ADVANCED GROWTH METHOD OF HIGH-QUALITY OXIDE FILMS WITH PEROVSKITE-RELATED STRUCTURE FOR FUTURE ELECTRONICS

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Nanomaterials and nanotechnologies bring new possibilities. In the nano range, special effects originating from the interplay between size and shape may occur. In addition, important is also continuous discovery of new systems or synthesis of artificial new structures. This is a promising field with unmatched possibilities for device applications. Our research effort is dedicated to growth, processing and application of oxide thin films heterostructures.

Thin films are convenient for device fabrication due to their high integration features. Also, due to current advanced technologies from the Si industry, growth of different stacked layers on a certain substrate is in principle straightforward. However, situation is complex and there are demanding requirements for the quality of the component stacked films, as well as for the substrate. Use of multicomponent materials for each layer is enhancing complexity and decreases reproducibility.

Oxide perovskite materials of practical interest show in many cases an intrinsic layered structure with high anisotropy. Sometimes, this is very useful and also promising for growth of new heterostructures, but dealing with anisotropy is not trivial and this is the case of high-temperature-cuprate-superconductors (HTCS).

HTCS are made of alternate superconducting and non-superconducting blocks along the *c*-axis direction. This structure is automatically producing a *natural* (intrinsic) nanocomposite material for which the principles of bottom-up layer-by-layer building of a material are realized.

One can imagine similar *artificial* heterostructures built by using different materials as layers, and such examples are also described in the literature. Often, the approach is to stack the different thin film layers in the *c*-axis direction of HTCS, and to take advantage for the device fabrication of the Josephson junction (JJ) tunneling effect that occurs when a current is applied along *c*-axis.

A simple configuration of a *c*-axis heterostructure would be with the composing materials of the heterostructure stacked with their *c*-axes parallel to each other and perpendicular to the surface of the substrate. Nevertheless, building a *c*-axis conventional superconductor-insulator-superconductor (SIS) artificial heterostructures showing JJ effect is not easy since the coherence length of HTS is short along *c*-axis, ξ_c=0.3-0.4nm.

This is resulting in necessity to grow very thin insulating layers with the thickness of approximately the same or lower values. To solve this problem one possibility would be growth and characterization of non-*c*-axis thin films. The most simple non-*c*-axis heterostructures are obtained when stacking of the superconducting and insulating layers is along *c*-axis direction, but with this direction being tilted vs. substrate surface.

Another example that is theoretically considered as the most effective SIS JJ, can be obtained by stacking of a-axis superconducting HTCS layers and insulating superconducting barriers. In this case it is expected to make the most use in the JJ tunneling of the larger coherence length within ab-plane (ξ_{ab}=1-2nm).

Through extrapolation of the presented examples, one can imagine different combinations of stacking orientations and different materials (e.g. not only insulators). Considering different physico-chemical properties on different crystal directions of a perovskite layered oxide, expectations are to enable new possibilities in materials growth and design for generation of new type composites. The new *c*-axis and non-*c*-axis thin films and heterostructures, if realized, may possibly show new properties and effects useful for future devices with enhanced or new functionality.

To realize orientation control we applied the film-substrate lattice engineering through the control and selection of a certain substrate-film relationship (Fig. 1 for c-axis and Fig. 2 for non c-axis thin films). Some examples for c-axis and non c-axis thin films growth by metal-organic-chemical-vapor deposition (MOCVD) will be presented (Fig. 3).

Experimental procedure is as follows:

Thin films were prepared by MOCVD using three unique laboratory-designed machines, two of horizontal type and one of vertical type. Raw materials were Metal DPM (DPM is abbreviation for di-pivaloyl-methanate and Metal = Sr, Ca, Cu, Y, Ti) and $Bi(C_6H_5)_3$ (triphenyl-Bi). The films were $Bi_2Sr_2Ca_2Cu_3O_{10}$ (Bi-2223), $Bi_2Sr_2CaCu_2O_8$ (Bi-2212), $YBa_2Cu_3O_7$ (Y-123), $Bi_4Ti_3O_{12}$ (BTO), $(Sr,Ca)CuO_2$ (SCCO) and $(Ba,Ca)CuO_2$ (BCCO). Substrate for *c*-axis growth was (100) $SrTiO_3$ (STO), while for non-*c*-axis growth was (110) STO.

