METHOD PRODUCING AN SNS SUPERCONDUCTING JUNCTION WITH WEAK LINK BARRIER

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References Cited

U.S. PATENT DOCUMENTS

4,891,355 11/1990 Hayashi et al. 505/1
5,034,374 7/1991 Awaji et al. 505/1
5,047,900 9/1991 Higashino et al. 505/1
5,221,661 6/1993 Housley 505/1

FOREIGN PATENT DOCUMENTS

63252316 10/1988 Japan

OTHER PUBLICATIONS


ABSTRACT

A method of producing a high temperature superconductor Josephson element and an improved SNS weak link barrier element is provided. A YBaCuO superconducting electrode film is deposited on a substrate at a temperature of approximately 800° C. A weak link barrier layer of a nonsuperconducting film of N–YBaCuO is deposited over the electrode at a temperature range of 520° C. to 540° C. at a lower deposition rate. Subsequently, a superconducting counter-electrode film layer of YBaCuO is deposited over the weak link barrier layer at approximately 800° C. The weak link barrier layer has a thickness of approximately 50 Å and the SNS element can be constructed to provide an edge geometry junction.

27 Claims, 6 Drawing Sheets
**FIG. 8**

Graph showing the relationship between current density ($J_c$) in kiloampères per square centimeter ($kA/cm^2$) and temperature ($T$) in Kelvin ($K$). The graph includes data points for 25A, 50A, and 100A.

**FIG. 9**

Graph showing the logarithm of $J_c$ in microamperes ($\mu A$) plotted against the logarithm of $(1-T/T_c)$. The graph is linear with a positive slope.
FIG. 10
FIG. 12

FIG. 13
METHOD PRODUCING AN SNS SUPERCONDUCTING JUNCTION WITH WEAK LINK BARRIER

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract, and is subject to the provisions of Public Law 96-517 (35 U.S.C. Section 202) in which the Contractor has elected not to retain title.

TECHNICAL FIELD

The present invention is directed to a high temperature superconductor junction produced from a family of rare earth-alkaline earth-cuprate superconductors, and more particularly to an SNS structure having a weak link barrier of a structure compatible with growth on a first superconductor electrode and consistent with providing a good, uniform layer interface for growth of a second superconductor electrode and a method of producing the same.

BACKGROUND ART

The investigation of superconductor devices has been extremely active in recent years because of the potential benefits that can be achieved if their performance and production methods can be made practical for reliable and economical applications in the electronic fields. A tunnel junction and microbridge are the two basic active superconductor tunnel junctions to date. The extremely short coherence lengths in YBa$_2$Cu$_3$O$_{7-x}$, 2-15 Å, place stringent requirements on the quality of the tunnel barrier material and its interfaces in superconductor-insulator-superconductor (SIS) device structures. These requirements include that the barrier material be extremely thin (~10-20 Å), pin hole free, chemically compatible with the superconductor, and that the superconducting energy gap be fully developed within a coherence length of the interfaces.

The fabrication of high Tc superconductor/normal metal/superconductor (SNS) microbridges are believed to be less difficult to fabricate than tunnel junctions, due to fewer problems with material interaction and because the normal metal weak link layers can be thicker and hence more easily controlled than the typical tunnel barriers. The stringent requirements for SIS structures are thus somewhat relaxed for SNS structures, though the requirement of high quality interfaces remains. Unfortunately, high quality interfaces are difficult to attain since most metals are reactive with orthorhombic YBaCuO, (o-YBaCuO) and use of a nonactive Ag or Au makes growth of a high quality of o-YBaCuO counter-electrode difficult due to the mismatch between the o-YBaCuO and Ag or Au crystal lattices.

