PS-8-23

Extended Abstracts of the 2015 International Conference on Solid State Devices and Materials, Sapporo, 2015, pp314-315

Epitaxial growth of yttrium monoxide thin film

Kenichi Kaminaga[1,2], Ryosuke Sei[1,2], Tomoteru Fukumura[2,3] and Tetsuya Hasegawa[1,3]

[1] Dept. Chemistry, The Univ. Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Phone: +81-3-5841-7595 E-mail: kaminaga@chem.s.u-tokyo.ac.jp
[2] Dept. Chemistry, Tohoku Univ.
6-3, Aoba, Aramaki, Aoba-ku, Sendai 980-8578, Japan
[3] JST-CREST
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

Abstract

Solid phase yttrium monoxide epitaxial thin film was grown by pulsed laser deposition. In contrast with dielectric insulator Y_2O_3, YO was electrically conducting with an opaque color suggesting its narrow band gap.

1. Introduction

Yttrium sesquioxide (Y_2O_3) has been widely investigated as a gate insulator for field effect transistor because of the high permittivity and robust insulating properties [1], owing to high stability of trivalent yttrium ion in solid phase oxides. On the other hand, it has been known that divalent yttrium ion exists only in gaseous phase of yttrium monoxide (YO) [2]. Until now, there has been no report on the solid phase of YO, hence its physical properties has been unknown. In this study, rock salt YO epitaxial thin films were synthesized by pulsed laser deposition (PLD) method.

2. Experimental

YO epitaxial thin films were grown on CaF_2 (100) substrates by PLD. Y_2O_3 sintered pellet was used as a target. The thin films were grown at 350 °C in different oxygen pressure during growth by introducing Ar and O_2 1 % mixed gas in order to control the amount of oxygen vacancy. Crystal structures and chemical compositions of the films were evaluated by x-ray diffraction (XRD) and x-ray photoemission spectroscopy (XPS). Temperature dependence of resistivity was measured with four probe method.

3. Result and Discussion

Figure 1 shows out-of-plane XRD pattern of YO thin film. Rock salt structure YO *h*00 peaks were clearly observed representing the formation of YO (100) epitaxial thin film. In addition, α-Y_2O_3 *h*00 peaks were observed as explained below. The lattice constants of rock salt YO film calculated from out-of-plane and in-plane XRD patterns were $a = b = 4.966$ Å, $c = 4.791$ Å.

Figure 2 shows depth profile of each element measured by XPS with in-situ Ar ion sputtering. From the areal peak intensities of Y 3*d* and O 1*s* the atomic ratio of Y/O was determined. The Y/O ratio inside the film was approximately 1.0. The peak position of Y $3d_{5/2}$ of Y^{2+} in YO phase

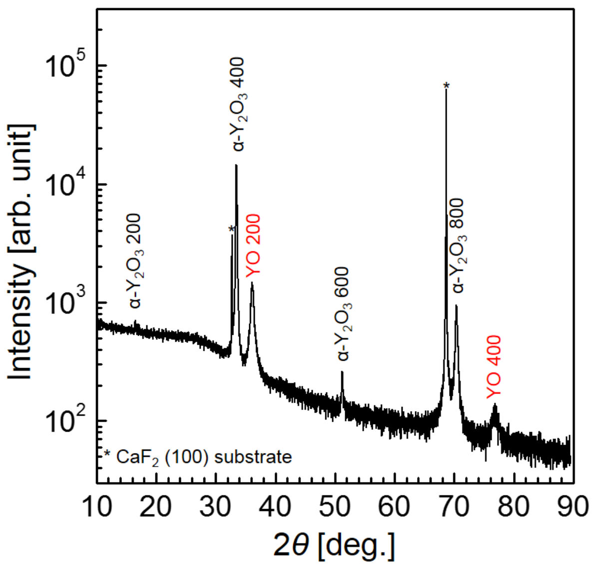

Fig. 1 Out of plane XRD pattern of YO thin film.

