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### Properties of $YBa_2Cu_3O_{7-\delta}$ Superconducting Films on $Sr_2YSbO_6$ Buffer Layers

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#### 1. Introduction

In a previously published work we have shown that the  $Sr_2YSbO_6$  material can be successfully used as a buffer layer for the epitaxial growth of  $YBa_2Cu_3O_{7-\delta}$  films with high density current value in self-field at 77 K (Ortiz-Diaz et al., 2010). The layer of  $Sr_2YSbO_6$  material plays the role of a buffer layer because the negative effects of MgO over the superconducting properties of  $YBa_2Cu_3O_{7-\delta}$  films were eliminated, and because it evidences an excellent structural matching with  $YBa_2Cu_3O_{7-\delta}$  and with MgO. These results show that  $Sr_2YSbO_6$ can be an excellent substrate material for the  $YBa_2Cu_3O_{7-\delta}$  layers in coated conductors, using the IBAD–MgO templates. Besides which, with the  $Sr_2YSbO_6$  material the architecture of the coated conductors can be simplified, because only a single  $Sr_2YSbO_6$  buffer layer is used.

The importance of this work is the fact that during the last decade, significant advances in the performance levels of high-temperature superconducting (HTS) wire have made it suitable for commercially viable applications such as electric power cables, fault current limiters, motors, and generators (Maguire&Yuan, 2009; Shiohara et al., 2009). For instance, both the United Sates Department of Energy and private industry have been developing a key superconductor cable and fault current limiter projects (Maguire&Yuan, 2009), and there is a five year Japanese national project for materials and power applications of coated conductors, which was started in 2008 (Shiohara et al., 2009). These power applications share a common requirement: that the superconducting material is formed into a long, strong, and flexible conductor so that it can be used like the copper wire it is intended to replace. And this is where the problems began, because the HTS materials are ceramics that are more like a piece of chalk than the ductile metal copper (Foltyn et al., 2007). The first solution to this problem, the so-called first generation wire, was a tape that was made packing Bi-Sr-Ca-Cu-O (BSCCO) superconducting powder into a silver tube, following a series of rolling and heating steps (Heine et al., 1989). In spite of successful applications, this type of conductor is expensive for most commercial applications due to the use of silver.

Further, BSCCO is not suitable for applications such as motors and magnets at liquid nitrogen temperature; it loses its ability to carry super current in a magnetic field (Foltyn et al., 2007; Heine et al., 1989). High critical current density in more successfully multifilamentary BSCCO wires, with magnetic field, happen at helium liquid temperatures (Goyal et al., 1996; Shen et al., 2010). The alternative approach, known as the second generation wire, uses the epitaxial growth of an YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconducting coating on a thin metal tape. The

advantages of this wire are that very little silver is needed, making it inexpensive, and that the compound  $YBa_2Cu_3O_{7-\delta}$  retains much higher current carrying ability in a magnetic field.

Despite these advantages of superconductors, the ability to carry current without loss is limited to current densities lower than a critical value, *Jc*. In order to carry a higher current in a wire, the objective of research efforts is to increase *Jc*. In this context, the preparation of bi–axially textured substrates and subsequent epitaxial buffer layers is very important for the realization of long–length YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7– $\delta$ </sub> coated conductors. The buffer layer should not only satisfy chemical stability, but structural matching with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7– $\delta$ </sub> as well because the alignment of the superconductor is required for high *Jc* values (Foltyn et al., 2007; Ying et al., 2009).

Different oxide materials have been successfully used as a buffer layer to fulfill these requirements (Foltyn et al., 2007; Huhne et al., 2006; Jia et al., 2002; 2003; Nishikawa et al., 2003; Parans et al., 2003; Sathyamurthy et al., 2003; Wang et al., 2005; Wee et al., 2005). However, most of them are really multilayer architectures, which significantly increase the complexity as well as the cost of production (Ying et al., 2009). Therefore, the development of a single buffer layer is of great interest, as this might simplify the preparation process and lead to a more cost–effective fabrication of coated conductors. To fabricate templates of great length, the most promising approach is, generally, with ion beam assisted deposition, IBAD yttria–stabilized zirconia (YSZ),  $Gd_2Zr_2O_7$  or MgO (Arendt et al., 2004; Groves et al., 2002; Hanyu et al., 2007; Koa et al., 2007). Of these, the best is IBAD–MgO because very good biaxial texture can be obtained with films only 10 nm thick, which reduces the production costs (Arendt et al., 2004; Foltyn et al., 2007; Koa et al., 2007). Section 3 is extended a bit the issue of buffer layers and materials used in them.

 $Sr_2YSbO_6$  appears to be a promising material for fulfill these requirements as a buffer layer, as it has a lattice parameter exhibiting a good lattice match with  $YBa_2Cu_3O_{7-\delta}$  (mismatch between *a* and *b*  $YBa_2Cu_3O_{7-\delta}$  parameters and *a* of  $Sr_2YSbO_6$  is 5%). Previously we have showed that  $Sr_2YSbO_6$  has been applied effectively as a buffer layer for  $Sr_2YSbO_6$  film growth by DC sputtering (Ortiz-Diaz et al., 2010). This superconducting film has a *Jc* value  $10^3$  times higher than one grown on MgO. The  $Sr_2YSbO_6$  films were deposited over MgO single–crystal substrate, because  $Sr_2YSbO_6$  has a good match with MgO, which is the material of the IBAD–MgO tapes. Other applications for the  $Sr_2YSbO_6$  material are in a Josephson junction because they are an insulating material for the deposition of superconductor films in microwave applications, and for the elaboration of crucibles for the preparation of superconductors due to their chemical non reactivity with  $YBa_2Cu_3O_{7-\delta}$ .

The Sr<sub>2</sub>YSbO<sub>6</sub> material was chosen because we had been working to find new substrates for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> within the perovskite family A<sub>2</sub>BB'O<sub>6</sub> since by means of substitutions they permit adjusting the lattice parameters (Ortiz-Diaz et al., 2004a). Preliminary studies of the material in polycrystalline form showed that it was viable as a substrate for the growth of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films (Ortiz-Diaz et al., 2004b; 2010).

The goal of this chapter is to show a summary of these works, which were taken from a period of 2004–2010, showing the technology of manufacturing, since synthesis and evaluation of a material as a potential substrate for superconducting films, until the effective utilization as a substrate for films with excellent superconducting properties.

Section 2 begin with definition of elementary concepts of critical temperature, critical current density *Jc* and critical magnetic field. One of these topics concerns about the temperature

262

effect on *Jc*, based on unpublished experimental results of curves current-voltage (*I-V*), which permit to calculate the critical current. Also is shown the relevancy of the critical parameters for applications of superconducting films and layers. Section 3 present a short overview of state of the art about the coated conductors (CC), relevance of the buffer layers for the increase of Jc in the second generation of superconducting wires. Special emphasis is made on importance the single buffer layers in order to simplify the fabrication process of CC. We are show the relevance of our Sr<sub>2</sub>YSbO<sub>6</sub> perovskite for this goal. In section 4 We will describe details of the evaluation of the properties of Sr<sub>2</sub>YSbO<sub>6</sub> polycristalline material, such as crystallographic matching and chemical stability between  $Sr_2YSbO_6$  and  $YBa_2Cu_3O_{7-\delta}$ ; also We show details of the fabrication of Sr<sub>2</sub>YSbO<sub>6</sub> films on MgO single crystal by magnetron sputtering, besides the structural matching of Sr<sub>2</sub>YSbO<sub>6</sub>with MgO. Section 5 describes the fabrication of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> target and the growth process of films on MgO and SrTiO<sub>3</sub> (STO) single crystals and on the  $Sr_2YSbO_6$  buffer layer. Also is shown the preparation of the conductor path, for electrical measurements, by means of photolitography, and show the results of critical temperature for all the films, and the measurements I-V based on which were determined the critical current density.

#### 2. Superconductivity elementary notions and relevant properties for applications

A superconductor is the material that show two important properties: zero DC resistivity and magnetic induction zero inside the material when it is cooled below temperature Tc, known as critical temperature. For temperatures T > Tc, the superconductor it is in the normal state, and is like normal metal with poor conductivity (Cyrot & Pavuna, 1992; Pool et al., 1995). For a superconductor with a high Tc value, in the normal state, the resistance depends linearly on temperature, such as a typical conductor, as shown in figure 1(a). On the other hand, zero magnetic induction in the superconducting state means that the magnetization takes negative values below Tc and it is usually zero for temperatures above Tc, as shown in figure 1(b).



