CRYSTALLINE GROWTHS AND ORIENTATIONS OF DOUBLE-LAYRED OXIDE THIN FILMS BY IBS, AND OXYGN-PLASMA EFFECTS ON LOW-TEMPERATURE DEPOSITIONS

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Introduction

Short review of recent oxide researches

Oxides have been very traditional and popular materials for long years, however they have been minor in electronics fields so far. Though after discovery of perovskite oxide High Tc Superconductors (HTS), they suddenly became major [1]. It triggered huge amount of oxide research works, resulting in another big progress of colossal magnetoresistive manganites [2]. Even old style of oxide materials such as ZnO, TiO_2 and $SrTiO_3$ were re-focused, leading to extremely fine thin film growth of ZnO [3]. Owing to these exceptional rush of oxide developments, we come to one idea of Oxide Electronics which means that we can fabricate a total assembly of devices composed of all oxides, and the other idea of Function Harmonized Oxides (FH-Oxides) which means we can fabricate novel functional devices composed of variety of oxides with originally different properties. Here we introduce two cases of FH-Oxides composed of double layers.

Function Harmonized Oxides

Tunable microwave filters

One typical example of FH-Oxides is the tunable microwave filters used at base stations of mobile phone systems [4]. We stack superconducting YBCO ($YBa2Cu_3O_x$) and ferromagnetic LBMO ($La(Ba)MnO_3$) into a double layer. This is desirable because both have perovskite crystal structures. When magnetic field (Ha) is applied, permeability of the ferromagnetic layer is modified, then microwave propagation mode in the superconducting layer is modified, leading to shift of resonant center frequency of the microwave. Thus we can tune the filter frequency easily by adjusting Ha even after the device is fixed in the base station. Usually YBCO thin film is grown in a-axis oriented and c-axis oriented. Then we have to investigate the double-layer growths for a/c-YBCO and LBMO systems.

Novel p-n junctions

Now a days manganites (say, LBMO) and ZnO are widely investigated and popular, then we can prepare the excellent crystalline thin film for each of them. When they are combined into a double layer, it may give completely new functional device [5]. LBMO is p-type semiconductor due to accepter (Ba) doping, while ZnO is n-type semiconductor due to intrinsic donor of oxygen vacancy. Then the double layers must be curious p-n junctions. The junction detects only UV light because ZnO has a wide band-gap (3.4 eV) then UV-generated high density carriers are injected into diffusion layer. On the other hand, LBMO has enigmatic properties due to colossal magnetoresistance. Then p-n junction I-V characteristics can be sensitively modified by magnetic field as well as temperature. However, the stacking is not so easy due to different crystal structures, LBMO has

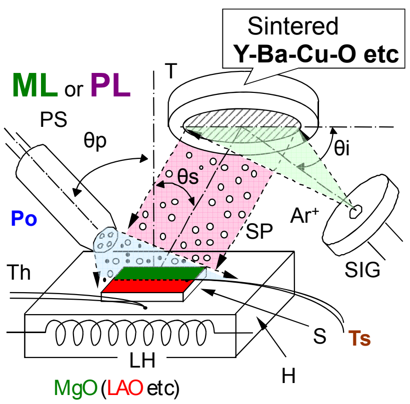

Fig.1 IBS system. Target is displaced for each deposition of YBCO, LBMO (LSMO) and ZnO.

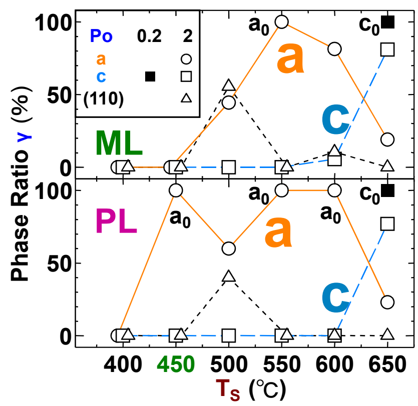

Fig.2 Phase ratios vs Ts for ML and PL.

cubic while ZnO has hexagonal systems. Thus investigations of orientation growths are important.

