min.. Moreover, the resistivity of AlNd does not show appreciable grain size dependence after RTA. It is concluded that the decrease of resistivity after RTA is due to the increase of grain size. The annealed AlNd is found to be hillock free. The etching profiles of AlNd was good and the minimun contact resistance was about 110 μΩcm. Caculation results reveal that the AlNd (2wt.%) thin film can be applicable to 25" SXGA class TFT-LCD panels.

요 약 – TFT-LCD(thin film transistor-liquid crystal display) 패널의 데이터 배선 재료로 사용하기 위하여 AlNd(2 wt%)의 Al합금 박막을 dc 마그네트론 스퍼터링 방법으로 유리 기판에 증착하여 열처리전과 열처리 후의 구조적, 전기적, 식각 박막 특성을 조사하였다. 또한 증착한 박막을 식각하여 그 특성을 조사하였고, ITO를 증착하여 AlNd과의 접촉 저항을 Kelvin resistor를 사용하여 측정하였다. 증착된 박막을 350°C에서 20분간 열처리하였을 때 AlW 박막은 비저항이 감소하였고 약 4 μΩcm의 아주 좋은 비저항 특성을 보였다. 주사전자현미경(SEM)과 원자힘현미경(AFM)으로 표면을 분석한 결과 좋은 힐록방지 특성을 보임을 알 수 있었다. AlNd의 식각 특성은 아주 좋게 나타났고, ITO와 AlNd의 최저 접촉저항값은 약 110 μΩcm이었다. 측정된 특성들을 바탕으로 AlNd(2 wt.%) 박막의 적용 가능성을 해상도와 화면 크기 측면에서 살펴보았을 때, 25인치 SXGA급 패널에 적용 가능함을 알 수 있었다.

1. Introduction

Longer gate line and smaller pixel size which affect the RC time delay of gate signal are required for high resolution and large screen size TFT-LCD. Because of its low resistivity, Al is usually used as gate line and data line material [1]. However, pure Al has a serious drawback related to the formation of hillock.

Therefore many kinds of Al alloy were used as gate metal [2, 3]. Al alloy has low hillock density and resistivity of about 10~30 μΩcm. In this paper, AlNd [3] was selected and its properties for TFT-LCD applications were examined.

2. Experiments and Results

AlNd thin films were deposited on the corning class 1737 using dc magnetron sputtering system [4]. A 2-inch target of AlNd (2 wt%.) is employed in the sputtering system. The thickness of the film was controled by the deposition time. The deposition rate was about 100 Å/min..

To evaluate the characteristics of AlNd, the resistivity, uniformity of crystalilzation, grain size, hillock density and contact resistance of ITO/AlNd were investigated by SEM, XRD, AFM, 4-point probe and

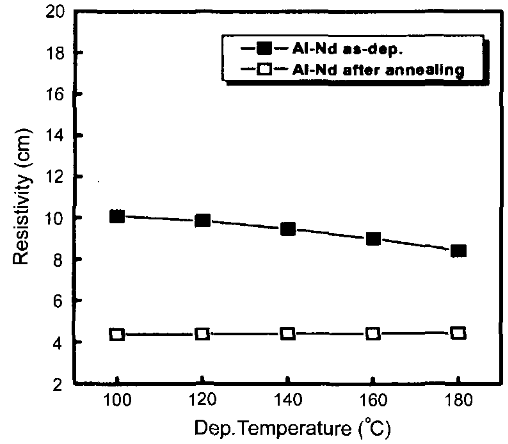

Fig. 1. Deposition Temperature vs. Resistivity (Al-Nd : 125 W, 0.4 Pa, Ar 30 sccm Annealing : 350°C, 20 min).

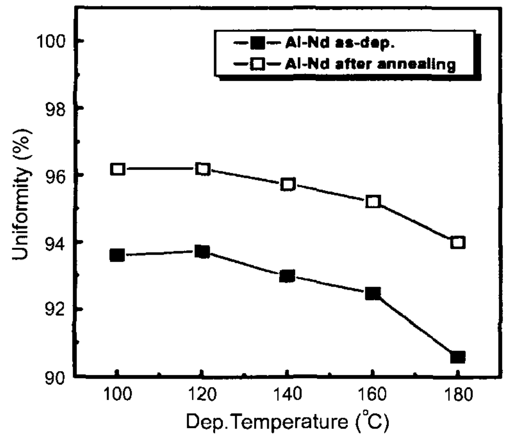

Fig. 3. Dep. Temperature vs. Uniformity (Al-Nd : 125 W, 0.4 Pa, Ar 30 sccm Annealing : 350°C, 20 min).

Kelvin resistor, respectively.

