Extended Abstracts of the 2011 International Conference on Solid State Devices and Materials, Nagoya, 2011, pp594-595

Effects of Excimer Laser annealing of Oxide Semiconductor Films

Mami Fujii[1], Ryoichi Ishihara[2], Tao Chen[2], Johan van der Cingel[2], Mohammad R.T. Mofrad[2], Masashi Kasami[3], Koki Yano[3], Masahiro Horita[1,4], Yasuaki Ishikawa[1,4], Yukiharu Uraoka[1,4]

[1]Nara Institute of Science and Technology, 8916-5 Takayama, Ikoma, Nara 630-0192, Japan
Phone:+81-743-72-6072 Fax:+81-743-72-6079 E-mail:f-mami@ms.naist.jp
[2]Delft University of Technology, Feldmannweg 17, POBox 5053, 2600 GB Delft, The Netherlands
[3]Idemitsu Kosan Co., Ltd., 1280 Kamiizumi, Sodegaura, Chiba 229-0293, Japan
[4]CREST, Japan Science and Technology Agency, Honcho, Kawaguchi, Saitama 332-0012, Japan

1. Introduction

Oxide semiconductor films deposited by sputtering have recently attracted considerable attention in fields of transparent and flexible electronics for the next generation displays in comparison with conventional semiconductors. Especially, IZO thin film has a higher field effect mobility than the IGZO film when applied to the thin film transistors (TFT).[1-3] In general, the annealing process with about 300ºC or more is effective to obtain good characteristics when the oxide semiconductor films are applied to electronic devices such as TFTs.[2,3] In the case of IZO film, amorphous phase has a high conductivity of about 400Ω^{-1}cm^{-1}, that is much higher than suitable conductivity as a channel layer. Here, the conductivity of this material decreases by crystallization with thermal annealing. On the other hand, IGZO TFTs claims decreasing the oxygen vacancies with keeping amorphous phase to get good electrical properties. Hence, thermal annealing with high temperature of about 300°C is required when IZO or IGZO films are applied to TFTs. However, the high temperature process in such a post-annealing limits a choice for plastic flexible substrates in the fabrication of TFTs. Excimer laser annealing (ELA) process with short pulses is possible to achieve the annealing without thermal damage against the plastic substrate. In this study, we investigated effect of ELA for Indium-Zinc-Oxide (IZO) and Indium-Gallium-Zinc-Oxide (IGZO) thin films with various thickness and oxygen contents on their optical and electrical properties.

2. Experiments

The two kinds of oxide semiconductor (IZO and IGZO) films with a thickness of 50 nm were deposited by RF magnetron sputtering on oxidized silicon wafers with a gas mixture of argon and oxygen at room temperature. The silicon dioxide film was formed on the silicon wafer for the 1000 nm as a buffer layer. Oxygen partial pressure ratio P during the RF magnetron sputtering was varied from 0 to 10 percent to change the oxygen contents in the oxide semiconductor films. One shot of XeCl excimer laser, which is a wavelength of 308 nm and a pulse duration of 25 ns at FWHM, were irradiated at the surface of oxide semiconductor films.

3. Results and Discussion

Optical properties

Absorption coefficient of IZO at laser wave length (308 nm) with various P value is shown in Fig. 1. Before the laser annealing, absorption coefficient α at 308 nm of the IZO with the P value of 0 percent was measured to be 2.7×10^{5} cm^{-1}. (see solid-square symbol on the Fig. 1) With increasing the P value to 3 percent, the α was reduced by 40 percent, due to the reduction of oxygen vacancy resulting in widening the bandgap. Further increasing P did not make increase the α value. Similar α values and trends were obtained for IGZO film as well. This behavior has a relation with changing of the carrier density of IZO from 3.5×10^{19} cm^{-3} to 1.5×10^{19} cm^{-3}, estimated from the conductivity. The irradiation of excimer-laser with an energy density of 65 mJ/cm^{2} to the IZO (P=0%) decreased the α about 20 percent. (see solid-circle symbol on Fig. 1) This could be attributed to the fact that the annealing with the laser reduced the oxygen vacancy by lattice reconstruction as shown in the Fig.2. This corresponds to decrease in the conductivity of IZO from 379.27 Ω^{-1}cm^{-1} to 170.79 Ω^{-1}cm^{-1} by the ELA. With increasing the energy density to 165 mJ/cm^{2}, the film ablation was observed on the IZO (P=0%). We simulated the transient heat diffusion behavior, and the maximum temperature of the IZO film was estimated to reach as high as 2100 K, at which vaporization of the oxygen may occur.[4] Here, physical parameters used in the simulation were referred to the reported value. [5-7] The ablation energy density increases with increasing the P value to 3 percent due to the less absorption. Further increase in the P value does not change the ablation energy density. IGZO films showed the similar tendencies of conductivity and ablation energy.

Electrical properties

Next, we considered the relation between the crystallinity and the electrical properties on the IZO films because the conductivity of the IZO film is possible to change with the crystallization. The conductivities were measured using four prove measurement. X-ray diffraction measurement (XRD, Rigaku RINT-TTRⅢ/NM) was also carried out for the several IZO films received ELA.