Experimental

Thin film fabrication

All the thin films were deposited by Ion Beam Sputtering (IBS) system as shown in Fig.1. A target is sputtered by Ar ion beam, sputtered particles are deposited on heated substrates, oxygen molecule (ML) or plasma (PL) is supplied during the deposition. Substrate temperatures (Ts) and oxygen partial pressures (Po) are controlled. This system is unique because thermal energy, kinetic energy and excited energy can be controlled independently. Especially for low-Ts depositions, we can supply and control the kinetic and excited energies compensating shortage of the thermal energy [6,7].

Characterizations

Thin films were characterized by XRD for crystallinities, and by AFM for surface morphology. Their properties were characterized by electrical resistance, magnetization, magnetoresistance (MR), ferromagnetic resonance (FMR), microwave absorption and optical transmittance.

Results and Discussions

Single layer YBCO and LBMO

The deposited a-YBCO and c-YBCO has 0.33 and 1.04 nm surface roughness corresponding to each one unit cell length, i.e., ultimately smooth. YBCO crystallinity gets worse with decreasing Ts for ML supply, but it is much improved by PL supply resulting in excellent crystallinity even at very low Ts of 450°C. As shown in Fig.2, the c-phase ratio deceases while the a-phase ratio increases with decreasing Ts, the a-phase growth is enhanced by PL. The a-YBCO shows smaller microwave absorption, then it is useful for microwave filters.

LBMO thin film shows very enigmatic properties, insulating to metallic transition and paramagnetic to ferromagnetic transition at different temperatures, then it is insulating and metallic in 82-140 K. Then it can be used for tunable filters. Further LBMO shows negative MR and positive MR at intermediate and lower temperatures, respectively. Those can be interpreted by phase separation and magnetostriction models. They are confirmed by FMR doublet signal.

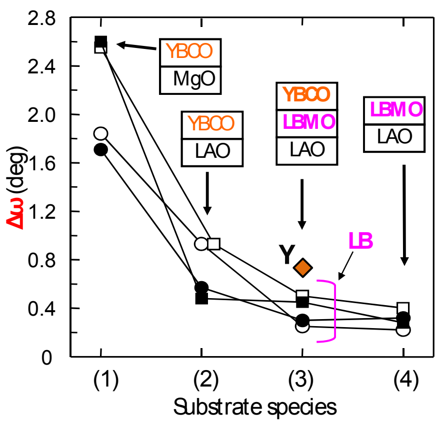

Fig.3 Crystallinity (mosaicity) of upper YBCO compared with that of single layers.

Double layers of YBCO/LBMO and ZnO/LSMO systems

We have fabricated variety of double layers, and succeeded in crystalline growths of a/b-YBCO on LBMO, LBMO on a/c-YBCO, ZnO on LSMO and LSMO on ZnO. The a-YBCO with excellent mosaicity (Δω:rocking curve halfwidth) can be grown on LBMO as shown by Y in Fig.3. YBCO/$LaCaMnO_3$ superlattice shows infinitesimal microwave absorption for Ha parallel to its plane, indicating suitable microwave filter material. We deposited ZnO on LSMO, ZnO has two axes orientations of (001) and (110) as shown by XRD in Fig.4. LSMO was deposited on ZnO, LSMO shows three orientations of (001), (110) and (111). We can control these orientation growths by deposition conditions, then obtain each single phase.

Summary

The concept of Function Harmonized Oxides is mentioned. Using superior IBS technique, we can fabricate variety of oxide double layers for the function harmonized oxides.

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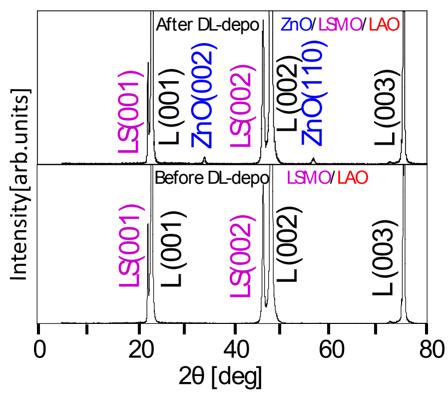

Fig.4 XRD for ZnO/LSMO double layers.