Thin Solid Films 624 (2017) 106–110

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Annealing-free copper source-drain electrodes based on copper–calcium diffusion barrier for amorphous silicon thin film transistor

Zhinong Yu [a,*], Jianshe Xue [b], Qi Yao [b], Guanbao Hui [b], Yurong Jiang [a], Wei Xue [a]

[a] School of Optoelectronics and Beijing Engineering Research Center of Mixed Reality and Advanced Display, Beijing Institute of Technology, Beijing 100081, China
[b] Beijing BOE Optoelectronics Technology Co., Ltd, Beijing 100176, China

ARTICLE INFO

Article history:
Received 22 October 2015
Received in revised form 21 October 2016
Accepted 11 January 2017
Available online 12 January 2017

Keywords:
Thin film transistor
Copper metallization
Copper–calcium alloy
Adhesion

ABSTRACT

The copper (Cu) source-drain electrodes based on copper–calcium (CuCa) diffusion barrier were fabricated without annealing process and in one wet etching step in order to develop the applications of Cu in hydrogenated amorphous silicon thin film transistor (α-Si:H TFT). The results show that oxygen flux and substrate temperature in depositing CuCa buffer layer affect greatly the adhesion of source-drain electrodes, and a perfect adhesion was obtained by an increasing oxygen flux to 4 sccm or an increasing substrate temperature to 150 °C, despite no annealing process. The specific resistance of source-drain electrodes has a slight increase with the increasing oxygen flux or substrate temperature or CuCa thickness. Auger electron spectroscopy (AES) show that the CuCa alloy barrier layer has perfect anti-diffusion between Cu film and α-Si:H. A much-desired taper angle of 43.4° and a little critical dimension (CD) bias of 0.91 μm for the Cu/CuCa electrodes were obtained in one wet etching step. The α-Si:H TFT with the Cu/CuCa source-drain electrodes demonstrated the field-effect mobility of 0.73 cm^2/Vs, the subthreshold slope of 0.73 V/dec, the threshold voltage of 0.45 V, and the I_{on}/I_{off} ratio of 10^6 due to the superior performances of the source-drain electrodes with the desired adhesion, specific resistance and taper angle despite no annealing process.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

In recent years, with the rapid development of high-resolution thin film transistor liquid crystal displays (TFT-LCDs), copper (Cu) has received considerable attention due to its lower resistivity in comparison with that of the pure aluminium (Al), which helps to increase the transmission speed of digital signals and reduce the power consumption [1]. However, copper thin films exhibit poor adhesion to silicon based materials; and copper atoms may diffuse into the silicon based materials, resulting in reduction in reliability. In this case, it is necessary to provide an auxiliary film, which has an adhesion property and a barrier property against diffusion to ensure structural integrity and electrical reliability [2–4].

Several techniques have been suggested to overcome the problems. For example, molybdenum or titanium has been employed as a buffer layer in a bilayer structure of Cu/Mo or Cu/Ti in TFT-LCDs [5–6]. However, these heterogeneous metal bilayer structures give rise to problems in wet etch patterning due to the differences in electrochemical properties between Cu and the refractory metals as Mo, Ti, and so on. Since etchants used for copper thin films and used for buffer layer are not the same, the copper thin film and the buffer layer cannot be etched in one etching step [7–8]. For this reason, a buffer layer which has a barrier property and an adhesion property and can be etched by the same etchant as a copper thin film is desired. A technique using Cu based alloy film attracts considerable attentions. For example, Cu-Mn alloy film allows the self-forming of a layer which prevents diffusion and aids adhesion as a reliable and cost-effective alternative to an extra layer of Mo or Ti [9]. With this technique, Cu-Mn alloy is first deposited directly on oxygen-containing material such as silicon oxide or glass. During subsequent annealing, Mn migrates towards the interface and reacts with a surface oxide layer until a Mn complex oxide layer forms, which strengthens adhesion and blocks diffusion. However, a technical problem in attempting to apply Cu-Mn alloy to source/drain interconnects is a lack of oxygen at the interface between the Cu-Mn alloy and phosphorus doped hydrogenated amorphous silicon (n-type α-Si:H). To overcome this problem, surface oxidation pretreatment of the n-type α-Si:H is required before depositing the alloy. Junichi Koike adopted a 10 nm SiO_2 grown by oxide plasma pretreatment of n-type α-Si:H surface to improve the adhesion and diffusion barrier of Cu-Mn electrode [10].