Fig. 1. Resistance and magnetization curves for a  $YBa_2Cu_3O_{7-\delta}$  samples, in function of temperature.

The second property of the superconductors is called diamagnetism. When it is perfect a superconducting material does not permit an externally applied magnetic field to penetrate into its interior. However, superconductivity dissapears and the material returns to the normal state if one applies an external magnetic field of the strength greater than some critical value,  $B_c$ , called the critical thermodynamic field. It worth to say that we are calling magnetic field to the magnetic field B. The superconducting state can also destroyed by passing an

excessive current greater than some value  $I_c$ , called critical current, which creates a magnetic field at the surface. This limits the maximum current value that the material can sustain and it is a crucial problem for applications of superconducting materials. Those materials that totally exclude an applied magnetic flux, for T < Tc, are known as type I superconductors.

There are other superconductors, known as type II superconductors, that totally exclude magnetic field when the applied magnetic field is low, but only partially exclude it when the applied field is higher. For this superconductors there are tow critical fields: the lower  $B_{c1}$  and the upper  $B_{c2}$ . The flux is totally expelled only up to the lower critical field  $B_{c1}$ . Then, in applied fields smaller than  $B_{c1}$ , the type II superconductor behaves like a type I superconductor below  $B_c$ . Above  $B_{c1}$  the flux penetrate into the material until the upper critical field  $B_{c2}$  is reached. Above  $B_{c2}$  the material returns to the normal state.

Between  $B_{c1}$  and  $B_{c2}$ , the type II superconductor is said to be in the mixed state. The Meissner effect is only partial. For this range of fields magnetic flux partially penetrates the superconducting sample in the form tiny filaments known as vortices. A vortex consists of a normal core in which the magnetic field is large, surrounded by a superconducting region in which flows supercurrent.

Critical magnetic field and, obviously, critical current depends on temperature. Because of that it is important to report the temperature value at which the measures of critical current are carried out. Figure 2(a) shows a typical curve of voltage *V* in function on applied current *I* at temperature of 82 K for a YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film which was growth on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer. Note that this temperature is higher than 77 K, usually reported for critical current measurements in high temperature superconductors. In these measurements one applies current *I* and takes a voltage value between two electrodes. In the so–called criterion of a microvolt/cm ( $\mu$ V/cm), the current value for which the voltage drop in a 1 cm length is 1 $\mu$ V is defined as a critical current value. Figure 2(b) shows an expanded region of the figure 2(a), in which the red dashed line is a visual guide to determine the current value for which the drop voltage is 1 $\mu$ V. For this example, the critical current value is 4.14 mA, from which by dividing by the cross–sectional area of the sample, yields a relatively high value of  $Jc \sim 0.2 \times 10^6$  A/cm<sup>2</sup>.



Fig. 2. Voltage in function of current, at 82 K for a YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7 $-\delta$ </sub> film growth on Sr<sub>2</sub>YSbO<sub>6</sub>/MgO substrate.

Figure 3(a) shows the voltage curves as a function of current for  $YBa_2Cu_3O_{7-\delta}$  film on MgO at different temperatures from 5 K to 82 K and, Figure 3(b), the behavior of the density critical



Fig. 3. *I–V* curves for several temperatures and critical current in function of temperature for  $YBa_2Cu_3O_{7-\delta}$  on MgO single crystal.

current as a function of temperature, calculated for each temperature in the same way as was done for the data in Figure 2. As the temperature increases, the current value for which the potential drop is  $1\mu$ V decreases dramatically, so that at 82 K the curve approaches the linear behavior as a sign that is disappearing superconducting state. This is equivalent to the reduction of critical current density with increasing temperature as shown in Figure 3(b). In contrast, as shown in Figures 2, for this temperature of 82 K the superconductor film grown on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer maintains a relatively high critical current value. From applications viewpoint, is important to determine the critical current value for at determined temperature. For HTS superconductors often the critical current is measured at the reference value of 77 K.

It worth noting that the issue of the temperature is crucial factor for the cost of practical uses of superconductors. For the called conventional superconductors is required the liquid helium coolant which have very higher cost. Nitrogen becomes liquid at 77 K; it is far less costly to liquefy this gas than to liquefy helium. For any application in which liquid nitrogen can replaced liquid helium, the refrigeration cost will be about 1000 times less (Sheahen, 2002). High-*Tc* oxides have critical temperatures above liquid nitrogen. For instance, the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> has been found to be superconducting up to ~ 90 K; then liquid nitrogen is sufficient to cool YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> in the superconductor range.

The maximum current density, Jc, that a superconductor can carry without exceeding a voltage drop criterion  $(1\mu V/cm)$  depends both on the superconductor temperature and the applied magnetic field. From the practical point of view the critical temperature, Tc, is the temperature at which a very small *Jc* may flow at zero applied field. At a fixed temperature less than *Tc*, *Jc* will usually drop very rapidly above some threshold value of applied field. Thus, it is common to see a critical B plotted as a function of T, defined at some value of Jc. For an HTS, this critical magnetic field is called the irreversibility field, B<sub>irr</sub>, which is the field at which flux lines or vortices to flow and causes dissipation. This value is often considerably lower than the  $B_{c2}$  of the material (Hull, 2003). Figure 4(a) shows  $B_{c2}$ in function of temperature for some common superconductor materials. For YBa2Cu3O7-6 and BSCCO  $B_{c2}$  has high values at liquid nitrogen temperature. Figure 4(b) shows  $B_{irr}$  in function of temperature for some materials. The  $B_{irr}$  curve for BSCCO is noteworthy because it is relatively low at 77 K but starts to rise rapidly as temperatures drop below about 30 K. Thus, at temperatures near 77 K, applications for BSSCO will be limited to low magnetic field applications, such as transmission lines. Higher field applications, such as motors and generators, will require the expensive helium cooling of the BSSCO. This mean that the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> is an ideal candidate for these applications at liquid nitrogen temperature, which appears as a dashed line in figure 4(b). This is the main reason why the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> is the preferred material for applications involving high magnetic fields, and therefore, the reason why we decided to use YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> and no other superconductor material for our study.



Fig. 4. Magnetic field in function of the temperature for some superconductors. Data adapted from (Hull, 2003).

Structural and transport properties of the HTS oxide materials is highly anisotropic. For this reason it is helpful, for the understanding of the properties of the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>, a description

of its structure. The unit crystallographic structure of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>, shown in figure 5, can be seen as a stacking of three perovskites. So, crystallographers classify the structure of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> as the perovskite type with vacancies of oxygen; the oxygen contents it is in the range 6 to 7, as indicates the subscript 7 –  $\delta$ . The lattice parameter *c* is around three times larger than *a* and *b* parameters.



Fig. 5. Schematic representation of  $YBa_2Cu_3O_{7-\delta}$  structure.

Thus, its structure consists of a sequence of oxide layers perpendicular to the *c*-axis separated by Y and Ba atoms, which can be seen in figure 6. Figure 6(a) corresponds to  $\delta = 1$ , that is, to YBa<sub>2</sub>Cu<sub>3</sub>O<sub>6</sub> and, figure 6(b) is the representation of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub>. The sequence of oxide layers are as follows:

- a Cu–O layer with two vacancies of oxygen for figure 6(b); each Cu is surrounded by 4 O. Thus the typical octahedral coordination has been replaced for a square planar coordination. So along the *b*-axis are formed the called chain copper oxygen connect by oxygen atoms. In the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>6</sub> there is not chains because each copper ion has surrounded by two oxygen,
- a barium layer,
- a Cu<sub>2</sub>O layer where each copper exhibit fivefold pyramidal coordination. The basis of pyramids linked by oxygen atoms, forms the called copper oxygen planes through the *ab*-plane,
- a layer of Y with for oxygen vacancies sandwiched between two Cu–O planes.

These sequence is duplicated in the upper half of the structure.

The tetragonal YBa<sub>2</sub>Cu<sub>3</sub>O<sub>6</sub> compound is an insulator. By increasing of oxygen concentration the *ab*-planes are gradually doped with holes and eventually it reaches the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> composition in which there are not vacancies of oxygen. The maximun Tc = 94 K is obtained for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>6.93</sub> and for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> the critical temperature is lower (Cyrot & Pavuna, 1992;



Fig. 6. Schematic representation of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> structures, shown the planes and chains.

