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A competition between (001) and (011) alignments in yttria stabilized zirconia thin films fabricated by ion beam assisted deposition

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ABSTRACT

Biaxially textured yttria stabilized zirconia (YSZ) thin films, were deposited on glass substrates by ion beam assisted deposition method with different deposition time. As contrasts, films were also fabricated without assisting ion beam. The orientation properties of the films were characterized by X-ray diffraction. A comparative study shows that there is a competition between (001) and (011) alignments during the growth process. Assisting ions make the films (001)-advantaged and biaxially textured. The competitive growth and the orientation development are explained by selective resputtering and anisotropic damage on growing films induced by assisting ions.

1. Introduction

Ion beam assisted deposition (IBAD) technique, defined as the bombardment on growing thin films with energetic ions, can fabricate biaxially textured buffer layers of high temperature superconductor coated conductors on non-textured substrates without epitaxial relationships between substrates and films [1–3]. Much experimental work has been done to study the effects of assisting ion beam (AIB) on film properties [4–8]. A biaxial grain alignment formed by the off-normal bombardment of AIB has been reported on metal [9], nitride [10], and oxide films [11,12]. Various microscopic mechanisms of biaxial texture development, such as selective resputtering [13], shadowing [2], and anisotropic damage [11], were proposed and modeled by computer simulations [14–16]. Dzick et al. [6] investigated the biaxial texture development of YSZ thin films and proposed that (001)-oriented grains grow epitaxially on (011) grains. Though lots of research work has been done, roles of AIB are not understood completely yet.

In this paper, we will study a series of yttria stabilized zirconia (YSZ) films deposited by IBAD with different time and a series of YSZ films fabricated without AIB (non-IBAD) with a comparative method. The difference between IBAD samples and their non-IBAD contrasts will be shown and discussed. Some opinions for understanding the development mechanism of IBAD inducing biaxial texture will be presented.

2. Experimental details

For the deposition of YSZ buffer layers, an ion beam assisted sputtering deposition system was employed with three ion sources of Kaufman type including two (11 cm beam diameter) as sputtering sources and one (21 cm beam diameter) as an assisting ion source. The experimental configuration is shown in Fig. 1. Deposition atoms were sputtered by two beams of Kr^+ from a 12.5%Y to 87.5%Zr (atom ratio) alloy target and deposited along normal on glass substrates, while being bombarded by an Ar^+ beam. We supplied krypton instead of argon for sputtering sources in order to enhance the sputtering rate. The incidence angle of the AIB, defined between the assisting ion beam axis and the substrate normal, is 55°. The substrates were bombarded with AIB to clean the surface for one minute before deposition. No additional heating was applied on the substrates and deposition occured within ambient temperature. Argon flow and Krypton flows were maintained for the assisting ion source and sputtering sources, respectively. An oxygen flow was maintained near the samples to ensure full oxidation of the films. The deposition time is 2, 5, 10, 20, 50, and 100 min for different samples. The parameters used in experiments are shown in Table 1. As contrasts, non-IBAD samples were also fabricated with the same experimental parameters as IBAD ones.

The X-ray diffraction (XRD) analyses of the films were carried out using a D/MAX-RB system, with Cu Kα1 source. XRD θ–2θ scans revealed the film orientation. Based on the full width at half maximum (FWHM) values of the corresponding peaks, the size of crystal grains of the films was calculated with the software in the XRD system. The quality of in-plane texture of the films was character-

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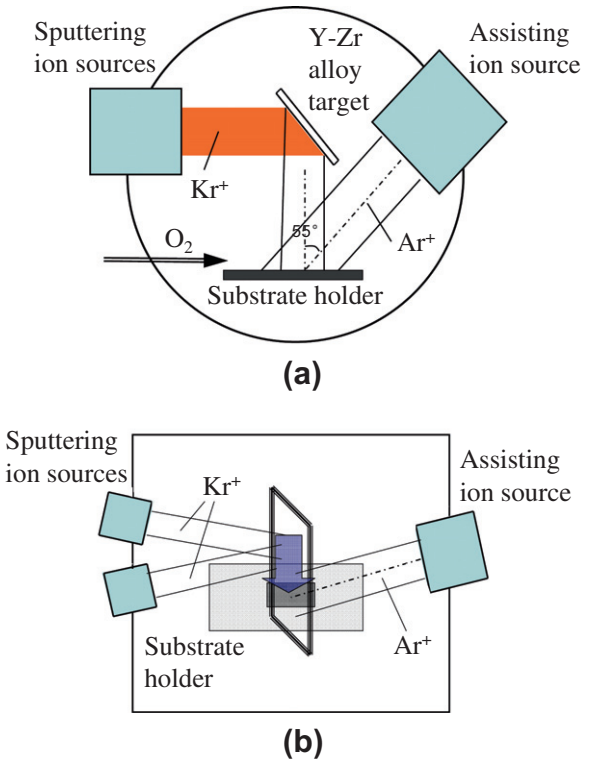

Fig. 1. (a) Top view of our experimental configuration, only one of the two sputtering ion sources is drawn because of the vertical line of sight and (b) Side view of our experimental configuration.

Table 1
Experimental parameters used to fabricate IBAD YSZ films.