In our previous work, it was testified that copper – calcium(CuCa) alloy thin film deposited in the optimal conditions can be used as diffusion barrier for copper metallization [11]. Sang Ho Lee also adopted CuCa alloy layer as the barrier of Cu soure/drain electrodes in the In-Ga-Zn-O (IGZO) TFT to enhance the adhesion and diffusion barrier of

* Corresponding author.
E-mail address: znyu@bit.edu.cn (Z. Yu).

http://dx.doi.org/10.1016/j.tsf.2017.01.019
0040-6090/© 2017 Elsevier B.V. All rights reserved.

the electrodes by thermal annealing 250 for 15 min in a N_2 ambient [12]. In this paper, the annealing-free copper source-drain electrodes based on CuCa diffusion barrier were investigated in order to develop the applications of Cu in the α-Si:H TFT, and the superior performances of α-Si:H TFT with the Cu/CuCa source-drain electrodes were obtained for the desired adhesion, specific resistance and taper angle despite no annealing process and only one wet etching step.

2. Experimental details

For the fabrication of α-Si:H TFT, a heavily doped Si wafer with 200 nm-thick thermally grown SiO_2 was used as common gate electrode and gate dielectric, respectively. Two layers of α-Si:H (150 nm), n^+ α-Si:H (40 nm) were consecutively deposited on the SiO_2/Si in a PECVD reactor at a substrate temperature of 300 °C. The α-Si:H was deposited from a mixture of SiH_4 (1 sccm), He (100 sccm), H_2 (2 sccm), and the n^+ α-Si:H was deposited from a mixture of 2% PH and 98% SiH_4. Then, a bilayer of CuCa film and Cu film was successively deposited on the n^+ α-Si:H layer by magnetron sputtering using Cu-1 at.% Ca alloy target (99.999% purity) and Cu target (99.999% purity), respectively. The deposition atmosphere of CuCa thin film was oxygen/argon (O_2/Ar) mixture gas, and the deposition pressure was set to 0.5 Pa. The O_2 gas flow rate varied from 0 to 5 sccm, and the substrate temperature varied from room temperature to 250 °C. The deposition atmosphere of Cu thin film was Ar gas, and the deposition pressure was set to 0.3 Pa. The thickness of Cu film was kept same as 300 nm, and the substrate temperature was room temperature. The bilayer of CuCa film and Cu film was processed into source/drain electrodes for the production of α-Si:H TFT. The TFT structure is shown in Fig. 1. The source/drain electrodes with the channel width (W) of 10 μm and channel length (L) of 5 μm were defined by photolithography and wet etching methods.

The critical load (L_c), as the evaluation index to describe the adhesive strength of Cu/CuCa electrode film, was recorded by a CSEM Instruments Micro Scratch Tester with a spherical Rockwell C diamond stylus. The tip radii was fixed as 50 μm and the applied load varied from 0 to 20 N which generated scratches. The tip was drawn across the film substrate system to be tested, and the critical load (L_c) was defined as the smallest load at which a recognisable failure occurred [13].

The sheet resistance was measured by the four-point probe (FPP) technology and the specific resistance of the film was calculated by simple relation $\rho = R_S \times t$, where, ρ is specific resistance, R_S is the sheet resistance and t is the film thickness. The taper angle and critical dimension (CD) bias of the Cu/CuCa electrode after the etch process were confirmed by scanning electron microscopy (SEM). The depth profile was obtained with Auger electron spectroscopy (AES) using a probing energy of 10 kV and 10 nA corresponding to a beam size of 20–25 nm. The electrical characteristics of the TFT devices were performed using semiconductor parameter Hewlett–Packard 4156C.

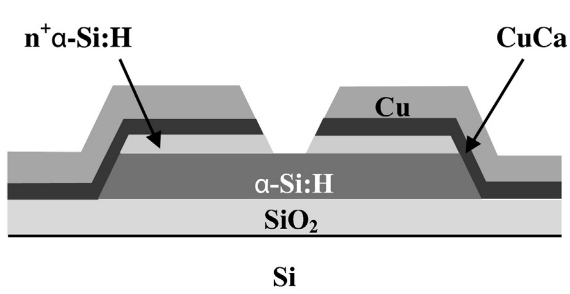

Fig. 1. Cross-sectional view of α-Si:H TFT with Cu/CuCa alloy source-drain electrodes.