Pool et al., 1995). Those compounds  $YBa_2Cu_3O_{7-\delta}$  with optimally oxygen contents have orthorombic structure and are superconductors. They are called  $YBa_2Cu_3O_{7-\delta}$  optimally doped.

Conductivity in *ab*-planes are around 100 times than *c*-axis conductivity. For this fact is accepted that superconductivity essentially takes place within quasi dimensional planes, and  $YBa_2Cu_3O_{7-\delta}$  is considered as Cu–O planes separated by a charge reservoir (the chains).

As the conductivity, the *Jc* of the ceramic oxide materials is too highly anisotropic. For this reason a good alignment of the crystalline axes of all the grains is essential to pass high current density from one superconducting grain to another. For polycristalline specimens the *Jc* is very low, of order hundred A/cm<sup>2</sup>. In contrast, higher *Jc* values, around  $\sim 10^7$  A/cm<sup>2</sup>, are obtained in single crystals and a good films.

To explain the low value of *Jc* in polycrystalline samples and understand how to improve these values by using the superconductor in the form of films, it is worth noting, as mentioned in section 4 that for the production of a polycrystalline sample in the form of pellet, one mix a precursor components, which are subjected to heat treatment and appropriate oxygenation for optimal superconducting properties. However, even the best polycrystalline samples consist of many randomly oriented polycrystalline grains, each of them with their anisotropic layered structure. It also contains grain boundaries, structural defects such as twins, voids, which act as non conducting grains. All this conspires against applications that require high critical current densities. In contrast, with single crystals and epitaxially grown films are obtained large values of *Jc* at 77 K and self field, because superconductivity occurs through the *ab* planes.

268

To produce films is necessary to use a substrate, which must satisfies basic requirements to promote epitaxial growth and micro structural properties to obtain high current density values: must have good matching of lattice constants with superconductor; must be chemically non reactant with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> even under heat treatment at temperature of film deposition and; should not affect the values of critical temperature and critical current density of the superconductor. It worth to say that the recent analyses, about current limiting defects in coated conductors, have shown that the major local current–limiting defects are *a*–axis grains, which exert a big effect on current flow and local dissipation in the coated conductor samples studied (Li et al., 2012). By reducing the amount of grains grown along the *a* axis, the quality of the superconducting layers substantially improves. To achieve this purpose, besides optimizing the deposition conditions, also, the substrate plays a crucial role.

The crystallography and preparation of the substrate is of primary importance in determining the quality of the film deposition. Some of the highest critical current densities at 77 K and highest film uniformities have been achieved in YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films grown on commercially available (100) SrTiO<sub>3</sub> substrates (Huhne et al., 2006; Jia et al., 2002; 2003; Ortiz-Diaz et al., 2004a; Sathyamurthy et al., 2003; Varanasi et al., 2008; Wang et al., 2005; Wee et al., 2005; Wu et al., 2005; Ying et al., 2009). However, SrTiO<sub>3</sub> is fairly expensive, has high dielectric constant, and undergoes phase transition at ~ 110 K. LaGaO<sub>3</sub> with ~ 0.5% mismatch it is neither cheap nor twin free (Cyrot & Pavuna, 1992). Other commercial substrate, LaAlO<sub>3</sub> was reported as a problematic substrate for the deposition of thin YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films, especially when a thick substrate is required, because detrimental extended defects are developed. The use of LaAlO<sub>3</sub> layers of 0.5 mm is advantageous, provided the deposition temperature is kept as low as possible (Koren & Polturak, 2002).

MgO single crystal substrates have been widely used for its economy and acceptable matching of lattice constants. However, it is widely accepted that MgO affects the superconducting properties. In particular, *Tc* and *Jc* values for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> and REBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films are generally lower when are deposited on MgO than the values for films grown on other commercial substrates (Hollmannt et al., 1994; Wee et al., 2005). This has been attributed to chemical reaction between the superconductor and the MgO, which causes the formation of third phases, which act as "non-superconducting dead layers" and; grains (001) growth rotated 45° with respect to MgO (100) surface.

Sapphire is another cheap substrate, free twining. However, has relatively high mismatch with  $YBa_2Cu_3O_{7-\delta}$  and reacts chemically with superconductor, thus, the interfacial  $BaAl_2O_4$  layer is formed, which affects the epitaxial growth of the film and result in poor superconducting films (Hollmannt et al., 1994).

The list of materials tested as substrates for superconducting films is broad and includes a variety of compounds and crystal structures, ranging from oxides and simple perovskites to complex perovskites and pyrochlore structures. For instance, Yttrium Stabilized Zirconium Oxide (YSZ) and cerium oxide, CeO<sub>2</sub> have been widely used, sometimes as a combination of layers. Among simple perovskites that have been proposed, perhaps the most successful are SrTiO<sub>3</sub>, LaAlO<sub>3</sub> and SrRuO<sub>3</sub>, which are commercially availables as single crystals. Examples of other simple perovskites proposed as substrate materials are YAlO<sub>3</sub>, GdAlO<sub>3</sub>, EuAlO<sub>3</sub>, SmAlO<sub>3</sub>, LaGaO<sub>3</sub>, NdGaO<sub>3</sub>, PrGaO<sub>3</sub>. Also, were proposed to make substitutions with the idea that variation in the composition allows the lattice parameters vary, and then the matching can be improved, but question arises about the chemical compatibility with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> (Hollmannt et al., 1994); thus, are tested as potential substrates, for

YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> applications in microwaves and electronics, many complex perovskites with formula A<sub>2</sub>BB'O<sub>6</sub>, besides, some pyrochlore structures. Some examples of complex perovskites proposed are Sr<sub>2</sub>AlTaO<sub>6</sub> for superconducting devices (Findikoglu et al., 1992; Ying & Hilbert, 1994); Ca<sub>2</sub>GaNbO<sub>6</sub>; Sr<sub>2</sub>GaTaO<sub>6</sub> (Brandle, 1996); Ba<sub>2</sub>LaNbO<sub>6</sub> (Pai et al., 1997); DyBa<sub>2</sub>SnO<sub>5.5</sub> (Koshy et al., 1995); DyBa<sub>2</sub>ZrO<sub>5.5</sub> (Yadava et al, 1998); HoBa<sub>2</sub>SbO<sub>6</sub> (Aguiar et al., 1998) and Ba<sub>2</sub>NdTaO<sub>6</sub> (Kurian et al., 2002; Kurian & Morishita, 2003).

As can to see, the search for new substrates for the deposition of superconducting films is continuous, since it is hard to find the substrate to produce the perfect film.

#### 3. Buffer layers for superconducting films

As was say in previous section, there are many potential substrates for  $YBa_2Cu_3O_{7-\delta}$  films deposition, but only a few commercially available in single crystal form. Also, each substrate has a problem or disadvantage to the film that has to grow on. To solve this problem without having to wait for the manufacture of new mono–crystalline substrates, some groups began to use these materials in the form of film on any of the commercial MgO and SrTiO<sub>3</sub> substrates for growth of superconducting films. The idea was to eliminate the negative effect of single–crystal substrate by using a buffer layer that acts as a chemical barrier that eliminates the reaction between the crystal and the superconductor. In addition, the buffer layer plays the role of template to facilitate the epitaxial growth of superconducting film with improved superconducting and microstructural properties. RF sputtered and laser ablated films of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on a MgO single crystal substrate using a buffer layer of SrTiO<sub>3</sub> began to be manufactured in the 1990's.

In 1993 SrTiO<sub>3</sub> buffer layers were grown on MgO (100) substrates to provide a better match to RF sputtered YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films. This heterostructure allows a highly textured growth to be achieved over thickness as high as 1  $\mu$ m. The improvement of lattice matching makes the critical current density increase from 10<sup>3</sup> A/cm<sup>2</sup> for 1  $\mu$ m films grown to 4 × 10<sup>5</sup> A/cm<sup>2</sup> for films grown with a SrTiO<sub>3</sub> buffer layer (Lucia et al., 1993).

Laser ablated thin films of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on a MgO substrate using a SrTiO<sub>3</sub> buffer layer was grown, which is perfectly oriented with respect to the MgO substrate. Superconductivity is improved in a spectacular manner with respect to YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> directly deposited on MgO. A critical temperature *Tc* = 92 K and a critical current density of 4 × 10<sup>6</sup> A/cm<sup>2</sup> at 82 K are reached for the first time for films deposited on MgO substrate (Proteau et al., 1995).

