Deposition Condition for High Crystalline Fraction of Yttria-Stabilized Zirconia (YSZ) Films Deposited by Reactive Sputtering at Room Temperature

Japan Adv. Inst. of Sci. & Tech. (JAIST), O(M2) Jyotish Patidar and Susumu Horita
E-mail: s1810430@jaist.ac.jp

Introduction: Our research group has reported that yttria-stabilized zirconia (YSZ) film is quite effective to stimulate crystallization of amorphous silicon (a-Si) at low temperature. Also, a crystallized YSZ film can be deposited on a non-heat resistive Cellulose Nanopaper (CNP) without any damage using DC magnetron sputtering with Ar and O_2, which indicates a high possibility to fabricate a poly-Si TFT on CNP [1]. In the previous meeting, we reported the pre-sputtering condition is very important to improve crystalline quality or fraction of the deposited YSZ film. In this meeting, we show that, one of the deposition conditions, pumping speed is also an important factor.

Experimental procedure: YSZ films were deposited on chemically cleaned glass substrates by reactive sputtering with Ar and O_2 [2]. A Zr + Y metal target was pre-sputtered for 3 min at the sputtering power and pressure of 10 W and 18 mTorr, respectively, with 2.1 sccm oxygen flow rate. The films were deposited for 10 min at 100 W and 5 mTorr. Pumping speed of the system was controlled by opening degree of the main valve, and the deposition pressure was kept constant by changing the flow rate of Ar (F_{Ar}) from 5.8 to 17.4 sccm and flow rate of O_2 from 0.4 to 0.78 sccm, respectively, with a constant ratio between them. The substrate temperature monitored by thermo-label attached on holder side was always less than 80°C during the YSZ film deposition. The crystallinity of deposited films was examined by X-ray diffraction (XRD) technique.

Results and Discussion: Fig. 1 shows schematically how to estimate integrated crystalline intensity, I_x for deposited YSZ films. Fig. 2 shows variation of the I_x with increasing F_{Ar} for about 50-nm-thick YSZ films. It can be seen that I_x or crystalline fraction, X_c of YSZ film increases with F_{Ar} monotonically. We discuss this result briefly below.

It is well known that O^- ions are detrimental for the quality of a deposited YSZ film because they attack the deposited film with too high energy and hinder the crystallization process of the film. It has been also reported by Welzel et al. that an oxidized target surface is major source of formation of O^- ions during the reactive sputtering[3]. Therefore, keeping balance between oxidation of the metallic target surface and simultaneous sputtering of the oxide layer can be a key to reduce the O^- ions in plasma for improvement in crystallization fraction of deposited films. According to the relationship between Q(total flow rate), S (pumping speed) and P (pressure), viz. Q = SP, S is proportional to Q or F_{Ar} because of constant P in our case. So, by increasing S, corresponding to higher F_{Ar}, residence time of O_2 gas near the target surface can be reduced, which may cause the oxidation of target surface to reduce. Therefore, abundance of O^- ions in plasma can be effectively reduced by controlling S or F_{Ar}.

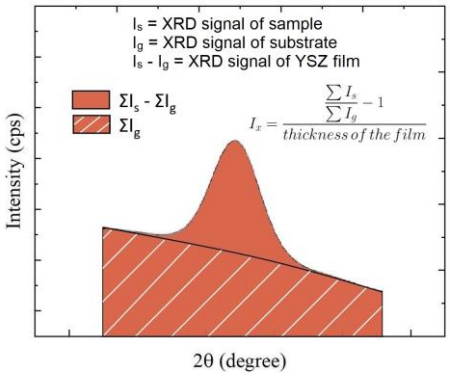

Fig. 1. Calculation of integrated crystalline intensity for deposited YSZ thin films.

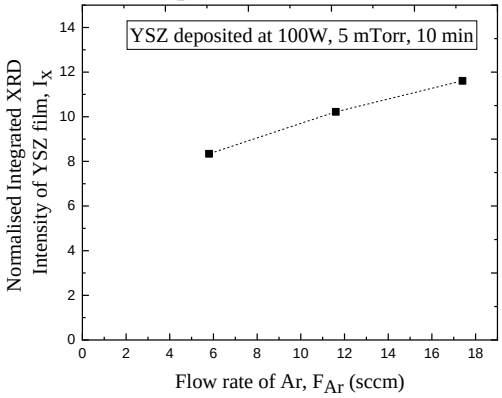

Fig. 2. Dependence of the integrated intensity of YSZ films on the flow rate of Ar gas.

Summary: It was found that the target surface condition is very important in controlling O^- ions formation during the sputtering in order to deposit highly crystallized YSZ films. In the presentation, investigation results about other deposition conditions will be shown and discussed for higher X_c of YSZ film.

References: [1] S. Horita, Abstract JSAP 65th Spring meeting, 2018, 20a-C103-1.
[2] J. Patidar and S. Horita, Abstract JSAP 80th Autumn meeting, 2019, 21a-C310-7.
[3] T. Welzel and K. Ellmer, Negative ions in reactive magnetron sputtering, 2013, Vakuum in Forschung und Praxis, 2.25, 52-56.