The resistivity of AlNd films deposited at various temperature are shown in Fig. 1. The resistivity of AlNd was decreased when the deposition temperature was increased. This trend is normal for thin alloy films. After the 350°C annealing, it is almost same trend. The resistivities were reduced after 350°C, 20 min. annealing. It was presumed that after annealing reduction of resistivity was occured by Nd atom's gathering caused thermal activation in Al matrix. The lowest resistivity was about 4 μΩcm (AlNd; 2 wt.%). Therefore it has good enough resistance to replace pure Al. Resistivities of AlNd for various thickness are shown in Fig. 2. It can be seen that the resistivity is nearly independent of thickness [5]. For the thickness between 1500~3500 Å, the being was constant.

The average uniformity of AlNd resistivity in each sample for various deposition temperature is shown in Fig. 3. As the deposition temperature was higher the reduction of uniformity was caused by increasing of deposition rate and smoothing of surface by atom having high reactive energy. The uniformity after annealing is about 2% higher than that of the as-deposited film. this property was caused by increasing of crystallizing of thin film. Fig. 4 is the roughness of AlNd for various deposition temperature. When the temperature was increased, the roughness was increased. It is explained by fast nucleation of adatom on surface and increasing of grain size. The average uniformities of AlNd resistivity in each sample for various dc power

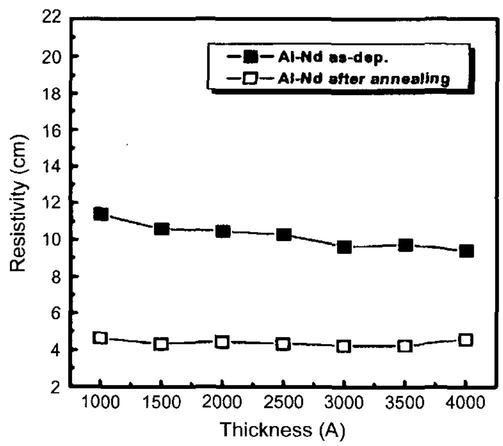

Fig. 2. Thickness vs. Resistivity (Al-Nd : 120°C, 125 W, 0.4 Pa, Ar 30 sccm Annealing : 350°C, 20 min).

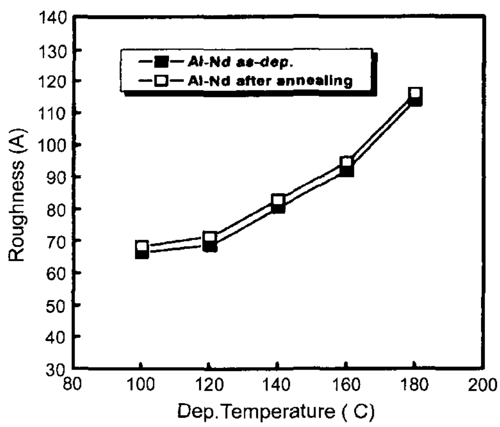

Fig. 4. Dep. Temperature vs. roughness (Al-Nd : 125 w, 0.4 Pa, Ar 30 sccm Annealing : 350°C, 20 min).

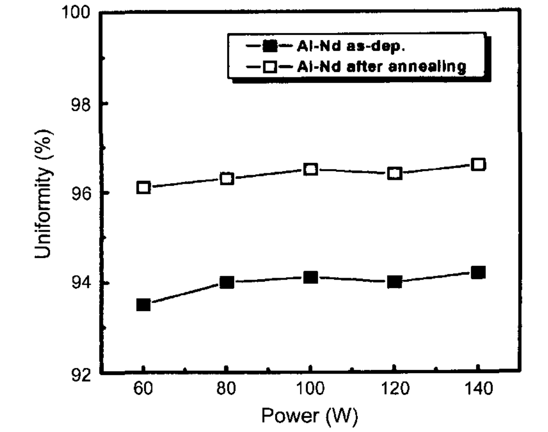

Fig. 5. Power vs. Uniformity (Al-Nd : 100°C, 125°C, 0.4 Pa, Ar 30 sccm Annealing : 350°C, 20 min).

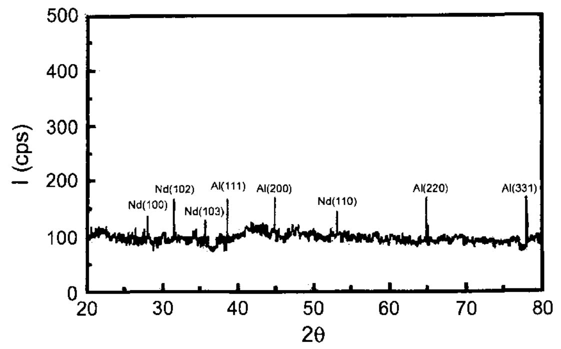

Fig. 6. XRD pattern of AlNd.

are shown in Fig. 5. According to increasing of dc power, the uniformity was increased. It was explained that the atom having high reactive energy was working by medium of surface cleaning. Between 60~140 W there was no change. It is observed that the deposition mechanism is almost same in these power ranges.