In 1996 were grown epitaxial YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films by pulsed laser ablation on SrTiO<sub>3</sub> buffered (100) MgO and was found that the SrTiO<sub>3</sub> buffer layer provide a better lattice match to the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film and play a crucial role to prevent the interaction between YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> and MgO. Thus, were obtained YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films with  $Jc \sim 10^6$  A/cm<sup>2</sup> at 77 K and zero magnetic field (Boffa et al., 1996).

A comparative study of NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films deposited, by laser ablation, on different substrates showed that the transport *Jc* value of  $3.5 \times 10^{6}$  A/cm<sup>2</sup> at 77 K in self–field was obtained from the NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on SrTiO<sub>3</sub> with *Tc* value of 91.2 K, while the NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on MgO with *Tc* of 86.8 K exhibited the low *Jc* value of  $0.25 \times 10^{6}$  A/cm<sup>2</sup>. On the other hand, *Jc* value of  $1.55 \times 10^{6}$  A/cm<sup>2</sup> was obtained from NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film on SrTiO<sub>3</sub> buffered MgO(100) substrate with *Tc* of 91.5 K. The low *Jc* value of the NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on MgO can be attributed to both depressed *Tc* value and the existence of 45° rotated grains

with  $(0\,0\,1)$ NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>(110)MgO (Wee et al., 2005). NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film properties were improved too using a buffer layer of Ba<sub>2</sub>NdTaO<sub>6</sub> on MgO (Kurian & Morishita, 2003).

The above example is a sample of the use of compounds different to the commercial substrates as a material for buffer layers. Also, with the emergence of the second generation of superconducting wires took great importance to study and search for new buffer layers. For instance, Biaxially textured La<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> with CeO<sub>2</sub> and Ce<sub>0.7</sub>Gd<sub>0.3</sub>O<sub>3</sub> buffer layers were grown on Ni–RABiTS (rolling-assisted biaxially textured substrates) to obtain suitable buffer layer architectures for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> coated conductors (Knoth et al., 2005). More recently, it has been used as textured substrate for coated conductors a NiW alloy with a Gd<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> buffered Ce<sub>0.9</sub>La<sub>0.1</sub>O<sub>2-y</sub> for the growth of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films with *Jc* ~ 1 × 10<sup>6</sup> A/cm<sup>2</sup> (Zhao et al., 2012). This work is an example of current interest in improving the manufacturing process of superconducting tapes with different combinations of deposition technique and combinations of buffer layers.



Fig. 7. Schematic representation of the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer.

Film deposition	Buffer layer	$Jc (\times 10^6 \mathrm{A/cm^2})$	Reference
Sputtering RF	SrTiO <sub>3</sub>	0.4	(Lucia et al., 1993)
PLD	Sr <sub>2</sub> AlTaO <sub>6</sub> /LaAlO <sub>3</sub>	1.3	(Findikoglu et al., 1992)
PLD	CeO <sub>2</sub> /IBAD–YSZ	2.2	(Li et al., 2012)
PLD	SrO/Sr <sub>2</sub> AlTaO <sub>6</sub>	$\sim 0.5$	(Takahashi et al., 2003)
PLD	Ba <sub>2</sub> LaNbO <sub>6</sub>	$5 imes 10^6$	(Pai et al., 1997)
PLD	SrTiO <sub>3</sub>	4	(Proteau et al., 1995)
PLD	$Ce_{0.9}La_{0.1}O_{2-y}/Gd_2Zr_2O_7$	$\sim 1$	(Zhao et al., 2012)
Sputtering RF	Sr <sub>2</sub> YSbO <sub>6</sub> /MgO	0.86	(Ortiz-Diaz et al., 2010)

Table 1. Values of critical current density for  $YBa_2Cu_3O_{7-\delta}$  films on some buffer layers at 77 K and self-field. PLD means Pulsed Laser Deposition.

We have mentioned a few examples of materials used for buffer layers; a more extensive list can be consulted by the interested reader in an excellent review of coated conductors (Foltyn et al., 2007). With all this it can see two things: first, the problem of the epitaxial growth appears overcomed and; second, the optimization and reduction of cost of deposition can be obtained with the uses of buffer layer sandwiched between the single substrate and superconducting film, as is shown in figure 7 (Foltyn et al., 2007; Hanyu et al., 2007; Nishikawa et al., 2003; Ortiz-Diaz et al., 2010; Parans et al., 2003).

Most promising applications of type II superconductors are in the power area, where the most advantageous superconductor material is  $YBa_2Cu_3O_{7-\delta}$ , because high critical current densities needed for this applications can be achieved with it, with acceptably low energy dissipation, even with magnetic fields, as was shown in section 2. These applications require that the superconductor be formed as a long coated conductor tape so that it can be used

like the copper wires. The architecture of the superconducting tapes is like the buffered  $YBa_2Cu_3O_{7-\delta}$  films showing in figure 7, but with additional protective layer of gold or silver and with the single substrate replaced for a flexible tape of commercially alloy textured with an oxide layer. The most promising technology for the manufacture of coated conductor tape is based on Ion Beam Assisted Deposition (IBAD) (Arendt et al., 2004; Foltyn et al., 2007), where MgO and Gd\_2Zr\_2O\_7 are successfully used for texturing. Intermediate oxide layers are epitaxially grown on this textured substrate. The architecture of the tapes can be simplified and, then, the cost of manufacture can be reduced if these intermediate layers are replaced with a single buffer layer. It is the principal motivation for the evaluation of new materials, such as Sr\_2YSbO\_6. Also, the evaluation is made using the MgO single substrate, because the MgO is one of the oxides successfully used in IBAD technology. Generally, the route followed to evaluate a material as a possible constituent of the buffer layer in a superconducting tape begins with tests on a small sample of single crystalline substrate. That is why in our work the films are grown on single crystal, instead of on a textured tape directly.

#### 4. Evaluation of Sr<sub>2</sub>YSbO<sub>6</sub>, step by step

The evaluation of  $Sr_2YSbO_6$  stars with the preparation, which was made by the solid state reaction method. Stoichiometric mixtures of high purity (99.99%) commercial precursor oxides  $Y_2O_3$ , SrO and  $Sb_2O_3$  in adequate amounts are mixed thoroughly, pelletized and calcined at 1100°C for 18 h. The calcined material was reground, pressed as circular discs and sintered at 1090°C for 135 h. All the above processing was carried out in ambient atmosphere.

For the compatibility studies, single phase YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconducting material was prepared by the solid state reaction method. High purity (99.99%) constituent commercial chemicals Y<sub>2</sub>O<sub>3</sub>, BaCO<sub>3</sub>, and CuO were mixed in stoichiometric ratio. The mixed powder was finely ground and calcined at 900°C for 24 h at ambient atmosphere. The calcined material was reground, pressed as circular discs at a pressure of 1.6 ton/cm<sup>2</sup>. The pellets were sintered at 930°C for 24 h, followed by slow cooling up to 500°C for 13 h and annealing at this temperature for 24 h at O<sub>2</sub> atmosphere. Samples were finally furnace cooled to room temperature over a span of 12 h.

For the study of the structural characteristics of the materials, X Ray Diffraction (XRD) patterns of the samples were recorded by a Siemens D5000 X Ray diffractometer, using Cu-K $\alpha$  radiation ( $\lambda = 1.5406$  Å) and studied by Rietveld method with the programs EXPGUI and GSAS (Larson & Dreele, 2000; Toby, 2001).

Powder XRD pattern of Sr<sub>2</sub>YSbO<sub>6</sub> is shown in figure 8. It consists of strong peaks which are characteristics of a primitive cubic perovskite plus a few weak line reflections arising from the superlattice. Thus, the whole XRD pattern of Sr<sub>2</sub>YSbO<sub>6</sub> can be indexed in a A<sub>2</sub>BB'O<sub>6</sub> cubic cell with the cell parameter a = 8.2561 Å.

