Blackening of TFT Wiring by Depositing High Durability Film

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ABSTRACT

Blackening of TFT wiring enables higher resolution and improved design of various kinds of displays. In this paper, we will introduce the material design concept and properties of high durability thin film for blackening of TFT wiring.

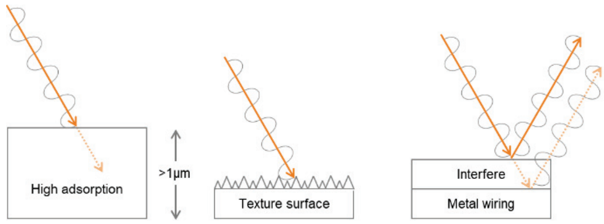
1 INTRODUCTION

High-resolution displays contribute to the image realism. When the pixel size decrease in display, the color density is increased. However, that results in the decrease of aperture area in the pixel [1]. The demands of “high resolution” is shrinking the width of the TFT wiring to maintain decent aperture ratios. The approaching through adjacent pixels may leads to reduced light reproducibility due to the reflection of TFT wiring. In addition, the TFT wiring is located in the visual side such as bottom emission type OLED, the TFT wiring is likely visible. Under these circumstances, it is required to hide the TFT wiring in display. In the field of metal mesh touch sensor, CuO is known by black layer to hide the metallic wiring [2]. When the black film for touch sensor such as copper oxide is applied to TFT wiring, it is easily reduced and changed to metallic by H_2 plasma in TFT producing process. Moreover, that kind of material has less heat resistance. In this study, we designed the material with high durability for hiding TFT wiring.

2 EXPERIMENT

2.1 Simulation of Reflectance

There are several kinds of method to decrease reflectivity on metal surface. Fig. 1 shows the schematic images of three kinds of method to reduce the metal reflectance. When the single layer has high absorption to reduce the reflectance, the thickness became thicker over 1μm. It’s hard to make narrow pitch wiring in this case. In addition, the material would be low conductivity became of its band gap. The second method is using surface structure. The reflectivity could be obtain below 0.05% [3]. However the surface roughness is not suitable for TFT wiring. Moreover, there would be a problem in the electrical contact on its surface. The third method is using interfere in stacked film. The light is reflected on both upper and lower surface. Each reflected light is interfered by the difference in the phase. This structure is reasonable because the upper film thickness would be below 100nm and the lower metal film could be electrical conductivity.



(a) (b) (c)

Fig. 1 Schematic images of three kinds of method to reduce the metal reflectance.

Firstly, the reflectivity in stacked film was simulated to obtain optimal characteristics in interfere layer. Fig.2 a) shows the simulation result of interfere layer/Cu stacked film. The film thickness of interfere layer was determined to minimize the reflectivity. When the refractive index “*n*” of interfere layer is lower value and the extinction coefficient “*k*” is around 0.5, the reflectivity of stacked film became lower. Fig.2 b) shows the film thickness of each results. When the *n* is higher value, the thickness decreased. We tried to make suitable optical thin film by selecting and adjusting materials.

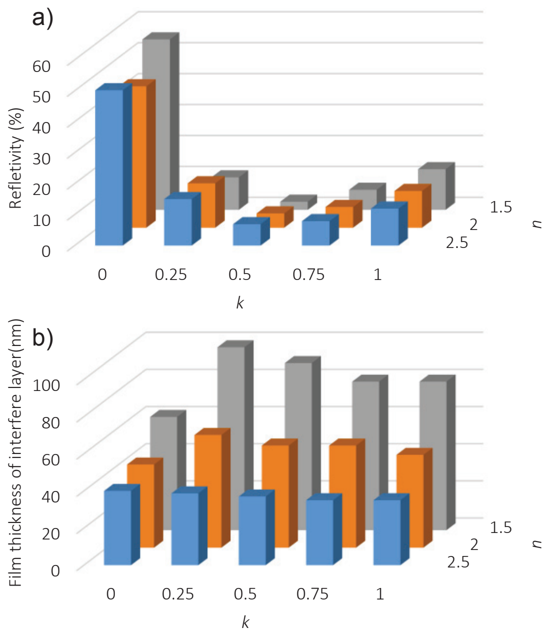


Fig. 2 Simulation result of the a) reflectivity in interfere layer/Cu stacked film which has different interfere optical constant b) film thickness of interfere layer.