3. Results and discussion

The poor adhesion of Cu film deposited on glass or silicon has been confirmed, and some methods were proposed to enhance the adhesion in view to the formation of an oxide layer by an inset of buffer layer and a high temperature annealing process [1–10]. In the experiments, the adhesion, resistance and diffusion properties of Cu film as source-drain electrodes of α-Si:H TFT were improved with an inset of CuCa buffer layer prepared at an optimal deposition condition without annealing process. Among the deposition parameters of CuCa buffer layer, the oxygen flux and substrate temperature remarkably affect the adhesion of Cu films and the optimal oxygen flux and substrate temperature induce the perfect adhesion of Cu film despite no post-annealing.

Fig. 2 shows the effects of oxygen flux (a) and substrate temperature (b) in depositing CuCa buffer layer on the adhesion of source-drain electrodes. For the samples prepared at substrate temperature of 150 °C, without oxygen introduction into the deposition of CuCa film, almost all the Cu film peels off without loading and the critical load (L_c) is defined as 0 N. The adhesion strength increases slowly from 2 N to 2.8 N and fast from 2.8 N to 19.5 N with the increase of oxygen flux from 1 to 2 sccm and from 2 to 4 sccm, respectively. When the oxygen flux exceeds 4 sccm, the source-drain electrodes shows perfect adhesion and the adhesion strength almost keeps invariable as 20 N, as shown in Fig. 2(a). For the samples prepared with oxygen flux of 4 sccm, the adhesion strength increases from 2 N to 19.5 N with the increase of

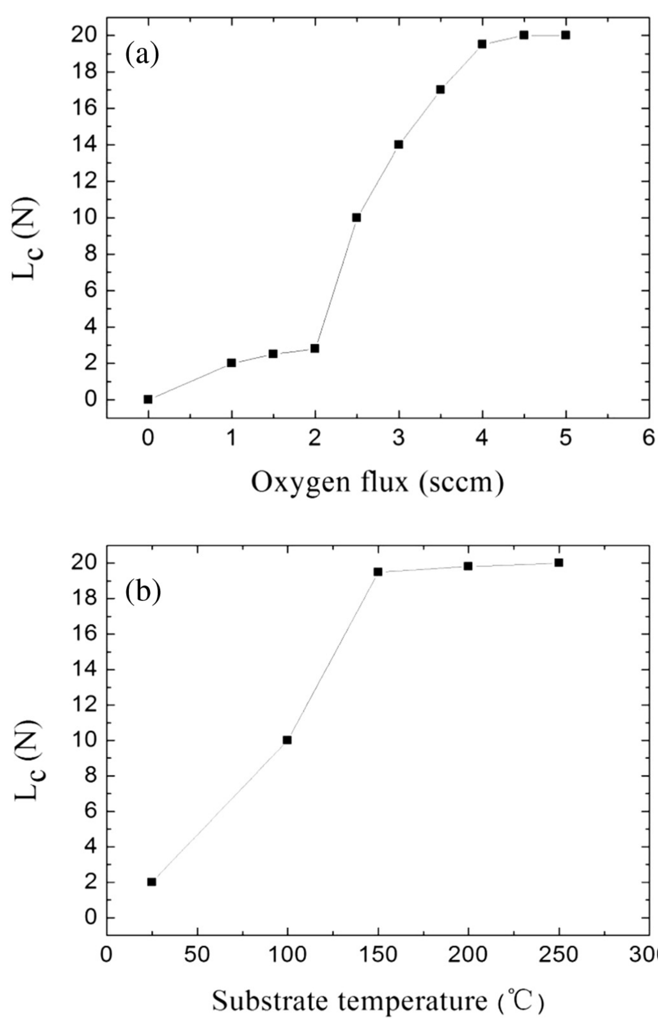

Fig. 2. The effects of oxygen flux (a) and substrate temperature (b) in depositing CuCa buffer layer on the adhesion of source-drain electrodes as-deposited.

Download English Version:

https://daneshyari.com/en/article/5466356

Download Persian Version:

https://daneshyari.com/article/5466356

Daneshyari.com