Advanced Materials Research
ISSN: 1662-8985, Vol. 662, pp 413-416
doi:10.4028/www.scientific.net/AMR.662.413
© 2013 Trans Tech Publications, Switzerland
Online: 2013-02-13

Properties of Al films Depend On Substrate Temperature by DC Magnetron Sputter Deposition

Yi Shen[1], Ruohe Yao[2]

School of Electronic and Information Engineering

South China University of Technology

Guangzhou, China

e-mail: [1.]yishen@goworld-lcd.com, [2.] phrhyao@scut.edu.cn

Keywords: DC magnetron sputter deposition, Substrate temperature, Rresistivity, Grain growth

Abstract. Al films were prepared by DC magnetron sputter deposition at different substrate temperatures. The sheet resistance of the films was measured by four point probe sheet resistance meter, and the film thickness, which was obtained by surface profiling system. The surface and cross-section morphology of the films was observed by AFM and FESEM. As a result, the resistivity of the films decreases obviously as the substrate temperature increases gradually. The higher substrate temperature is, the rougher the films surface is and the larger the grain size is.

Introduction

The thin film transistor liquid crystal displays and touch panel, are developed in larger sizes with higher resolution and lower resistivity is strongly required for the interconnections of TFT-LCD and TP in order to improve display quality. The Al films, which are widely used, have been recently applied for interconnections of TFT-LCD and TP to reduce significantly the resistivity [1].

Substrate temperature, one of the most important sputtering parameters, has great impact properties of Al films, such as resistivity, grain growth, films texture, etc. In the conventional Al films, hillocks which growth lead to interlay shorts are formed due to high temperature resulting in texture changed significantly, and it must be avoided. From this, the multi-layer films, general Mo/Al/Mo three-layer, are widely used to prevent the hillocks formed [2].

In the present paper, experimental data will be presented to show the effects of substrate temperature on the films resistivity and microstructure.

Experimental

Al films were prepared on soda-lime glass by DC magnetron sputter deposition. The base pressure of the vacuum system was 6.0×10^{-6}Torr and the deposition pressure was 2.0×10^{-3}Torr. The deposition was implemented at power density 1.5-7W/cm2 and the thickness of the samples was approximately 2500Å and the substrate temperature was carried out at 25˚C to 140˚C in this study.

The sheet resistance of the films was measured by four point probe sheet resistance meter (RTS-5) and the films thickness was obtained by surface profiling system (ET-4000M). The resistivity can be calculated by the sheet resistance and films thickness. The surface morphology and cross-section micrograph of the metal films was observed by AFM and FESEM.

Results and Discussion

Fig.1 shows the dependence of resistivity on substrate temperature. It is seen that the resistivity reduces nearly linear as the substrate temperature is increased. The lowest resistivity was simulated at 7.0μΩ•cm when the substrate temperature was carried out at 140˚C, while the highest resistivity was simulated at 13.2μΩ•cm at substrate temperature 25˚C.

All rights reserved. No part of contents of this paper may be reproduced or transmitted in any form or by any means without the written permission of Trans Tech Publications, www.ttp.net. (#69776785, Pennsylvania State University, University Park, USA-15/09/16,21:31:00)

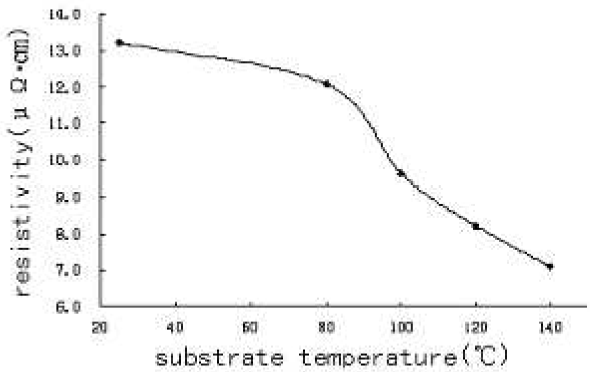


Fig.1. Relationship between resistivity and substrate temperature

Fig.2 demonstrates the average deposition rate of the Al films, which can be calculated through the films thickness and sputtering time. The deposition rate can be practically negligible as shown in the fig.2 while substrate temperature increases. In other words, the substrate temperature is almost no effect on the deposition rate for DC magnetron sputter deposition.