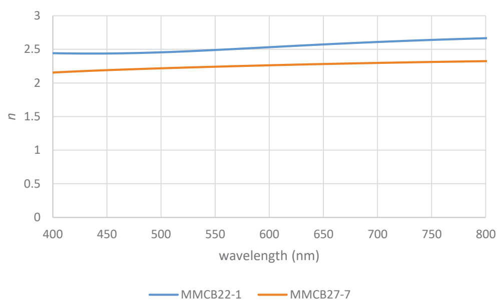
2.2 Sputtering Deposition and Analysis

The sputtering target for interfere layer was obtained by sintering of several kinds of powder mixture. Firstly, the optical constant was optimized by changing raw material combination to get low reflectivity in metal stacked film. In addition, high durability of the film was ensured by using highly durable Nb-based materials. We call this material "MMCB". Some kinds of MMCB series will be described in the presentation. These MMCB sputtering targets have conductivity, therefore the DC sputtering could be applied. Moreover, only Ar gas was used for MMCB sputtering to prevent the in-plane composition variation of oxygen or nitrogen in reactive sputtering. The MMCB thin films was deposited on metal thin film. The reflectivity of the MMCB/metal stacked film was observed by spectrophotometer. In order to evaluate the durability, heat treatment in a nitrogen atmosphere and an H_2 plasma exposure were performed. Then the reflectivity after the test was measured.

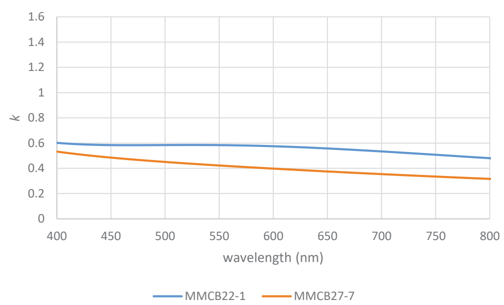
3 RESULTS

3.1 MMCB single layer

Fig. 3 shows the optical constant of MMCB22-1 and MMCB27-7 which were determined by spectroscopic ellipsometer. The MMCB22-1 and 27-7 are partly different in the composition. The MMCB22-1 is designed for HF-HNO_3 etchant and the MMCB27-7 is for phosphoric acetic nitric acid. By optimizing the combination and ratio of the raw materials, the refractive index of the MMCB film showed 2.0 to 2.5, and the extinction coefficient was kept between 0.4 and 0.6 in visible range.



a)



b)

Fig. 3 Optical constant of a) refractive index *n* and b) extinction coefficient *k* in MMCB single layer on Si substrate.

3.2 MMCB/metal stacked layer

Fig.4 shows the reflectivity of Cu with and without MMCB22-1 layer. The reflectivity of the Cu decreased by depositing MMCB22-1 layer. When the MMCB22-1 layer is thinner, the reflectivity of high wavelength is higher. On the other hand, when the MMCB22-1 layer is thicker, the reflectivity of low wavelength is higher. These trends indicate that MMCB reduces metal reflections due to interference. In order to minimize the reflectance of Cu, the MMCB22-1 layer need to be deposited about 40 nm. The reflectivity shows 9.8% in average value of visible range (380nm-780nm). Fig.5 shows the reflectivity of Mo(20nm)/Al(100nm)/Mo(20nm) stacked film with and without MMCB27-7 layer. The Mo/Al/Mo reflection decreased due to the deposition of MMCB27-7, and the effect of the film thickness showed similar results to Fig.4. When the MMCB27-7 film thickness is 30nm, the reflectivity shows 8.1% in average value of visible range (380nm-780nm). From these results, by reproducing an ideal optical film with a combination of actual materials, we were able to demonstrate that the interfere/metal stacked film with low reflectivity can be realized.

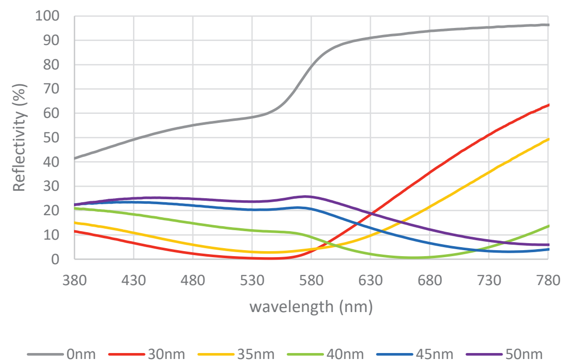


Fig. 4 The MMCB22-1 film thickness dependence of reflectivity in MMCB22-1/Cu/glass stacked film. (The MMCB22-1 = 0nm data shows Cu/glass sample.)