All high Tc Josephson weak links are potentially useful for high frequency sources and detectors, for high speed, low power digital logic, and for sensitive magnetic field detectors. For optimal performance in these applications, certain device characteristics are desirable, including large (~1 mV) values of the critical current-normal state resistance product (I$_C$R$_N$) accompanied by strong ac and dc Josephson response, device resistances on the order of 50 Ω, and high critical current densities (J$_c$) for high speed operation. A great deal of effort has been focused on obtaining useful all high Tc Josephson devices with published reports on a wide variety of device structures. The various junction geometries that have been studied include grain boundary weak links as reported in Mannhart et al. “Critical Currents in [001] Grains and Across Their Tilt Boundaries, in YBa$_2$Cu$_3$O$_y$”, Phys. Rev. Lett. 61, pg. 2476 (1988) and Russek et al. “Scaling Behaviour of YBa$_2$Cu$_3$O$_y$, Thin Film Weak Links”, Adv. Phys. Lett. 57, pg. 555 (1990), all YBa$_2$Cu$_3$O$_{7-x}$ step edge microbridges, see Simon et al., “Engineered HTS Microbridges”, IEEE Trans. Magnetics 27, pg. 3209 (1991), Au or Ag-coupled microbridges, and epitaxial sandwich or edge-geometry structures using barriers such as Pr$_x$YBa$_{2-x}$Cu$_3$O$_{7-y}$, Bi$_2$Sr$_2$CuO$_6$, or Ge treated YBa$_2$Cu$_3$O$_{7-y}$, see Gao et al., “Preparation and Properties of All High Tc, SNS-Type Edge DC Squids”, IEEE Trans Magnetics 27, pg 3062 (1991), Chin et al., “Novel All-High T, Epitaxial Josephson Junction”, Appl. Phys. Lett. 58, pg. 753 (1991), Mizuno et al., “Fabrication of Thin-Film-Type Josephson Junctions Using a Bi—Cr—Cu—O/Bi—Sr—Cu—O/Bi—Sr—Ca—O—O Structure”, Appl. Phys. Lett. 56, pg. 1469 (1990), and Koren et al., “Properties of All YBa$_2$Cu$_3$O$_{7-y}$ Josephson Edge Junctions Prepared by in situ Laser Ablation Deposition”, Appl. Phys. Lett. 58, pg. 634 (1991). Although progress has been made with these devices, their electrical characteristics are often less than ideal with many devices suffering from one or more of the following problems: 1) current-voltage (I-V) characteristics inconsistent with the resistively-shunted junction (RSJ) model; 2) weak magnetic field and microwave response; and 3) low I$_C$R$_N$ products (~500 µV).

U.S. Pat. No. 4,891,355 discloses a method of producing a superconducting circuit, wherein a laser beam is used to form nonsuperconducting barrier regions between superconducting portions of the film. These barrier regions appear to electrically separate various superconducting parts of the circuit and the dimension of the nonsuperconducting segments will be limited to the dimensions of the laser wavelengths, due to diffraction effects. In essence, a film of a ceramic superconductive material is deposited on a substrate in a superconducting state and then exposed to the laser beam as part of a high temperature heat treatment to turn it into a nonsuperconducting state.

An article “Cubic Phase in the Y—Ba—Cu—O System” by Agostinelli et al., Physics Review B 43, pg. 11396 (1991), discloses a cubic phase of a rare earth-alkaline earth-cuprate film that was deposited as a thin film on a single crystal magnesium oxide substrate by excimer laser ablation.

U.S. Pat. No. 5,034,374 teaches a method of producing a high temperature superconductor element formed from rare earth-alkaline earth-cuprate superconductors with an insulating layer formed between the lower and upper ceramic high temperature superconductor films by an interdiffusion of ceramic superconductors to thereby form a tunnel junction exhibiting Josephson effects.

U.S. Pat. No. 5,047,390 discloses another configuration of a tunnel junction Josephson device.

Finally, the Japanese laid-open patent application No. 63-252316 apparently refers to the deposition of a barrier layer between a substrate and a superconducting material.

The prior art is still seeking to provide an optimum superconducting device exhibiting Josephson effects that can be efficiently manufactured with high yield.

STATEMENT OF THE INVENTION

The present invention discloses a method of providing a high temperature superconductor Josephson element and a...
novel Josephson element having a weak link barrier layer of a non-superconducting film in a family of rare earth-alkaline earth-cuprate superconductors. An appropriate substrate, such as LaAlO$_3$, is prepared and a film layer of YBa$_2$Cu$_3$O$_{7-x}$ is deposited as a base electrode on the substrate by a pulsed excimer laser ablation technique in a vacuum chamber with an oxygen environment of approximately 100~200 mTorr. The backing plate temperature was approximately 790~850°C during the growth of the base electrode superconducting layer. The base electrode layer is annealed in 50~100 Torr of oxygen for approximately 12 minutes at about 500°C. Subsequently, a thick insulating layer, such as magnesium oxide was deposited and patterned by a photolithography and lift-off process. The magnesium oxide layer was utilized as an ion milling mask to define a self-aligning edge in the base superconductor electrode. An ion milling and cleaning step created an edge in the base superconductor electrode. A weak link barrier layer of a nonsuperconducting film of Y—Ba—Cu—O ("N—YBaCuO") is then deposited across the base electrode edge at a reduced temperature of approximately 520~540°C. Again, a laser ablation vacuum deposition procedure at 100~200 mTorr was utilized and the deposition rate was substantially reduced by limiting the laser repetition rate to 1 Hz compared to the 5 Hz that was utilized for the base electrode superconductor layer. Subsequently, the temperature of the backing plate was increased to approximately 800°C and a superconducting counter-electrode layer of YBa$_2$Cu$_3$O$_{7-x}$ was deposited at a laser repetition rate of 5 Hz. The resulting structure was then annealed in 50~100 Torr of oxygen at approximately 500°C for 12 minutes. The junction was then subject to a second lithography and ion milling step to cut holes through the magnesium oxide to the base electrode and lift-off gold pads. A third lithography and ion milling process define the specific counter-electrode patterns that were desired.

