Pre-sputtering Condition for Crystallized Yttria Stabilized Zirconia (YSZ) Film Deposition on Cellulose Nanopaper (CNP) by Reactive Sputtering

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Introduction: Our research group found that yttria stabilized zirconia (YSZ) film is quite effective to stimulate crystallization of amorphous Silicon (a-Si) at low temperature. For using the YSZ effect to fabricate electron devices, e.g., TFT, on a flexible substrate and environment friendly material of cellulose nanopaper (CNP), a crystallized YSZ must be deposited without plasma and thermal damage to CNP. Previously, we have reported that a crystallized YSZ film can be deposited on CNP without any damage using DC magnetron sputtering with Ar and O_2 [1]. In this meeting, we show that pre-sputtering condition or treatment of target surface before deposition is one of the important factors for deposition of a highly crystallized YSZ film.

Experimental procedure: YSZ films were deposited on glass substrates by reactive sputtering method with Ar and O_2. The sputtering target was a 99.9% Zr metal target on which 8 pieces of 1×1 cm^2 99.9% Y pellets were placed concentrically. A chemically cleaned glass substrate is used without CNP for initial investigation. For YSZ film deposition, the mass flow rate of Ar and O_2 were 5.8 and 0.4 sccm, respectively. Sputtering pressure and power were 5 mTorr and 100 W respectively, and the deposition time was 10 minutes. In the pre-sputtering, we used two O_2 mass flow rates (F_{O_2}), high (1 sccm) and low (0.4 sccm), and two sputtering times of 1 and 3 minutes. The substrate was not intentionally heated, and the temperature of sample holder was monitored during the deposition with a thermo label attached on the holder side. The temperature 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 the time variation of discharge current (I_D) during sputtering for YSZ film deposition. It can be seen from the figure that after the pre-sputtering at high F_{O_2} of 1 sccm, I_D keeps almost constant over 3 min of sputtering time. On the other hand, at the low F_{O_2} pre-sputtering condition of 0.4 sccm, the I_D was quite unstable since it sharply decreased after 3 minutes. This means that the sputtering discharge mode changed from oxide to metal mode. Pre-sputtering at the high F_{O_2} oxidizes more target surface and forms a thicker oxide layer on the metallic target. Because secondary electron yield of oxide is higher than that of metal, I_D through the oxide layer (oxide mode) is higher than without it (metal mode). During the sputtering deposition, the oxide layer is reduced due to sputtering because of less O_2 flow rate, which leads to decrease in I_D. When the oxide layer is removed completely, the current abruptly falls as shown in Fig.1 (Δ). Fig. 2 shows the XRD patterns of deposited YSZ films after the pre-sputtering with the low and high F_{O_2}. Clearly, it suggests us that pre-sputtering at the high F_{O_2} brings an increase in crystallinity leading to better film quality. This indicates that the pre-sputtering condition or oxide layer on the sputtering target is an important factor for crystallization of a deposited film.

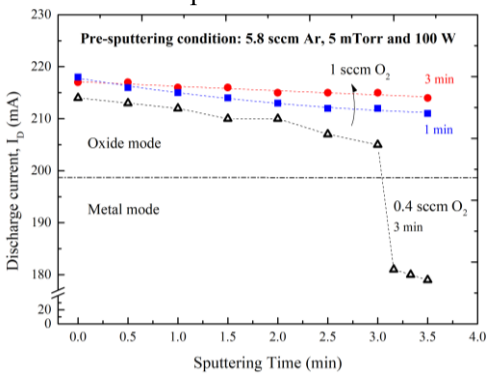

Fig. 1. Time variation of sputtering discharge current (I_D) after different pre-sputtering conditions with respect to O_2 flow rate (F_{O_2}) and sputtering time.

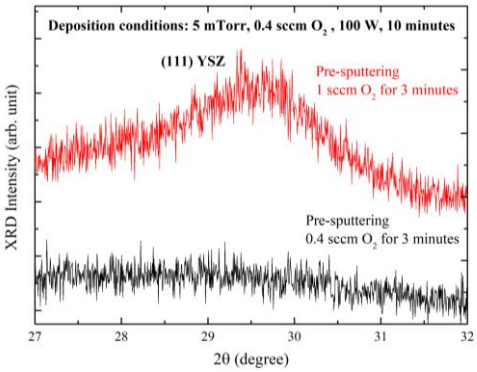

Fig. 2. XRD patterns of YSZ films deposited after pre-sputtering with 1 and 0.4 sccm O_2 flow rates.

Summary: From this experiment, it was found that stable target and discharge condition are very important to deposit highly crystallized YSZ films. In the presentation, investigation results on improvement of YSZ crystallinity will be shown and discussed in detail.

References: [1] S. Horita, Abstract JSAP 65th Spring meeting, 2018, 20a-C103-1.