Extremely large strain in rutile-type RuO_2(100) epitaxial thin films

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Strain engineering has been intensively studied as a powerful technique to tune physical properties of functional oxide epitaxial thin films, particularly for perovskite-type oxides, by using commercially available substrates [1]. Recently, strain effects on rutile-type oxides, which have crystallographically lower symmetry than perovskite oxides, were also reported such as emergence of superconductivity in RuO_2 [2] and enhanced catalytic activity in IrO_2 [3]. However, systematic control of strain in rutile-type oxides is difficult due to the lack of commercially available lattice-matched substrates. In this study, we developed a new route to control the lattice strain of RuO_2 epitaxial thin films in a wide range of 0.5–6.5% on large lattice-mismatched substrates via multiple growth mechanisms [4].

RuO_2 thin films were grown on yttria-stabilized zirconia (YSZ)(111) and *α*-Al_2O_3(0001) substrates at various growth temperatures by pulsed laser deposition. X-ray diffraction confirmed the epitaxial growth of RuO_2(100) thin films with a triple domain structure. The *a*-axis strain monotonically increased by decreasing the growth temperature and reached to an extremely large value of 6.5% at 250 °C (Fig. 1). Atomic force microscopy showed a morphological transition from 2D to 3D growth toward low growth temperature (Fig. 2), indicating the contribution of growth-mode-induced strain at the grain boundary [5]. At the same time, thickness- and substrate- dependences of strain indicated significant enhancement of strain also at the film/substrate interface and domain boundaries. Effects of strain on physical properties of the RuO_2 (100) epitaxial thin films were also investigated. While electrical resistivity was highly robust against the strain, catalytic activity for oxygen evolution reaction from water was enhanced by the strain.

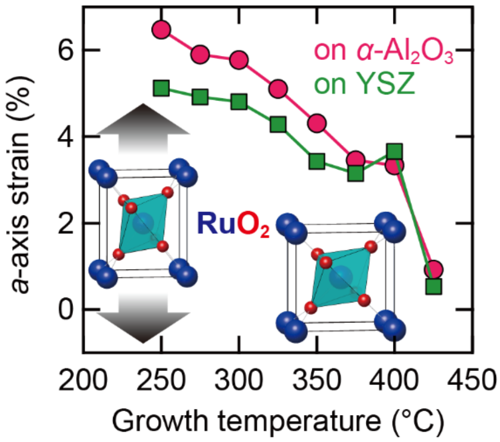

Fig.1. Growth temperature dependences of the *a*-axis strain for RuO_2(100) thin films on *α*-Al_2O_3(0001) and YSZ(111) substrates.

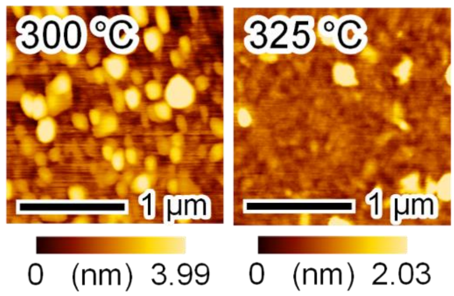

Fig. 2. Atomic force microscope images of RuO_2(100) epitaxial thin films grown on *α*-Al_2O_3(0001) substrates at 300 and 325 °C.

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