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Cu Electroplating process with magnetic field for Flexible Device

Naoki Ooi, Hidemitsu Aoki, Daisuke Watanabe, J.Jong-Hyeon,
Chiharu Kimura and Takashi Sugino
Dept. of Electrical, Electronic and Information Engineering, Osaka University,
2-1 Yamadaoka, Suita-Shi, Osaka 565-0871, Japan
Mail: aoki@steem.eei.eng.osaka-u.ac.jp

Abstract

We investigated the effect of a magnetic field during a Cu electroplating. We have succeeded in suppression of Cu oxidation and large grain growth without annealing and additives by using Cu electroplating process applying the magnetic field vertical to the electric field. In a conventional Cu electroplating process, the annealing is required to obtain a stable Cu film after electroplating. This process without annealing is useful for Cu interconnection of flexible devices.

Introduction

Recently flexible display and devices using plastic substrates have been investigated. Low temperature process less than 100°C is required to fabricate these devices. However, annealing more than 250°C for interconnection process of the devices is needed to obtain a stable Cu film. Especially, the annealing is required for rapid grain growth and desorption of hydrogen and residual additives (suppressor, accelerator and leveler) in Cu film after electroplating.

It has been reported that a static uniform magnetic field during the Cu electroplating process is useful for the step coverage and gap filling. The paper reports an effect of a paramagnetic force (J//B), where J is the current density and B is magnetic field [1]. On the other hand, we applied the magnetic field vertical to the electric field.

This study reports the characteristics of the electroplated Cu films which is deposited under Lorentz's force ($J \perp B$) without annealing and additives for flexible devices.

Experiment

Fig. 1 shows the schematic diagram of the Cu electroplating system in which is applied the magnetic field. A neodymium based magnet is used for applying strong magnetic field. An electroplating Cu film was deposited on a seed Cu layer without and with the magnetic field (0.3T) vertical to the electric field.

A conventional $CuSO_4$ based solution containing H_2SO_4 and Cl ion for Cu electroplating was used at 30°C. The deposition conditions include an electrode distance of 15 cm, on-time cathode current density of 3A/dm^2. XPS measurements were carried out to examine the property of Cu surface.

Results and discussion

Fig. 2 illustrates the time dependence of deposition thickness of the electroplated Cu films. The thickness of Cu film with the magnetic field increases with increasing deposition time and the deposition rate is approximately twice higher than that without magnetic field. The resistivity of Cu film with the magnetic field was lower than that without magnetic field. Fig.3 shows SEM surface photographs of the plated Cu films without (a) and with magnetic field at 0.3T (b). The Cu surface with large grain size is observed for applying magnetic field.

Fig.4 shows XPS spectra of Cu(2p) core level of Cu surface with and without magnetic field. The Cu-O peak of Cu surface without magnetic field is observed at 945eV. On the other hand, the Cu surface with magnetic field is not clearly observed. The O/Cu ratio on the Cu film measured after air exposure for a week. It is found that Cu oxidation with magnetic field was suppressed not only surface but also film inside.

Fig.5 shows the Cu deposition model of electroplating with vertical magnetic field. It is thought that the Lorentz's force induces micro stream of Cu ions near the surface. Thus, Cu atoms only can be effectively deposited on the substrate without including impurity such as Cl ions, SO^{4-} ions and H_2 gas. It is suggested that the oxidation of Cu film is suppressed.

We also attempted gap filling between photoresist patterns. Cu film with good gap filling is obtained by the electroplating with vertical magnetic field. Cu wires were formed by removing the photoresist and the seed layer by wet process as shown in Fig.6.

Conclusion

We have succeeded in suppression of Cu oxidation and large grain growth without annealing and additives by using Cu electroplating process applying the magnetic field vertical to the electric field. It is thought that Cu atoms can be effectively deposited by the micro stream due to Lorentz's force. This process without annealing is useful for Cu interconnection of flexible devices.

Acknowledgements

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References

[1] B.N.Park et.al, Microelectronic Engineering 85 (2008) 308.