This method produced a high $T_c$ edge geometry weak link superconductor Josephson element of an SNS device structure having a weak link barrier layer within a range of approximately 5 Å to 200 Å in thickness with a base electrode and counter-electrode of approximately 1000 Å to 3500 Å in film thickness. Preferably, the weak link layer thickness is in the range of 25 Å to 100 Å with a preferred embodiment having a thickness of approximately 50 Å and an effective metal coherence length of 20 Å at a temperature of 4.2 K.

Tests have indicated that the weak link layer provided a very good SNS device with a current-voltage characteristic consistent with the desired RSJ model and 80~100% critical current modulation in applied magnetic fields. As can be appreciated, the weak link barrier layer may have a relative close lattice match to the superconducting YBaCuO electrodes, with a similar crystal structure, and is obviously chemically compatible with the superconductor electrodes at their growth temperature. The weak link normal metal layer grew in a two-dimensional fashion with relatively few pin holes and had a relative long coherence length with a high resistivity that would suggest the capacity for appropriate scaling to 50 Ω with 0.1 μm lithography.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The objects and features of the present invention, which are believed to be novel, are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation, together with further objects and advantages, may best be understood by reference to the following description, taken in connection with the accompanying drawings.
The normal metal layer should have a relatively long coherence length and a high resistivity. An advantage of an edge geometry epitaxial tri-layer approach is that it allows a very small weak layer length to be achieved because the effective length is determined by the thickness of the normal metal layer.

The specific embodiments described herein were accomplished with a YBaCuO system which is in the family of rare earth-earth-alkaline-earth-cuprate superconductors. It is believed that the advantages of the present invention can be achieved with other ceramic high temperature superconductor systems, as would be expected by a person of skill in this field.

The present invention utilizes a nonsuperconducting Y—Ba—Cu—O (N—YBaCuO) weak link barrier material that is specifically grown at a reduced temperature. The choice of such a weak link barrier material has an obvious advantage of chemical compatibility with the base electrode and counter-electrode to form a high quality YBa2Cu3O7−x/normaLMetal/YBa2Cu3O7−x structure. It is believed that the particular choice of our normal metal weak link barrier material will encourage epitaxial overgrowth of the counter-electrode because the lattice constants reported for oxygen-deficient YBa2Cu3O7−x, and for the possible cubic YBa2Cu3O7−x phase are close to those for more fully oxidized YBa2Cu3O7−x.

The exact structure of the normal metal weak link barrier is not fully known and it is possible that a simple cubic perovskite structure is grown in accordance with the method of the present invention. There is difficulty in obtaining quantitative information on such very thin films grown on a small area and the experiments performed and reported herein suggest that our structure may be cubic. Another possibility is that a metastable, oxygen-rich, nonsuperconducting, tetragonal phase of YBa2Cu3O7−x may have been formed under the low temperature processing condition. For purposes of defining the present invention the procedure disclosed is sufficiently operative to reproduce the Josephson element of the present invention.

Recent theoretical results also suggest that higher resistivity materials, such as nonsuperconducting Y—Ba—Cu—O may be more suitable for obtaining high Ic product than low resistivity metals, such as Au or Ag.

In the preferred embodiment and method of the present invention, we have defined a particular junction configuration as an edge geometry weak link, because it is believed in the preferred embodiment that this structure offers some advantages over other possible geometry, such as the sandwich and lateral geometry devices that are known. It should be appreciated, however, that the present invention is not necessarily limited to an edge geometry, although it is believed that this is the preferred embodiment.

The basic device structure of the present invention is formed by depositing the N—YBaCuO layer and the YBa2Cu3O7−x layer counter-electrode on the exposed edge of a c-axis-oriented YBa2Cu3O7−x thin film overlaid by a thick insulator. The insulator prevents electrical contact to the top surface of the base electrode, so that the active device area is determined by the thickness of the lower YBa2Cu3O7−x film and the width of the patterned counter-electrode. This allows very small device areas to be achieved using conventional photolithography. In addition, the effective short bridge length is determined by the thickness of the deposited weak link material so that extremely short bridge lengths are possible, provided that thin, uniform layers can be grown on the YBa2Cu3O7−x edge. The edge geometry also has the advantages, that, for c-axis YBa2Cu3O7−x films, the current flow in the device active area and lead-in electrodes is along the high current density a-b planes, and that the critical normal-superconductor device interfaces are located on the longer coherence length surfaces perpendicular to the a-b planes.