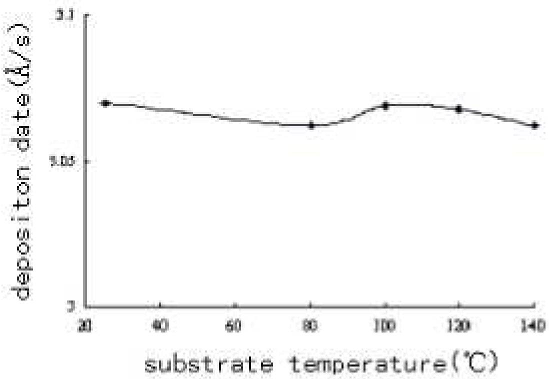
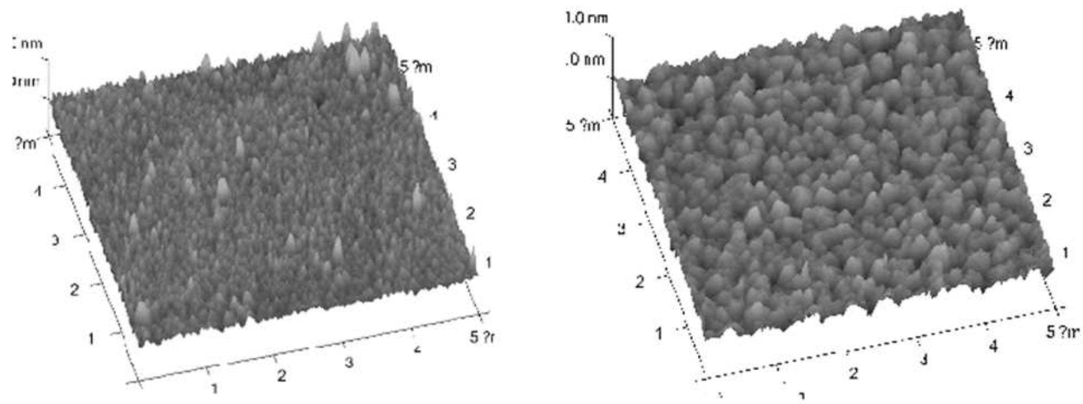
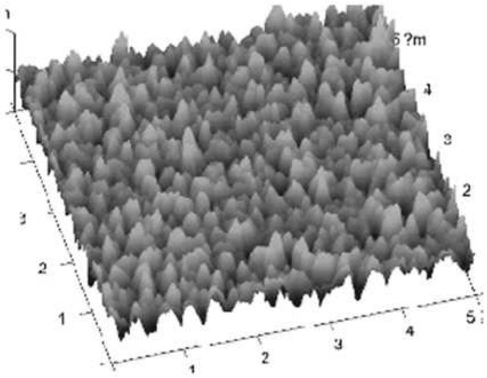


Fig.2. Relationship between deposition rate and substrate temperature

The plan-view AFM morphologies of the films are shown in Fig.3, and the substrate temperature corresponding to Fig.3(a), Fig.3(b) and Fig.3(c) were heated at 25˚C, 80˚C and 100˚C respectively. It is indicated that the average grain size, which is about from 20nm to 90.2nm, has been growing obviously as the substrate temperature is increased continuously. The mean roughness of films surface defined Ra value, which is from 3.67nm to 24.3nm, remarkably increases by heating substrate from 25˚C to 100˚C. From these results, it is concluded that the formation of the large grains results in increase of the mean surface roughness.



(a) (b)



(c)

Fig.3. AFM morphology: (a) substrate temperature at 25˚C; (b) substrate temperature at 80˚C; (c) substrate temperature at 100˚C

Fig.4 shows FESEM cross-section micrograph of Mo/Al/Mo multi-layer films at different substrate temperature. In the case of the multi-layer films, Mo films can suppress formation of hillock at Al films surface due to excessive substrate temperature, which is widely applied to TFT-LCD and TP. It is observed that as substrate temperature is 25˚C, interfaces of the multi-layer films are clearly visible, while after heated at 80˚C a slight change occurs at the interface between top layer and middle layer, and is almost constant between middle layer and bottom layer. As substrate temperature is 100˚C, the interface between top layer and middle layer completely interpenetrates and is nearly invisible. On the other hand, the interface between middle layer and bottom layer is still no change. It is evidenced that the influence degree of Al, which grain growth depends on substrate temperature, is more than the Mo.