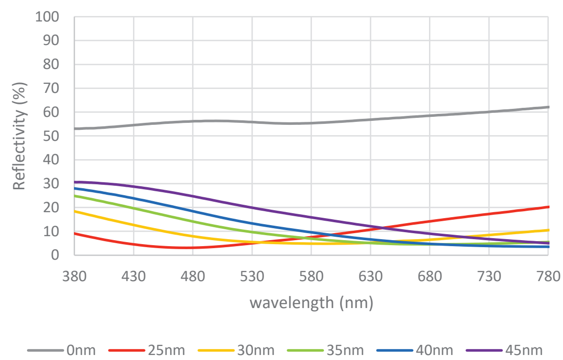


Fig. 5 The MMCB27-7 film thickness dependence of reflectivity in MMCB27-7/Mo/Al/Mo/glass stacked film. (The MMCB27-7 = 0nm data shows Mo/Al/Mo sample.)

Fig.6 shows the reflectivity of the MMCB22-1/Cu stacked film before and after durability test. The reflectivity was almost no change after the H_2 plasma exposure while the spectrum slightly changed after the heat treatment. When the temperature increased from 300°C to 400°C, the reflectivity was increased especially in high wavelength range. It is considered that the optical constant of MMCB22-1 was changed by heat treatment. As a result of adjusting the composition so as to improve the heat resistance, the reflectivity of the MMCB25-5/Cu stacked film was obtained as shown in Fig.7. The MMCB25-5 thin film has similar optical constant and etching properties to the MMCB22-1. The MMCB25-5/Cu stacked film has excellent heat resistance even if 400°C. Fig.8 shows the durability test of the MMCB27-7/Mo/Al/Mo stacked film. As with the MMCB22-1, there was almost no change after the H_2 plasma treatment, but there was a slight increase in reflectivity after the heat treatment.

In the presentation, we'll show the relationships between composition, optical constant and durability of MMCB series. There is some trade-off in those properties. Moreover, the etching characteristics and cross-section profile will be shown and discussed.

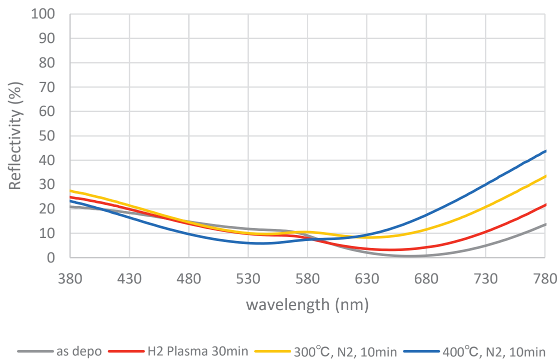


Fig. 6 The reflectivity of MMCB22-1/Cu/glass stacked film before and after durability test.

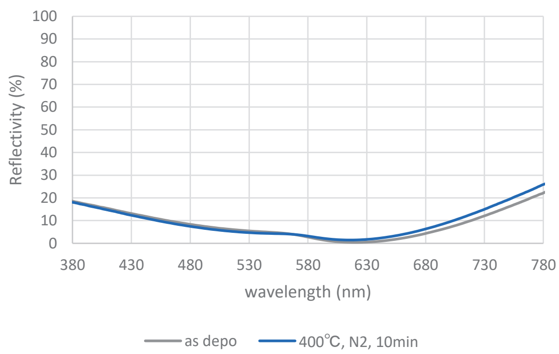


Fig. 7 The reflectivity of MMCB25-5/Cu/glass stacked film before and after durability test.

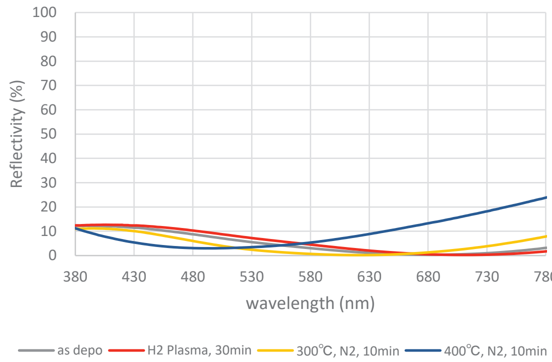


Fig. 8 The reflectivity of MMCB27-7/Mo/Al/Mo/ glass stacked film before and after durability test.

4 CONCLUSIONS

The blackening of TFT wiring was studied. The interfere layer on the metal wiring is the best method to get low reflectance metal wiring. From the simulation results, when the refractive index of interfere layer is lower value and the extinction coefficient is around 0.5, the reflectivity of stacked film became lower. We succeeded in adjusting optical constant with durability by combination of Nb-based materials. The MMCB/metal stacked film shows low reflectivity and almost no change after durability test. We believe this material is useful for designing high performance displays such as high resolution, transparent and so on.

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