The growth conditions for the superconducting and nonsuperconducting YBaCuO thin films used in the method of production were nominally identical except for the substrate temperature and the deposition rate. Each of the Y—Ba—Cu—O films were deposited by pulsed excimer laser ablation of a target source at 248 nm and an energy density of approximately 1 J/cm². The stoichiometry of our target source was 1:2:3:7 Y:Ba:Cu:O. The oxygen pressure during deposition was within the range of 100 to 200 mTorr and preferably at 200 mTorr, and the deposition rate was 1–2 Å/pulse.

The thin weak link N—YBaCuO layer was typically grown at a laser repetition rate of 1 Hz, while the thicker superconducting electrode layers were grown at 5–10 Hz. The backing plate temperature during growth of the nonsuperconducting YBaCuO films was approximately 520–540 °C, and about 790–830 °C during growth of the base and counter-electrode superconducting layers. In production the YBaCuO weak link barrier deposition was immediately followed by a higher growth temperature for depositing the counter-electrode, and the deposited layers were then annealed in 50–100 Torr of oxygen at approximately 500 °C for 12 minutes. This annealing procedure was also used after the depositing of the base electrode films. Typical film thicknesses are 25 Å to 100 Å for the N—YBaCuO, and 1500–3000 Å for the superconducting electrodes.

The preferred edge-geometry device fabrication process of the present invention avoids the use of shadow masks in favor of standard integrated circuit processing techniques, which should be readily extendable to more complex circuits. The basic processing steps are briefly outlined here with schematic side and top views of a completed device shown in FIG. 1 through 5. The fabrication process begins with the deposition of the YBa2Cu3O7−x base electrode film on a substrate, such as a properly cleaned and prepared SrTiO3 (100) or LaAlO3 (100) substrate. This is followed by the annealing step. Subsequently, a thick MgO film is patterned by photolithography and liftoff, as shown in FIG. 1. The MgO layer is utilized as an ion milling mask to define a self-aligned edge in the base electrode using 500 eV Ar ions, followed by a brief 50 eV Ar ion edge cleaning, see FIG. 2. In some cases, the ion-milling edge cutting process is done at non-normal incidence to produce a more tapered YBaCuO base electrode edge.

Immediately after this step, within the same vacuum system, the substrate temperature is increased and the N—YBaCuO barrier layer 8 and YBa2Cu3O7−x counter-electrode 10 are deposited. After annealing, a second lithography and ion milling step is used to cut via holes through the MgO to the base electrode and liftoff Au 12 pads, as shown in FIG. 3. Finally, a third lithography and ion milling process defines the counter-electrode patterns that can be seen in FIGS. 4 and 5.

The best results were obtained with edge-geometry weak links having 50 Å thick N—YBaCuO barrier layer at temperatures above 50 K. A typical 1-V characteristic at 61.5 K for such a device is shown in FIG. 6. The I-V curve is qualitatively consistent with the RSJ model, unlike the piecewise-linear or flux-flow characteristics often observed with other all-high Tc weak links. This particular weak link
had a current density of 6.5 kA/cm² and an $I_R \cdot J$ product of 105 pV at this temperature. While at 4.2 K, the $I_R \cdot J$ products are not as large as theoretically possible, it is believed that larger $I_R \cdot J$ values may result from improvements in counter-electrode overgrowth. The resistance of this 11 μm x 0.28 μm device is 0.5 Ω and it is believed that 5 Ω device resistances should be achievable with 1 μm lithography, and 50 Ω with 0.1 μm lithography.

As shown in FIG. 7, this invention exhibited strong microwave response, with ac Josephson steps at the expected voltages ($V_n=nh/2e$) under 10 GHz microwave irradiation. The microwave step amplitudes showed a Bessel-function-like oscillatory behavior with increasing RF field, qualitatively consistent with a RSJ current source model. At 4.2 K the 50 Å barrier devices had current densities of about $10^5$ A/cm², but showed less ideal device characteristics. In this case may be due to self-shielding effects related to the small Josephson penetration depth ($λ_J$) in these high $λ_J$, relative weak junctions.