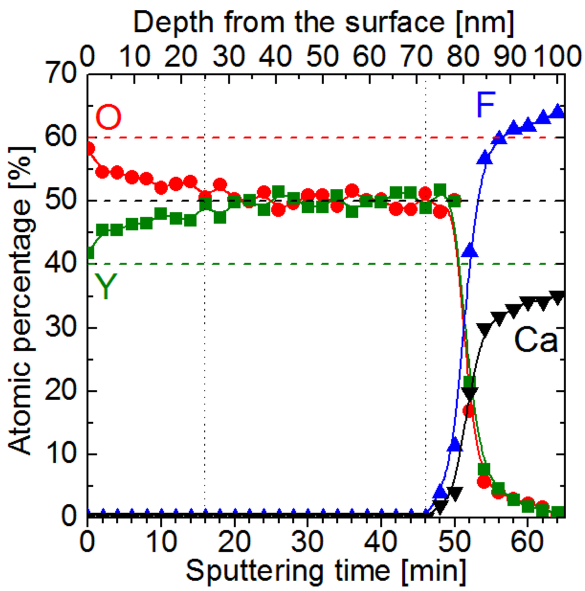

Fig. 2 XPS depth profile of YO thin film.

was 156.4 eV, which is similar to that of divalent yttrium ion in yttrium dihydride, 156.53 ± 0.1 eV [3]. Accordingly, this result represents the formation of YO phase with Y^{2+} ionic state. It is noted that the Y/O ratio near the surface was about 2/3 with ionic state of Y^{3+}, indicating the presence of 25 nm thick α-Y_2O_3 layer probably due to surface oxidation. This result is consistent with XRD data (Fig. 1) that both YO and Y_2O_3 phases were observed.

Figure 3 shows temperature dependence of resistivity (ρ) for YO thin film. A slight upturn of resistivity was observed below 20 K, which might be caused by Kondo effect. The resistivity and carrier density at 300 K were 6.2×10^{-2} Ωcm and 3.8×10^{20} cm^{-3}, respectively. Isothermal magnetoresistance at 2 K was slightly positive as shown in inset of Fig. 3. These electric properties are quite different from those of Y_2O_3, suggesting that $4d^1$ electron plays a principal role of electric conduction in YO.

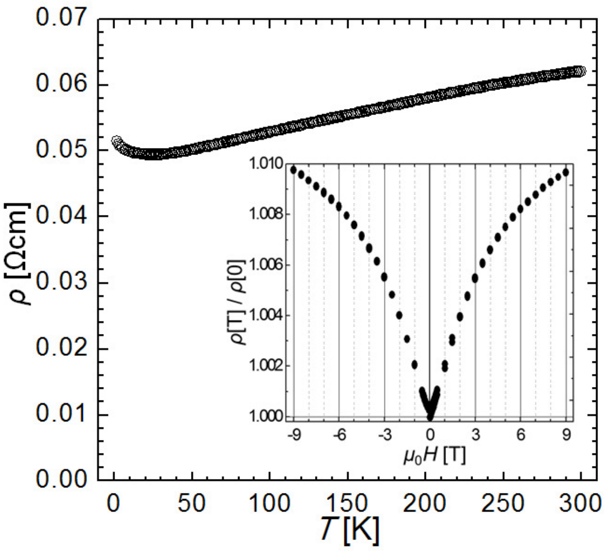

Fig. 3 Temperature dependence of resistivity and field dependence of magnetoresistance at 2 K (inset) for YO film.

3. Conclusions

Solid phase rock salt YO was grown in the form of epitaxial thin film by PLD method. The electronic transport properties were electrically conducting, thus were significantly different from those of Y_2O_3.

Acknowledgements

X-ray photoemission spectroscopy was conducted in Research Hub for Advanced Nano Characterization, The University of Tokyo, supported by MEXT, Japan. This research was in part supported by JSPS through the NEXT Program initiated by CSTP (GR029) and JSPS Grant-in-Aid for Scientific Research (26105002).

References

[1] H. Yabuta *et al., Appl. Phys. Lett.* **89**, 112123 (2006).
[2] J.M. Badie *et al., Chem. Phys. Lett.* **364**, 550 (2002).
[3] T. Monstad *et al., Sol. Energ. Mat. Sol. C.* **128**, 270 (2014).