Taking into account the doubling of the basic perovskite lattice parameter, the lattice constant a = 8.2561 Å (a/2 = 4.128 Å) of Sr<sub>2</sub>YSbO<sub>6</sub> is comparable to lattice constants a and b of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>. Thus, Sr<sub>2</sub>YSbO<sub>6</sub> has a lattice parameter a which presents a good match with the lattices parameters a and b of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconductors. This first result was crucial for work purposes. First, the Sr<sub>2</sub>YSbO<sub>6</sub> show acceptable fit with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>, one of the basic requirements of a substrate. On the other hand, the matching is also suitable with MgO, which would ensure the epitaxial growth of Sr<sub>2</sub>YSbO<sub>6</sub> films.



Fig. 8. XRD pattern of Sr<sub>2</sub>YSbO<sub>6</sub> sample after the Rietveld refinement.

For the study of chemical and physical compatibility, we have synthesized several composites of  $Sr_2YSbO_6$ -YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> with 15 to 90 vol% of  $Sr_2YSbO_6$  component in the composite. For synthesis of each composite, the component materials were mixed in desired vol% ratios and mixture was pelletized as circular discs at a pressure of  $1.6 \text{ ton/cm}^2$ . These pellets were heat treated at 900°C for 10 hour in oxygen and cooled down slowly at a rate of  $0.5^{\circ}$ C/min for proper oxygenation. Chemical stability of  $Sr_2YSbO_6$  with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> was examined by X-ray diffractometry of  $Sr_2YSbO_6$ -YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> composites. XRD patterns of  $Sr_2YSbO_6$ -YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> composites are shown in figure 9. As seen from these XRD patterns, all the XRD peaks could be indexed for either  $Sr_2YSbO_6$  or  $YBa_2Cu_3O_{7-\delta}$  and there is no extra peak corresponding to impurity phase. Within the accuracy of the XRD technique, these results show that there is no chemical interaction between these materials and  $Sr_2YSbO_6$  is chemically compatible with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconductors.

The effect of  $Sr_2YSbO_6$  addition on the superconductivity of  $YBa_2Cu_3O_{7-\delta}$  superconductors was investigated by measuring dc magnetization of  $Sr_2YSbO_6$ - $YBa_2Cu_3O_{7-\delta}$  composites in the temperature range 5–100 K using a Quantum Design SQUID magnetometer. Figure 10 shows the magnetization for  $Sr_2YSbO_6$ - $YBa_2Cu_3O_{7-\delta}$  composites for 0, 45 and 90 vol% of  $Sr_2YSbO_6$ . As shown from these figures all the  $Sr_2YSbO_6$ - $YBa_2Cu_3O_{7-\delta}$  composites gave a superconducting transition temperature  $Tc \sim 90$  K as that of the pure  $YBa_2Cu_3O_{7-\delta}$ superconductor. A saturated diamagnetic transition is clearly observed in every sample at temperatures well bellow Tc. However, with decreasing  $YBa_2Cu_3O_{7-\delta}$  superconductor volume fraction the magnitude of magnetization decreases in all  $Sr_2YSbO_6$ - $YBa_2Cu_3O_{7-\delta}$ composite samples.

These remarkable results guarantee that indeed the material does not react chemically with  $YBa_2Cu_3O_{7-\delta}$ , in spite of the severe heat treatment made to the composites at temperatures above the deposition of  $YBa_2Cu_3O_{7-\delta}$  films. For this reason the  $Sr_2YSbO_6$  material can be proposed as a potential substrate for the growth of superconducting films.

It worth noting that the  $Sr_2YSbO_6$  material has good structural matching with MgO. Thus, next step was the epitaxial growth of  $Sr_2YSbO_6$  films on (100) MgO commercial single crystal substrate, which were performed by magnetron sputtering (13.56 MHz, 70 watt) using a polycrystalline target, which was fabricated, like the firsts samples, by the solid state reaction



Fig. 9. XRD patterns for several composites  $Sr_2YSbO_6-YBa_2Cu_3O_{7-\delta}$ . First plot show, as a reference, XRD patterns of single phases of  $YBa_2Cu_3O_{7-\delta}$  and of  $Sr_2YSbO_6$ .

method, based on SrO, Sb<sub>2</sub>O<sub>3</sub> and Y<sub>2</sub>O<sub>3</sub>, powder oxides. The substrate temperature and oxygen pressure for the Sr<sub>2</sub>YSbO<sub>6</sub> growth were kept at 800°C and  $7 \times 10^{-3}$  mbar, respectively.



Fig. 10. Magnetization in function of temperature for composites  $Sr_2YSbO_6-YBa_2Cu_3O_{7-\delta}$ .

The X–ray diffraction pattern for films, were recorded by a PHILLIPS PW1710 diffractometer using Cu–K $\alpha$  radiation ( $\lambda = 1.5406$  Å). Figures 11 show XRD pattern for 2 $\theta$  between 10 and 80 degrees, and a short detailed scan for 2 $\theta$  between 41 and 46 degrees. Pattern of figure 11(a) consists of strong peaks (200) of MgO and (400) of Sr<sub>2</sub>YSbO<sub>6</sub>. Figure 11(b) shows the MgO peak in 2 $\theta = 43^{\circ}$  and the Sr<sub>2</sub>YSbO<sub>6</sub> peak in 2 $\theta = 43.1^{\circ}$ . This result reveals the successfully epitaxial growth of Sr<sub>2</sub>YSbO<sub>6</sub> films on MgO (100) substrate.



Fig. 11. XRD patterns for Sr<sub>2</sub>YSbO<sub>6</sub> film growth by magnetron sputtering on MgO.

In conclusion, in this section we have showed the preliminary study of structural characteristics of a complex ordered perovskite  $Sr_2YSbO_6$  for its use as substrate material for the fabrication of  $YBa_2Cu_3O_{7-\delta}$ .  $Sr_2YSbO_6$  has a fairly good lattice match (lattice mismatch ~ 8%) with this superconductor. X-ray diffractometry and magnetic measurements made on  $Sr_2YSbO_6$ - $YBa_2Cu_3O_{7-\delta}$  composites show that  $Sr_2YSbO_6$  is chemically and physically compatible with  $YBa_2Cu_3O_{7-\delta}$  material, even after a severe heat treatment at 900°C, processing temperature of  $YBa_2Cu_3O_{7-\delta}$ . These favorable characteristics of  $Sr_2YSbO_6$  show that it can be used as a buffer layer for deposition of superconductor  $YBa_2Cu_3O_{7-\delta}$  films using MgO single substrate.

#### 5. Sr<sub>2</sub>YSbO<sub>6</sub> as a successfully buffer layer for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films

In the previous section We show that  $Sr_2YSbO_6$  satisfies the requirements for  $YBa_2Cu_3O_{7-\delta}$  films deposition. For this reason, was made the growth and characterization of  $YBa_2Cu_3O_{7-\delta}$  film on buffered layer of  $Sr_2YSbO_6$ . This film, and additional films on commercial substrates of MgO and STO, for comparative studies, were carried by sputtering DC (~ 30 watt) at an optimized substrate temperature of  $850^{\circ}C$  an  $O_2$  pressure of 3.5 mbar for 1 hour, followed by cooling up to  $550^{\circ}C$  in 30 min at  $O_2$  pressure of ~ 850 mbar and therefore were annealed at  $550^{\circ}C$  for 30 min at the same  $O_2$  pressure.

Figures 12 show the XRD pattern of  $YBa_2Cu_3O_{7-\delta}$  film over  $Sr_2YSbO_6$  buffer layer, for  $2\theta$  between 10 and 90 degrees. It consists of peaks (00*l*) of  $YBa_2Cu_3O_{7-\delta}$ , besides the MgO and  $Sr_2YSbO_6$  peaks, such as is detailed in figure 12(b). These result reveals the epitaxial growth of  $YBa_2Cu_3O_{7-\delta}$  over  $Sr_2YSbO_6/MgO$  buffered substrate.



Fig. 12. XRD patterns for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7 $-\delta$ </sub> film growth on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer.

The superconducting properties of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films were characterized by measurements of the transition temperature (*Tc*) and critical current density (*Jc*) at 77 K in self field, by means of ACT measurements (bias AC current of 30 Hz) with four probe method, using the PPMS system of Quantum Design. These measurements were performed on YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> micro bridges, with 20  $\mu$ m of width and 100 nm of thickness, which were prepared by UV photo lithography.