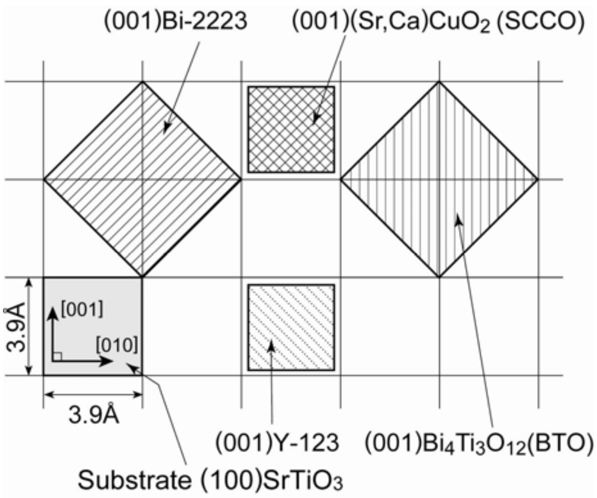

Fig. 1. Film-substrate lattice relationship for different c-axis thin films.

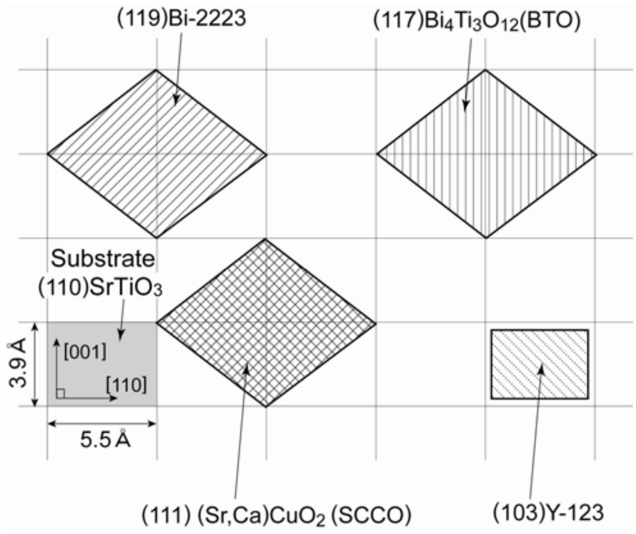

Fig. 2. Film-substrate lattice relationship for different non-c-axis thin films.

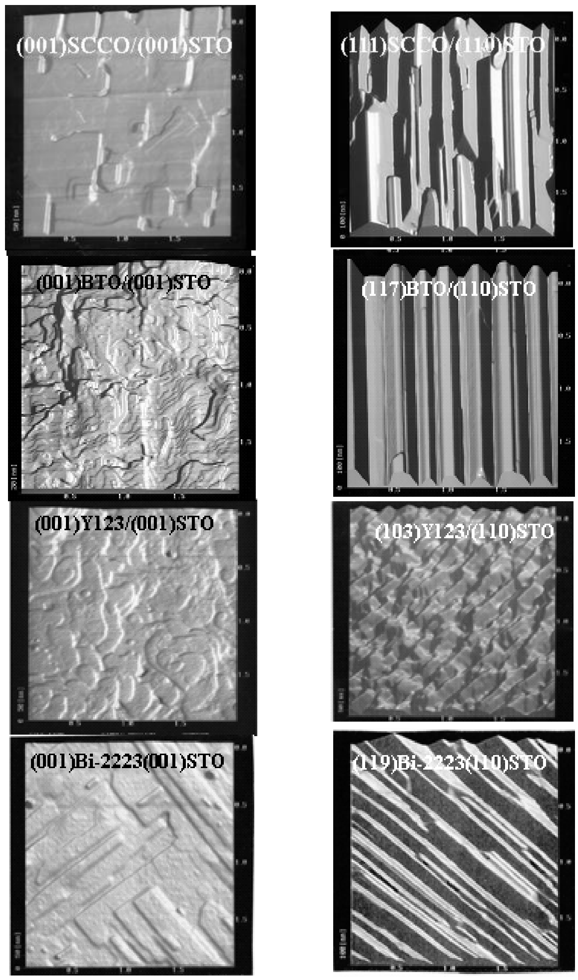

Fig. 3. Atomic Force Microscopy (AFM) images of different films on (001) and (110) STO. Substrates were flat substrates with low miscut angles (typically less than 1°).