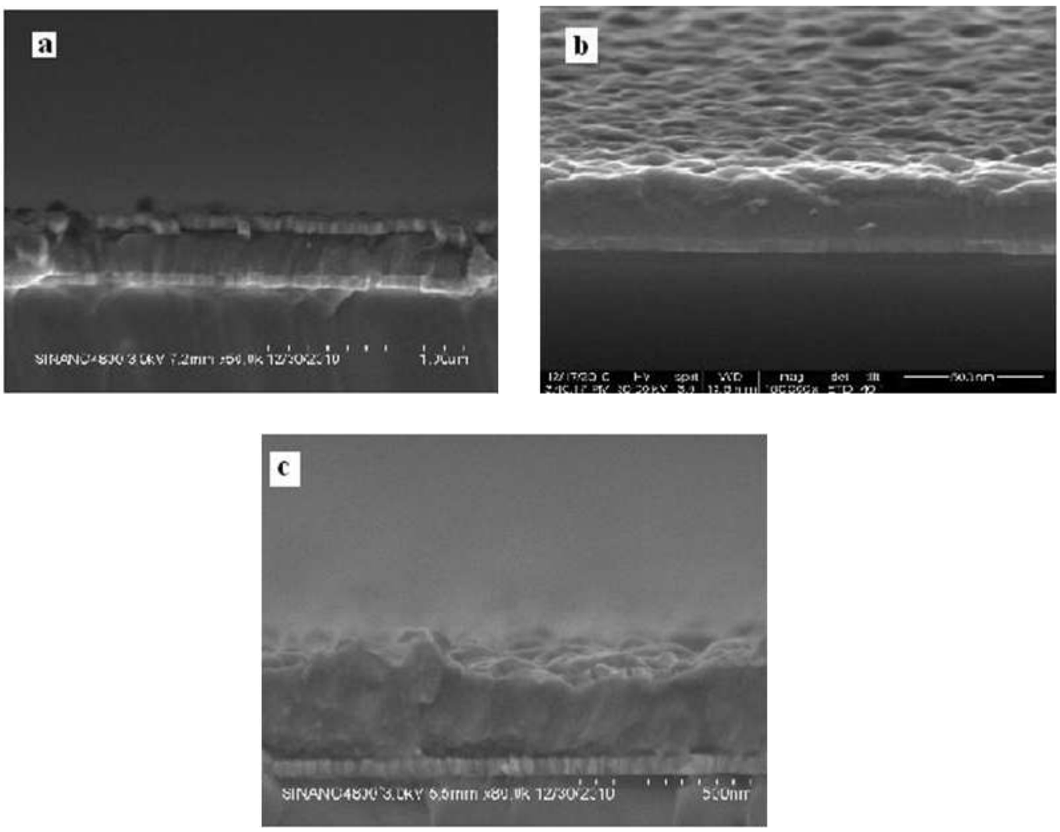


Fig.4. FESEM cross-section: (a) substrate temperature at 25˚C; (b) substrate temperature at 80˚C; (c) substrate temperature at 100˚C

It was confirmed that substrate temperature, an important factor to films texture, impacts adsorption, desorption and migration of the grains except deposition rate. As substrate temperature is increased, the films crystallinity improves and it shows a tendency from amorphous to polycrystalline and crystalline [3]. From these results, the grains have preferred orientation resulting in lower resistivity at high substrate temperature, but are almost the same deposition rate.

It is well known that the coefficient of thermal expansion mismatch between the metal films and the glass substrate, which induces the compressive stress in the grains. The individual grains orientation is inclined from the original <111> fiber texture in order to relax the compressive stress, defined the dislocation glide, which result in diffusion mass transport from the local region under the compressive stress. The growth grains is directly related to diffuse mass transport along grain boundaries from the regions under the compressive stress to condensate at the surface and combines with adjacent grains and forms secondary grain growth[4],[5]. It is inferred that the grain growth is the main factor in the change of the surface morphology of the films. With the grains growing, the mean surface roughness has been increasing significantly.

For DC magnetron sputter deposition, substrate is only as a carrier to receive the sputtered atoms, and the number of sputtered atoms is merely relationship with energy and density of Ar^+. That is the characteristic of the substrate, such as substrate temperature, can not determine the number of sputtered atoms.

Conclusions

In this work, the dependence of properties of Al films on substrate temperature was investigated. The resistivity of the films decreases as substrate temperature is increased due to the preferred orientation. The grains are growing and the surface is performing rough with heating the substrate. However, the deposition rate is nearly no change with the substrate temperature.

References

[1] Francis P. Fehlner, Norbert J. Binkowski, Kenneth R. Salisbury and Leslie Button. Journal of Non-Crystalline Solids, vol. 195, pp. 89-94. July. 1995.

[2] H-Mok Park, Soo-Jung Hwang, Je-Hun Lee and Young-Chang Joo. Met. Mater. Int, vol. 15, no. 4, pp. 661-664, Aug. 2009.

[3] B. C. Martin, C. J. Tracy, J. W. Mayer and L. E. Hendrickson. Thin Solid Films, vol. 271, pp. 64-68, July. 1995.

[4] Takashi Onishi, Eiji Iwamura and Katsutoshi Takagi. Thin Solid Films, vol. 340, pp. 306-316, Oct. 1998.

[5] Hiroshi Takatsuji, Toshiaki Arai. Vacuum, vol. 59, pp. 606-613, 2000.