For the photolithography, the films were coated with a layer of photolack. Then, the coated surface was put over a mask and was irradiated for 12 min with UV radiation. Irradiated film was submerged and moved into mix of H<sub>2</sub>O and NaOH, until we can saw a marks of mask. Then, the film was pasted to another recipient with 60 drops of H<sub>2</sub>O and five drops of phosphoric acid, and move until the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconductor paths that were used for electrical measurements were clears. Finally, film was retired and cleaned. Figures 13 show a YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> film after the photolithography and detailed microscopic image of the micro brigde. Films of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> were contacted by means of indium leads such as is show in figure 14, by measurements both resistance in function of temperature and voltage *V* in function of current *I*.

Figures 15 to 17 show the behavior of  $YBa_2Cu_3O_{7-\delta}$  films resistance as a function of temperature. For films growth over  $Sr_2YSbO_6$  the curve exhibits linear behavior up to a transition temperature *Tc*. In figure 16 the measurements corresponding to a  $YBa_2Cu_3O_{7-\delta}$ 



Fig. 13. YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7 $-\delta$ </sub> film after the photholitographic process for preparation of micro bridge.



Fig. 14. YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> with contacts for superconducting measurements.

films growth over MgO and on SrTiO<sub>3</sub>, with the same conditions, are shown. Figure 17 is shown for comparison of the resistance behavior.

It worth to say about the ways of defining the sharpness and superconducting transition temperature. There is two criteria widely used. Some authors talk in terms on the onset, 5%, 10%, midpoint, 90%, 95%, and zero resistance points (Pool et al., 1995). The onset, or 0% point is where the experimental curve begins to drop below the extrapolated linear behavior. With this criterion, the *Tc* value is midpoint at which the resistivity has decreases by 50% below onset. The point at which the first derivative of the resistive transition curve reaches its maximum value could be selected as defining *Tc*, since is the point of most rapid change from the normal to superconducting phase. Also, the width  $\Delta T$  between the half–amplitude points of the first derivative curve is good quantitative measure of the width of the transition.



Fig. 15. Resistance in function of temperature for  $YBa_2Cu_3O_{7-\delta}$  film on  $Sr_2YSbO_6$  buffer layer.



Fig. 16. Resistance in function of temperature for  $YBa_2Cu_3O_{7-\delta}$  films on STO and MgO single crystals.

Based on the first derivative criterion, we determined the *Tc* values as  $Tc = 86.6 \pm 6.6$  K for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on MgO;  $Tc = 88 \pm 3$  K for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on STO and;  $Tc = 88 \pm 2$  K for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer.

Linear fit for 140 K< T <280 K; 99 K< T <147 K and 150 K< T <250 K were made for R-T data for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on Sr<sub>2</sub>YSbO<sub>6</sub>, MgO and STO, respectively. The linear fit results are

$$R = -0.11 + 0.41T, \tag{1}$$

for  $YBa_2Cu_3O_{7-\delta}/Sr_2YSbO_6$  film,

$$R = 45.4 + 0.85T,$$
 (2)



Fig. 17. Resistance in function of temperature for  $YBa_2Cu_3O_{7-\delta}$  films.

for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>/MgO film, and

$$R = 5.1 + 0.50T, \tag{3}$$

for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7 $-\delta$ </sub>/STO film.

Although the *Tc* values are similar for films over STO and over  $Sr_2YSbO_6$  buffer layer, the resistance in the normal zone is less for the  $YBa_2Cu_3O_{7-\delta}$  growth on buffer layer; also, the extrapolated residual resistance for this film is less than the residual resistance of  $YBa_2Cu_3O_{7-\delta}$  film growth on SrTiO<sub>3</sub>.

Results of measurements for voltage *V* in function of current *I* (*I*–*V* curves) are shown in figure 18 for the films of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> over buffered substrate Sr<sub>2</sub>YSbO<sub>6</sub>/MgO. Based on this *I*–*V* data and on the *I*–*V* curves for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>/MgO, of the figure 3, with the 1  $\mu$ V/cm criterion, the critical current values, at 77 K, were determined in ~ 0.013 mA for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on MgO and ~ 17 mA for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer. So, the critical current density value for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films growth over Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer is *Jc* ~ 0.86 × 10<sup>6</sup> A/cm<sup>2</sup> which is three order of magnitud times the *Jc* of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>/MgO films. The *Jc* value for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>/Sr<sub>2</sub>YSbO<sub>6</sub>/MgO film growth over buffer layer appears to be less than those reported in the literature (*Jc* ~ 10<sup>7</sup> A/cm<sup>2</sup>). However, it is worth saying that the value for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub>/MgO is less too in comparison with references (*Jc* ~ 10<sup>6</sup> A/cm<sup>2</sup>). Thus, the sputtering deposition conditions perhaps are not yet optimized, and we believe that with other methods of deposition, such as laser ablation, we could improve the *Jc* results. The results reported in the literature are for films deposited in wealthy laboratories that have optimized deposition conditions.

The figure 18 also shows the voltage curves as a function of the applied current for temperatures of 82, 85 and 90 K. We observe a decrease in the value of critical current with increasing temperature and how at 90 K the linear behavior is similar to of conductors at this temperature, which is a sign that the YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> is in the normal state.

279



Fig. 18. *I–V* curves for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7– $\delta$ </sub> films on Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer at different temperatures.

#### 6. Conclusion

In this chapter We have showed some relevant properties of type II superconductors for applications that requires high critical current densities even with applied magnetic fields. Special attention was dedicated to structural properties of the substrates for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films in order to improve the *Jc* values. In this context, in this chapter was showed a case of study: the evaluation of the Sr<sub>2</sub>YSbO<sub>6</sub> as a potential material for buffer layer in growth of superconducting films, since preliminary studies of polycrystalline samples until the effective application of this material for deposition of high quality superconducting films. It worth noting that this chapter concerns only on structural issues that limits the *Jc* values, which is a problem practically solved. Nothing were said about the flux pinning, another property that can be improved in order to obtain *Jc* values higher that reported at the present.

There has been show a review of the role of substrate in the successful deposition of superconducting films for applications. Furthermore, it has illustrated the convenience of using buffer layers for the growth of superconducting layers. For these purposes also We showed the different steps in the manufacture of superconducting film on the Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer used, with a focus on techniques to evaluate the material as a potential substrate for the successful growth of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films.

Previous studies on a polycrystalline  $Sr_2YSbO_6$  material showed an acceptable structural matching with the  $YBa_2Cu_3O_{7-\delta}$  and the MgO, allowing the epitaxial growth of  $Sr_2YSbO_6$  film on MgO and subsequently, the superconducting film. Studies on chemical non-reactivity

with  $YBa_2Cu_3O_{7-\delta}$  despite the severe heat treatment applied to the two materials in contact with each other, at temperature above the deposition of the films, were crucial to ensure that the Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer to fulfill its role of chemical barrier to eliminate the negative effect of MgO on the superconducting properties of YBCO film. In fact, the critical current density at 77 K of the film on the Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer was three orders of magnitude larger than *Jc* of the films deposited on MgO directly under the same conditions, as has been widely mentioned in the literature.

The value of critical current density of  $YBa_2Cu_3O_{7-\delta}$  film on the Sr<sub>2</sub>YSbO<sub>6</sub> buffer layer is smaller than other values reported in the literature, as is shown in table 1, which can be explained by the deposition conditions not yet optimized and by use of magnetron as a technique of deposition. To support this assumption is worth mentioning, for example, that the laser ablated YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films on LaAlO<sub>3</sub> have 2 × 10<sup>6</sup> A/cm<sub>2</sub> and the quality of this films is better than of the films grown by sputtering DC (Koren & Polturak, 2002). In this reference Koren mentions that substrate thickness influences the formation of structural defects in the superconducting film, besides the size of superconducting grains is one order of magnitude lower for films deposited by laser ablation than for deposited with DC magnetron, so that their quality improvement. The optimum temperature of deposition is another factor to review, as there is evidence that it may affect the *Jc* value. For example, buffered substrate SrRuO<sub>3</sub>/MgO was used for growth of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films with Jc ~  $2.5 \times 10^{6} \text{ A/cm}^{2}$  at temperature of 770°C, while for deposition at 790°C Jc decreased to  $6 \times 10^5 \,\text{A/cm}^2$  (Uprety et al., 2004). Also, in a study by Takahashi is reported the effect of buffer layer thickness on the superconducting properties of  $YBa_2Cu_3O_{7-\delta}$ . There is a minimum thickness that ensures chemical isolation between YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> and other layers, but an increase of buffer layer thickness results in decreased critical current density. There is an optimum thickness of this layer that produces the films with the highest value of Jc (Takahashi et al., 2003). In our study, Sr<sub>2</sub>YSbO<sub>6</sub> film was deposited with any thickness, which is not necessarily optimal.