The XRD pattern of AlNd is shown in Fig. 6. It is observed that the direction of crystallization of Al was (111), (200), (220).

Fig. 7. is SEM images of AlNd thin film. It is observed that the grain size of after annealing is larger than as-deposition. The hillock density of AlNd was investigated by AFM (Fig. 8). The average roughness and maximum size are about 50 Å and 400 Å. They are smaller than 1000 Å, so there is no problem of hillock and there was no spike appearance.

Simple and effective way of Al alloy taper etching is developed. Normal etching chemical for pure Al is the mixture of H_3PO_4, CH_3COOH, HNO_3, and H_2O. It is

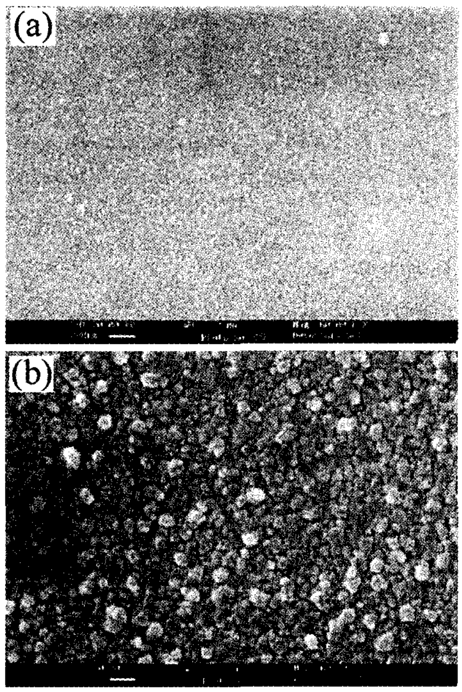

Fig. 7. SEM image of Al-Nd alloy 125 W, 100°C, 0.4 Pa, Ar 30 sccm (a) as-deposition, (b) after 350°C, 20 min annealing.

found that the mixing ratio of HNO_3 in Al etchant as well as the etching mode can affect the taper etching of Al and Al alloy [6]. AlNd was etched in pure Al etchant by dipping mode. The etching properties were that etching rate was about 50 Å/s, taper angle was about 40°, and etch residue was free. SEM images of taper angle of AlNd are shown in Fig. 9. AlNd we tested showed very good etched profile.

The contact resistance of ITO/AlNd was shown Table 1 and Table 2. These were different substrate temperature. Table 1 is the sputtering data in 300°C and Table 2 is the sputtering data in room temperature. ITO thin film was sputtered 200 Å, then 200 Å after 30 min. separately and 400 Å by one time on AlNd thin film. These were measured various hole sizes and sputtering conditions using Kelvin resistor. The current forcing was from −2.0 mA to 2.0 mA. The contacts resistance of ITO/AlNd were 110~500 $\mu\Omega cm^2$.

The minimum contact resistance was about 110 $\mu\Omega cm^2$. ITO/AlNd which ITO was sputtered in O_2 atmosphere has lower contact resistance than without O_2. ITO/AlNd which ITO was sputtered in 300°C has lower contact resistance than in room temperature [7].

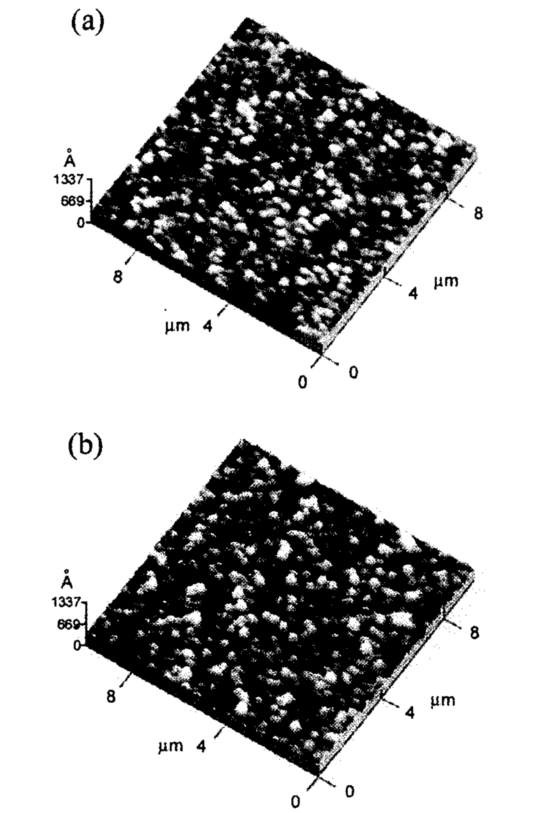

Fig. 8. AFM image of Al-Nd 150 W, 100°C, 0.4 Pa, Ar 30 sccm (a) as-deposition, (b) after 350°C, 20 min annealing.