Figure 3 shows the film conductivity of the IZO with 0% for P value. Before ELA, IZO film had a high conductivity of about 400 Ω^{-1}cm^{-1}, and it increased to 500 Ω^{-1}cm^{-1}

after 65 mJ/cm^2 laser annealing. Here, IZO film still kept amorphous phase as shown in Fig. 4. Figure 4 shows the XRD pattern of the IZO (*P*=0%) films after various laser annealing. When the laser energy increased up to 115 mJ/cm^2, XRD pattern showed the In_2O_3 (222) peak in the 2θ = 30.7 degrees. And then, film conductivity decreased in the 115 mJ/cm^2 laser energy as shown in Fig.3. These results indicate that we achieved the control of the film conductivity of the IZO by ELA. Moreover, we accomplished the suitable conductivity of around 10 $\Omega^{-1}cm^{-1}$[1] to TFT channel layer with the laser energy of 190 mJ/cm^2.

4. Conclusion

In this study, we discussed the ELA effect on the characteristics of the IZO thin film to achieve the lower process temperature and the high performance TFT. Our results could be attributed to the fact that the annealing with the laser reduced the oxygen vacancy by lattice reconstruction and crystallization. And we were able to achieve to obtain the low conductive IZO film suited to the TFT channel layer.

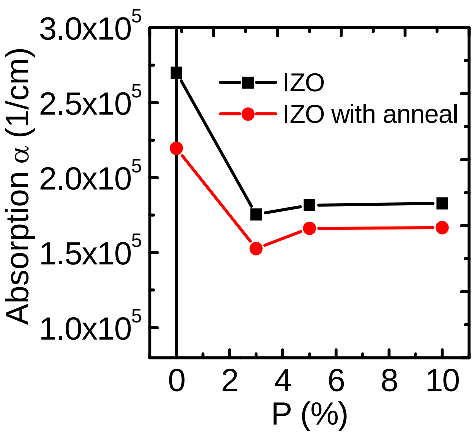

Fig. 1 Absorption coefficient α of IZO films at laser wave length of 308 nm with various *P* (oxygen partial pressure ratio) value.

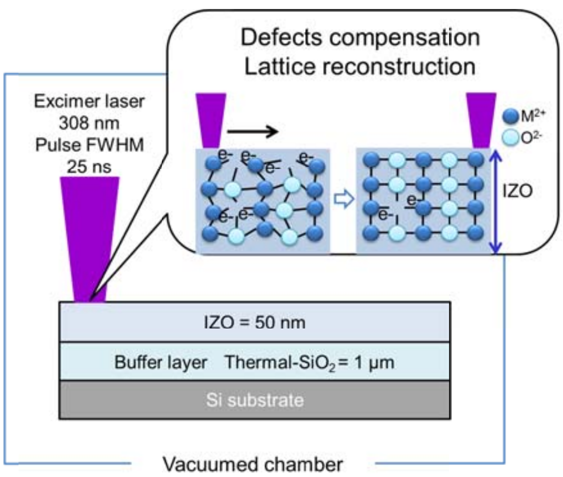

Fig. 2 Model of the film improvement by the excimer laser annealing process.

Acknowledgements

This study was supported by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science.

References

[1] E. Fortunato, P. Barquinha, A. Pimentel, L. Pereira, G. Goncalves, and R. Martins, Phys. Stat. Sol. (RRL) **1** (2007) No.1, R34-R36

[2] P-T Liu, Y-T Chou, and L-F Teng, Appl. Phys. Lett. **94** (2009) 242101

[3] P. Barquinha, G. Goncalves, L. Pereira, R. Martins, E. Fortunato, Thin Solid Films 515 (2007) 8450

[4]K. Nomura,T. Kamiya, M. Hirano, and H. Hosono, Appl. Phys. Lett. **95** (2009) 013502

[5] E. Nishimura, T. Sasabayashi, N. Ito, Y Sato, K. Utsumi, K. Yano, A. Kaijo, K. Inoue, and Y. Shigesato, Jpn. J. Appl. Phys. **46** (2007) 12, 7806.

[6] T. Ahida, A. Miyamura, Y. Sato, T. Yagi, N. Taketoshi, T. Baba and Y.Shigesato, J. Vac. Sci. Technol. A **25** (2007) (4)

[7] M. Nakata, K. Takechi, S. Yamaguchi, E. Tokumitsu, H. Yamaguchi, and S. Kaneko, Jpn. J. Appl. Phys. **48** (2009) 115505.

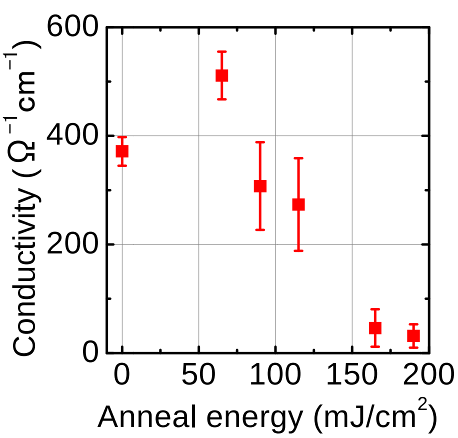

Fig. 3 The film conductivity of the IZO (*P*=0%) with various ELA energy

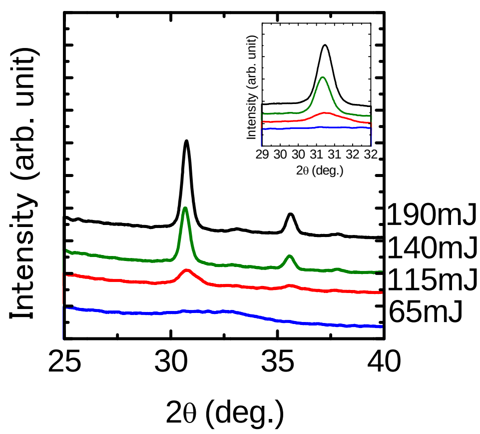

Fig. 4 XRD pattern of the IZO (*P*=0%) with various ELA energy.