As the emphasis was made on the application in coated conductors, it is worth noting that, once found the optimal conditions of manufacture, the  $Sr_2YSbO_6$  could be used as a single buffer layer, thereby simplifying the manufacturing process of the superconductor tapes. Although it appears that the workhorse to discuss possible applications of our material is the field of superconducting tapes, it is interesting to note that the material could be used in other application fields such as electronic devices and Josephson junctions.

#### 7. References

- Aguiar, J. A.; de Souza Silva, C. C.; Yadava, Y. P.; Landinez Tellez. D. A.; Ferreira, J. M.; Guzman, J. & Chavira, E. (1998). Structure, microstructure, magnetic properties and chemical stability of Ho<sub>2</sub>Ba<sub>2</sub>SbO<sub>6</sub> with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> superconductor. *Physica C*, Vol(307) 189–196
- Arendt, P. N.; Foltyn, S. R. Civale, L.; DePaula, R. F.; Dowden, P. C.; Groves, J. R.; Holesinger, T. G.; Jia, Q.X.; Kreiskott, S.; Stan, L.; Usov, I.; Wang H. & Coulter, J. Y. (2004). High critical current YBCO coated conductors based on IBAD MgO. *Physica C*, Vol(412–414), 795–800
- Boffa, V.; Petrisor, T.; Ciontea, L.; Gambardilla, U. & Barbanera, S. (1996). Properties of in–situ laser–pulsed deposited YBCO thin films on MgO with SrTiO<sub>3</sub> buffer layer. *Physica C*, Vol(260) 111–116
- Brandle, C. D. (1996). Preparation of perovskite oxides for high *Tc* temperature. *J. Mater. Res.*, Vol(5)No 5, 2160

- Cyrot, M. & Pavuna D. (1992). *Introduction to superconductivity and high-T<sub>c</sub> materials*, World Scientific
- Desgardin, G.; Monot, I. & Raveau, B. (1999). Texturing of High-Tc superconductors. Supercond. Sci. Technil., Vol(12), R115
- Findikoglu, A. T.; Doughty, C.; Bhattacharya, S.; Li. Q.; Xi, X. X. & Venkatesan, T. (1992). Sr<sub>2</sub>AlTaO<sub>6</sub> films for multilayer high-temperature superconducting devices, *Appl. Phys. Lett.*, Vol(61) 1718–1720
- Foltyn, S. R.; Civale, L.; MacManus-Driscoll, J. L.; Jia, Q. X.; Maiorovl, B.; Wang, H. & Maley, M. (2007). Materials science challenges for high–temperature superconducting wire. *Nat Mater*, Vol(6), 631–642
- Goyal, A.; Norton, D. P.; Budai, J. D.; Paranthaman, M.; Specht, E. D.; Kroeger, D. M.; Christen, D. K.; He, Q.; Saffian, B.; List, F. A.; Lee, D. F.; Martin, P. M.; Klabunde, C. E.; Hartfield E.; & Sikka, V. K. (1996). High critical current density superconducting tapes by epitaxial deposition of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> thick films on biaxially textured metals *Appl. Phys. Lett.*, Vol(69) No 12, 1795–1797
- Groves, J. R.; Arendt, P. N.; Foltyn, S. R.; Jia, Q. X.; Holesinger, T. G.; Kung, H.; DePaula, R. F.; Dowden, P. C.; Peterson, E. J.; Stan L.; & Emmert, L. A. (2002). Recent progress in continuously processed IBAD MgO template meters for HTS applications. *Physica C*, Vol(382), 43–47
- Hanyu, S.; Iijima, Y.; Fuji, H.; Kakimoto K. & Saitoh, T. (2007). Development of 500 m–length IBAD–Gd<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> film for Y–123 coated conductors. *Physica C*, Vol(463–465), 568–570
- Heine, K.; Tenbrink, J. & Thoner, M. (1989). High–field critical current densities in Bi<sub>2</sub>Sr<sub>2</sub>Ca<sub>1</sub>Cu<sub>2</sub>O<sub>8+δ</sub>/Ag wires. *Appl. Phys. Lett.*, Vol(55) No 23, 2441–2443
- Huhne, R.; Selbmann, D.; Eickemeyer, J.; Hanish J. & Holzapfel, B. (2006). Preparation of buffer layer architectures for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> coated conductors based on surface oxidized Ni tapes. *Supercond. Sci. Technol.*, Vol(19), 169–174
- Hollmannt, E. K.; Vendik, O. G.; Zaitsev, A. G. & Melekh, B. T. (1994). Substrates for High-*Tc* superconductor microwave integrated circuits. *Supercond. Sci. Technol.*, Vol(7) 609–699
- Hull, J. R. (2003). Applications of high-temperature superconductors in power technology. *Rep. Prog. Phys.*, Vol 66, 1865–1886
- Jia, Q. X.; Foltyn, S. R.; Arendt, P. N.; Groves, J. R.; Holesinger T, G.; & Hawley, M. E. (2002). Role of SrRuO<sub>3</sub> buffer layers on the superconducting properties of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films grown on polycrystalline metal alloy using a biaxially oriented MgO template. *Appl. Phys. Lett.*, Vol(81) No 24, 4571–4573
- Jia, Q.X.; Foltyn, S.R.; Arendt, P.N.; Holesinger, T.; Groves J.R. & Hawley, M. (2003). Growth and Characterization of SrRuO<sub>3</sub> Buffer Layer on MgO Template for Coated Conductors, *IEEE Trans. Appl. Supercond.*, Vol(13) No 2, 2655–2657
- Knoth, K.; Schlobach, B.; Huhne, R.; Schultz, L. & Holzapfel, B. (2005). La<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> and Ce–Gd–O buffer layers for YBCO coated conductors using chemical solution deposition. *Physica C*, Vol(426–431) 979–984
- Koa, K. P.; Hab, H. S.; Kimc, H. K.; Yuc, K. K.; Kob, R. K.; Moonc, S. H.; Ohb, S. S.; Parka C. & Yoo, S. I. (2007). Fabrication of highly textured IBAD–MgO template by continuous reel–to–reel process and its characterization. *Physica C*, Vol(463–465), 564–567
- Koren, G. & Polturak, E. (2002) Is LaAlO<sub>3</sub> a viable substrate for the deposition of high quality thin films of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>? *Supercond. Sci. Technol.*, Vol(15), 1335–1339
- Koshy, J.; Kumar, K.S.; Kurian, J.; Yadava, Y.P. & Damodaran, A.D. (1995). Transpor properties of the superconducting Bi<sub>2</sub>Sr<sub>2</sub>Ca<sub>2</sub>Cu<sub>3</sub>O<sub>10</sub>–DyBa<sub>2</sub>SnO<sub>5.5</sub>. *Phys. Rev. B*, Vol(51) 9096–9099