Table 1. The sputtering data in 300°C

	Normal	Remove O_2	Remove O_2
1st Dep.	400200 Å	400 Å	200 Å
2nd Dep.			200 Å
Hole Size		ρ_c ($\mu\Omega cm^2$)	
8×8	110	125	258
10×10	164	184	258
12×12	163	300	142

Table 2. The sputtering in room temp.

	Normal	Remove O_2	Remove O_2
1st Dep.	400 Å	400 Å	200 Å
2nd Dep.			200 Å
Hole Size		ρ_c ($\mu\Omega cm^2$)	
8×8	334	264	153
10×10	202	333	276
12×12	334	480	271

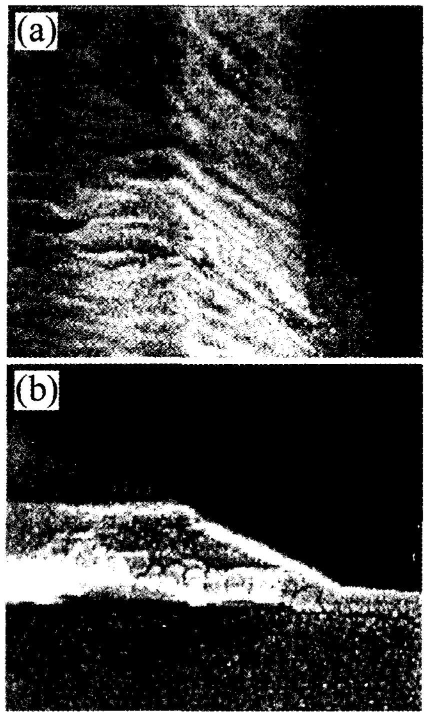

Fig. 9. SEM images of etch profile (a) top section, (b) cross section.

nd ITO/AlNd which ITO was sputtered by one time (400 Å) has lower contact resistance than separately 200 Å by 200 Å. The optimal condition for lowest contact resistance of ITO/AlNd was O_2 atmosphere and 200°C when it is sputtered by one time [8].

3. Conclusion

AlNd (2 wt.%) thin film was deposited on corning class (1737) and ITO was sputtered on AlNd thin film by dc magnetron sputtering system.

The minimum resistivity of AlNd is about 4 μΩcm. Also it is found that AlNd can effectively reduced the

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hillock formation without any surface treatment.

The etching rate was about 40 Å, taper angle was about 40 Å, and etch residue was free. AlNd has good etched profile.

The minimum contact resistance was about 110 $\mu\Omega cm^2$. At that time the optimal condition of sputtering was 300°C in O_2 atmosphere by one time sputtering.

Calculation retult reveal that AlNd (2 wt.%) is proposed to use as gate bus line material for 25" SXGA class TFT-LCD panels.

Acknowledgements

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Reference

[1] W. E. Howard, "Limitations and prospects of a-Si:H TFTs", Journal of the SID, 3/3, p. 127 (1995).

[2] M. Yamamoto, I. Kobayashi, T. Hirose, S. M. Bruck, N. Tsuboi, Y. Mino, M. Okafuji, Y. Tamura, To be Published IDRC 94, p.142 (1994).

[3] S. M. Bruck, M. Yamamoto, I. Kobayas hi, T. Hirose, N. Tsuboi, Y. Mino, M. Okafuji, T. Tamura, "High Performance Al-Zr Alloy for Gate Lines of TFT-LCDs", AMLCD '94, p.192 (1994).

[4] C. W. Kim, C. O. Jeong, H. S. Song, Y. S. Kim, J. H. Kim, J. H. Choi, M. K. Hur, H. G. Yang, J. H. Soul "Pure Al and Al-alloy Gate-Line Processes in TFT-LCDs", SID'96 Digest , p. 337 (1996).

[5] T. Tsujimura, Japan Display '92, p. 325 (1992).

[6] T. Tsujimura, H. Kitahara, A. Makita, P. Fryer, J. Batcy, AMLCD 94, p.188 (1995).

[7] Pung Keun Song, Yuzo Shigesato *et al.*, "Study on Crystallinity of Tin-Doped Indium Oxide Films" J. J. Appl. Phys. **37**, 1870 (1998).

[8] Ikeda Mitsushi "Large-size High Definition TFT-LCDs and Their Bus-Line Technologies", ディスプレ イアンドイメ-ジング , Vol. 4, pp. 199-206 (1996).