Assisting ion (Ar^+) current density	0.5 mA/cm^2
Assisting ion (Ar^+) energy	300 eV
Assisting ion incidence	55°
Sputtering ion (Kr^+) current density	3.5 mA/cm^2
Sputtering ion (Kr^+) energy	1500 eV
Oxygen flow	40 sccm
Argon flow	25 sccm
Krypton flow	30 sccm
Background vacuum	About 1.0×10^{-4} Pa
Deposition pressure	About 5.0×10^{-2} Pa
Deposition time	2, 5, 10, 20, 50, 100 min

ized by the FWHM values of the YSZ (1 1 1) reflection measured by the ϕ-scans in the standard Bragg case. The thickness of all the films were measured by an XP-1 surface profilometer of AMBIOS.

3. Results and discussion

Fig. 2 shows the XRD patterns of θ–2θ scan of the non-IBAD samples. We can see that (002) and (022) peaks of YSZ begin to appear at 20 min, and (022) peaks are much stronger than corresponding (002) peaks. The diffraction intensity of (022) peak can be found to increase in the deposition process, whereas the intensity of the (002) peak shown in panel (b) reaches its maximum at 50 min, and then decreases at 100 min. So we can say that with the increase of deposition time, the grains with (001) alignment cease to grow after a maximum, but the grains with (011) alignment continue growing and dominate the alignment of non-IBAD samples. The size of the grains can be reflected by the FWHM of (022) peak in XRD curves, which is also shown in Fig. 2. The FWHM of (022) peak does not show a change apparently with

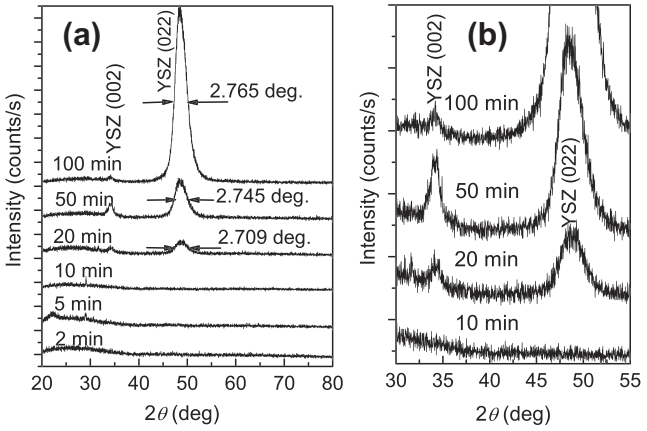

Fig. 2. (a) XRD patterns of θ–2θ scan of the non-IBAD YSZ films deposited with different times. (b) Details near (022) and (002) peak.

deposition time. The size of the (011) grains calculated with the software in XRD system is 31 Å for the films deposited for 20, 50, and 100 min. Obviously the (011) aligned grains do not keep growing during the deposition process.

Fig. 3a shows the XRD patterns of θ–2θ scan of the IBAD samples. The (002) and (022) peaks of YSZ begin to appear at 10 min, and (002) peaks are much stronger than corresponding (022) peaks for the thicker films. The diffraction intensity of (002) peak increases with deposition time. However the intensity of the (022) peaks shown in panel (b) has its maximum at 50 min and then decreases at 100 min. It can be concluded that (011)-aligned grains cease to grow after a maximum, but (001)-aligned grains keep growing and dominate the alignment of IBAD samples. The FWHM value of (002) peaks decreases as the deposition time increase. The size of the (001) grains calculated is 104, 118, and 124 Å for the IBAD films deposited for 20, 50, and 100 min respectively. We can say that the (001) aligned grains keep growing during the deposition process.

Fig. 4 shows the results of in-plane texture of the films. The XRD ϕ-scan results at YSZ (001) reflection of the non-IBAD samples are shown in panel (a). No peak is found in all samples, even for the thickest one, suggesting the random in-plane texture of the non-IBAD samples. The ϕ-scan results at YSZ (111) reflection of IBAD samples are shown in panel (b). Four peaks appear after 10 min and become stronger with the increasing deposition time. The FWHM of the corresponding ϕ-scan curves, a parameter to estimate the in-plane texture of the films, decreases with deposition

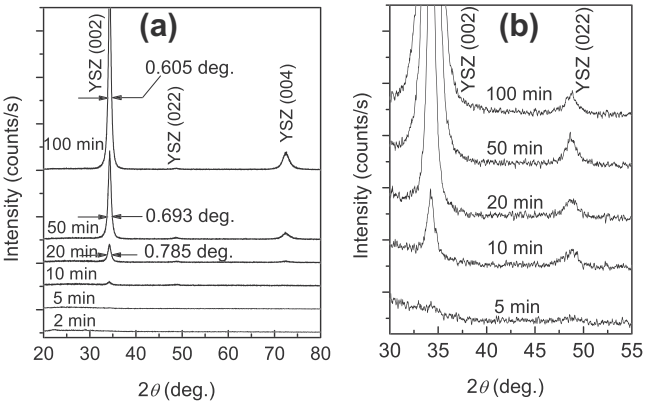

Fig. 3. (a) XRD patterns of θ–2θ scan of the IBAD YSZ films deposited with different times. (b) Details near (022) and (002) peak.