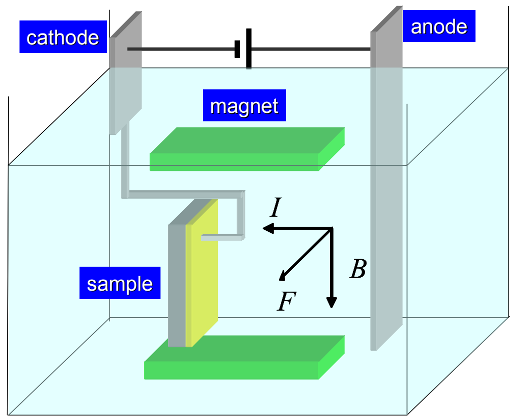

Fig.1 Schematic diagram of the Cu electroplating system with magnetic field.

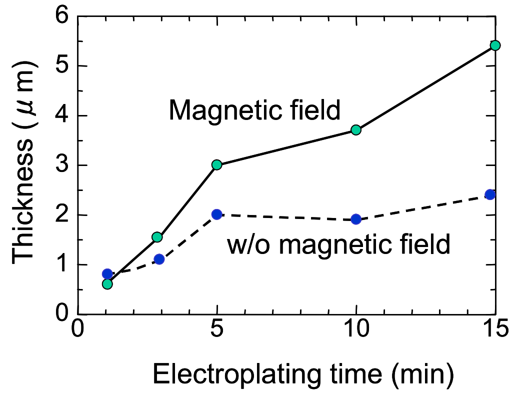

Fig.2 Time dependence of the plated Cu films with and without magnetic field.

(a)

(b)

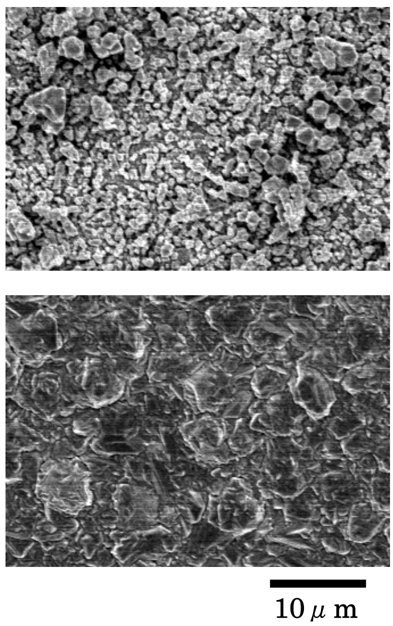

Fig3 SEM surface photographs of the plated Cu films for magnetic field at (a) 0 T and (b) 0.3T.

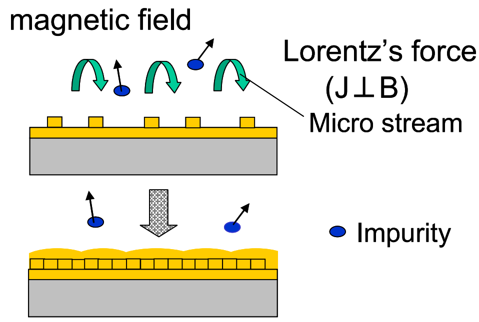

Fig.5 Cu deposition model of electroplating with vertical magnetic field.

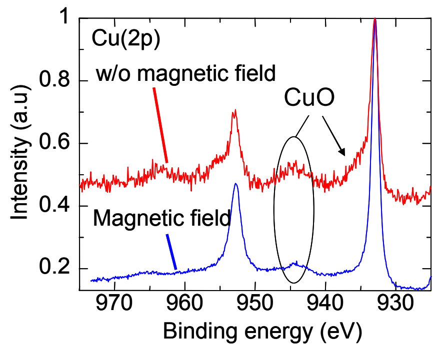

Fig.4 XPS spectra Cu(2p) of Cu surface with and without magnetic field.

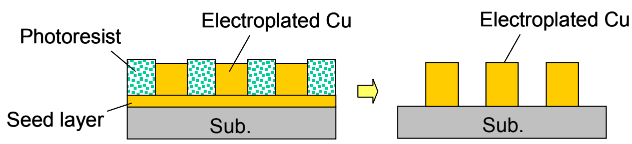

Fig.6 SEM photograph of Cu wires formed by the electroplating with vertical magnetic field.
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