- Kurian, J.; Takahashi, Y.; Amemura, T.; Susuki, T. & Morishita, T. (2002). The growth and characterization of epitaxial Ba<sub>2</sub>NdTaO<sub>6</sub> dielectric ceramic thin films on (100) SrTiO<sub>3</sub>. *J. Phys. D: Appl. Phys.* Vol(35) 3002–3006
- Kurian, J. & MOrishita, T. (2003). Epitaxial growth of NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films on (100) MgO buffered with Ba<sub>2</sub>NdTaO<sub>6</sub>, a potential dielectric buffer layer for NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films. *Supercond. Sci. Technol.* Vol(16) 422–425
- Larson, A. C. & Von Dreele, R. B. (2000) General Structure Analysis System (GSAS). Los Alamos National Laboratory Report LAUR 86–748
- Li, P.; Abraimov, D.; Xu, A. & Larbalestier D. (2012). Observation of important current-limiting pinning defects high MOCVD in а recent force Supercond. Sci. Technol., Vol(25) 025002 IBAD-MgO coated conductor. doi:10.1088/0953-2048/25/2/025002
- Liu, X. Z; He, S. M.; Wu, D. J.; Duan, K. Y. & Li, Y. R. (2006). Heteroepitaxial growth of YBCO/STO thin films for voltage tunable varistors. *Physica C*, Vol(433) 147–153
- Lucia, M. L.; Santamaria, J. Iborra, E.; Hernandez–Rojas, J. L. & Sanchez–Quesada, F. (1993). Texture improvement of sputtered YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> films on MgO (100) with a SrTiO<sub>3</sub> buffer layer. *Physcia C*, Vol(218) 59
- Maguire, J. F.& Yuan, J. (2009). Status of high temperature superconductor cable and fault current limiter projects at American Superconductor. *Physica C*, Vol(469), Issue 15–20, 874–880
- Nishikawa, H.; Hontsu, S.; Nakamori, M.; Tabata H. & Kawai, T. (2003). Preparation of Perovskite Type Manganite on Al<sub>2</sub>O<sub>3</sub> Substrate as an Excellent Buffer Layer for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Growth. *IEEE Trans. Appl. Supercond.*, Vol(13) No 2, 2725–2728
- Ortiz–Diaz, O.; Roa–Rojas, J.; Landinez Tellez D. A. & Aguiar, J. Albino. (2004). Evaluation of Sr<sub>2</sub>YSbO<sub>6</sub> as a new substrate for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> superconductor thin films. *Mod. Phys. Lett. B*, Vol(18), 1035–1042
- Ortiz–Diaz, O.; Lopez Carreno, L. D.; Albino Aguiar, J.; Roa–Rojas J. & Landinez Tellez, D. A. (2004). Structural ordering, chemical stability and percolative effect analysis in YSr<sub>2</sub>SbO<sub>6</sub>/YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7–δ</sub> complex perovskite composites, *Physica C*, Vol(408–410), 886–888
- Ortiz-Diaz, O.; Saldarriaga, W; Lopera, W.; Reyes, D.; Cortes, A.; Caicedo, J. M.; Landinez Téllez, D. A. & Roa-Rojas, J. (2011). Sr<sub>2</sub>YSbO<sub>6</sub> as a buffer layer for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> superconducting films. J. Mater. Sci., Vol(46), 688-692
- Pai, S. P.; Jasudasan, J.; Apte, P. R.; Pinto, R.; Kurian, J.; Sajith, P. K.; James, J. & Koshy, J. (1997). YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> films with high critical current density on epitaxial films of Ba<sub>2</sub>LaNbO<sub>6</sub>, a new perovskite substrate for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7- $\delta$ </sub> superconductor. *Europhys. Lett.*, Vol(39) No 6, 669–673
- Parans Paranthaman, M.; Aytug, T.; Kang, S.; Feenstra, R.; Budai, J. D.; Christien, D. K.; Arendt, P. N.; Stan, L.; Groves, J. R.; DePaula, R. F.; Foltyn S. R. & Holesinger, T. G. (2003). Fabrication of High *Jc* YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> Tapes Using the Newly Developed Lanthanum Manganate Single Buffer Layers. *IEEE Trans. Appl. Supercond.*, Vol(13) No 2, 2481–2483
- Poole, Ch, P.; Farach, H. A. & Creswick, R. J. (1995). Superconductivity, Academic Press
- Prouteau, C.; Hamet, J. F.; Mercey, B.; Hervieu, M.; Raveau, B.; Robbes, D.; Coudrier, L. & Ben G. (1995). Significant improvement of superconductivity of laser ablated "YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub>/MgO" thin films: introduction of a SrTiO<sub>3</sub> buffer layer. *Physica C*, Vol(248) 108–118
- Sathyamurthy, S.; Parans Paranthaman, M.; Zhai, H.Y.; Kang, S.; Christien, H.M.; Cantor, C.; Goyal A. & Martin, V. (2003). Solution Processing of Lanthanum Zieconate Films

as a Single Buffer Layers for High *Ic* YBCO Coated Conductors. *IEEE Trans. Appl. Supercond.*, Vol(13) No 2, 2658–2660

- Sheahen, T. P. (2002). Selected topics in superconductivity, Introduction to High-temperature superconductivity, Kluwer academis publishers
- Shen, T.; Jiang, J.; Kametani, F.; Trociewitz, U. P.; Larbaliester, D. C.; Schwartz, J.& Hellstrom, E. E. (2010). Filament to filament bridging and its influence on developing high critical current density in multifilamentary Bi<sub>2</sub>Sr<sub>2</sub>CaCu<sub>2</sub>O<sub>x</sub> round wires. *Supercond. Sci. Technol.*, Vol(23), 025009–025018
- Shiohara, Y.; Fujiwara, N.; Hayashi, H.; Nagaya, S.; Izumi, T. & Yoshizumi (2009). Japanese efforts on coated conductor processing and its power applications: New 5 year project for materials and power applications of coated conductors (M-PACC). *Physica C*, Vol(469), 863–867
- Takahashi, Y.; Wakana, H.; Ogawa, A.; Morishita, T. & Tanabe, K. (2003). Effects of thin SrO buffer layer on dielectric and superconducting properties of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>/Sr<sub>2</sub>AlTaO<sub>6</sub>/YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> multilayers. *Jpn. J. Appl. Phys.*, Vol(42) L283–L286
- Toby, B. H. (2001). EXPGUI, a graphical user interface for GSAS. J. Appl. Cryst., Vol(34), 210–213
- Uprety, K. K.; Ma, B.; Koritala, R. E.; Baurceanu, R. M.; Weber, T. P.; Fisher, B. L.; Dorris, S. E.; Erck, R. A.; Maroni, V. A. & Balachandran, U. (2004). Growth of YBCO film on SrRuO<sub>3</sub>–buffered MgO substrate. *Supercond. Sci. Tecnol.*, Vol(17) 671–675
- Varanasi, C. V.; Burke, J.; Lu, R.; Wu, J.; Brunke, L.; Chuck, L.; Smith, H. E.; Maartense, I. & Barnes, P. N. (2008). Biaxially textured YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> films deposited on polycrystalline flexible yttria–stabilized zirconia ceramic substrates. *Physica C*, Vol(468), 1070–1077
- Wang, H.; Foltyn, S.R.; Arendt, P.N.; Jia, Q.X.; Li, Y. & Zhang, X. (2005) Thickness effects of SrTiO<sub>3</sub> buffer layers on superconducting properties of YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> coated conductors. *Physica C*, Vol(433), 43–49
- Wee, S. H.; Moon, S. H.; Park, C. & Yoo, S. I. (2005) Effects of substrates on the NdBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> films fabricated by the PLD process. *Physica C*, Vol(426-431), 996–1000
- Wu, C. H.; Chen, M. J.; Hsu, M. H.; Chen, J. C.; Chen, K. L.; Chen, J. H.; Jeng, J. T.; Lai, T. S.; Horng, H. E. & Yang, H. C. (2005). Optimization of step–edge substrates for high–TC superconducting devices. *Physica C*, Vol(433) 108–114
- Yadava, Y. P; Landinez Tellez, D. A.; Melo, M. T.; Ferreira, J. M. & Aguiar, J. A. (1998). Structural ordering and chemical stability of a complex perovskite oxide DyBa<sub>2</sub>ZrO<sub>5.5</sub> with YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub> superconductors. *Appl. Phys. A*, Vol(66) 455–458
- Ying, Q. Y. & Hilbert, C. (1994). All–YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7–δ</sub> trilayer tunnel junctions with Sr<sub>2</sub>AlTaO<sub>6</sub> barrier. *Appl. Phys. Lett.*, Vol(65) 3005–3007
- Ying, L. L.; Lu, Y.M.; Liu, Z. Y.; Fan, F.; Gao, B.; Cai, C. B.; Thersleff, T.; Reich, E.; Huhne R. & Holzapfel, B. (2009). Thickness effect of La<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> single buffers on metallic substrates using pulsed laser deposition for YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>-coated conductors. *Supercond. Sci. Technol.*, Vol(22), 095005–095009
- Zhao, Y.; Li, X-F.; Khoryushin, A.; He, D.; Andersen, N. H.; Hansen, J. B. & Grivel. J-C. (2012). Development of all chemical solution derived Ce<sub>0.9</sub>La<sub>0.1</sub>O<sub>2y</sub>/Gd<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> buffer layer stack for coated conductors: influence of the post–annealing process on surface crystallinity. *Supercond. Sci. Technol.*, Vol(25) 015008 doi:10.1088/0953-2048/25/1/015008



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