Devices with 25 Å and 100 Å thick N—Ba—Cu—O weak link barrier layers were also tested. At 4.2 K and higher temperatures the weak links with 100 Å barriers sometimes exhibited RSJ-like I-V characteristics, but many of the devices had non-ideal piecewise-linear I-V curves. From these devices showed ac Josephson steps which modulated completely with increasing RF power, but typically the magnetic field modulation of the critical currents was less than 30%. The 25 Å barriers devices often showed RSJ I-V characteristics at higher temperatures with strong microwave response up to ~85 K. However, these weak links also showed incomplete (~70%) magnetic field modulation and exhibited hysteresis and switching noise at low voltages, which may be related to switching of weak spots or pin holes in these very thin barriers. In contrast to the 25 and 100 Å barrier devices, above 50 K the 50 Å barrier weak links typically showed 80–100% critical current modulation in applied magnetic fields. The $I_c$ vs $B$ data for such devices exhibited diffraction patterns approximating the expected Fraunhofer behavior, with a strong central peak and periodic $I_c$ modulation, but some asymmetry in the pattern, indicating a fairly good barrier uniformity. In these preliminary magnetic field measurements, the field was not applied parallel to the junction base electrode edge, so quantitative determination of the effective device area was not possible.

The 0.1 μm lithography is the scaling behavior of the critical current and device resistance with barrier thickness and device area. See FIG. 13 for a plot of $ln(J_c)$ as a function of N—YBaCuO normal metal thickness at 4.2 K. The linear data fit indicates that $J_c$ is proportional to exp$(-L/\xi_n)$, where to $\xi_n=20$ Å is the normal metal coherence length. Such exponential scaling of $J_c$ with the normal metal weak link barrier thickness is predicted by simple theories of SNS behavior. The temperature dependence of the critical current density for devices with 25, 50, and 100 Å barrier thicknesses is shown in FIGS. 8 and 9. The qualitatively shape of the $I_c$ vs $T$ curves is similar for all three barrier thicknesses, and a fit of the data for the 50 Å barrier device, see FIG. 9, indicates that $I_c$ goes as $(1-T/T_c)^2$ near $T_c$ as predicted by basic theories for SNS devices. FIG. 8 clearly shows the strong dependence of critical current on barrier thickness with $I_c$ at 4.2 K ranging from 8.3x10^5 A/cm² for the 100 Å barrier, to 3.8x10^5 A/cm² for the 25 Å barrier. These devices also show resistances which scale inversely with the device area, and average $R_{j, i}$ products at 4.2 K for the 25, 50, and 100 Å barrier thicknesses are 2.7x10^2, 7.7x10^2, and 1.2x10^3 Ω-cm², respectively. The scaling of $I_c$ and $R_{j, i}$ with barrier thickness and device area indicates that the N—YBaCuO weak link barrier layers are indeed relatively uniform, and that the device behavior is not dominated by pin hole conduction. In contrast to the lateral resistivity measurements of N—YBaCuO films on LaAlO₃ substrates, preliminary tests show a factor of 2–3 decrease in device resistance as the temperature is lowered from ~80 K to 4.2 K. However, the magnitudes of the device $R_{j, i}$ products are consistent with the low end of the resistivity range seen in lateral transport experiments.

In summary, high quality, all-high T, edge-geometry weak links have been fabricated using nonsuperconducting N—YBaCuO barrier weak link layers in a production process with excellent yields. The best results were obtained with devices incorporating 50 Å barrier layers, which show RSJ-like I-V characteristics with strong ac and dc Josephson effects. The scaling behavior of $J_c$ and $R_{j, i}$ with barrier thickness and area indicates that the N—YBaCuO barrier layers form uniform, high quality weak links with an effective normal metal coherence length of 20 Å at 4.2 K.

In an effort to further define the structure of the specific superconducting electrodes and weak link barrier layer, the results of X-ray photoelectron spectroscopy (XPS) measurements are presented. Each of the film layer specimens were immersed for 30–60 seconds in 1% Br₂ in absolute ethanol, followed by rinsing in ethanol and blow drying with nitrogen. The XPS spectra were accumulated at room temperature on a Surface Science Instruments SSS100-501 spectrometer with monochromatized Al Kα X-rays (1486.6 eV) and a base pressure <3x10⁻¹¹ Torr and a typical operating pressure of 4–6x10⁻¹¹ Torr. For these experiments, an X-ray spot size of 600 μm and an analyzer pass energy of 25 eV are used, yielding a peak full width at half maximum (FWHM) of 0.7 eV measured for the Au 4f₇/₂ peak from an evaporated Au film. For the measurements presented here, the standard sample mount for this spectrometer has been replaced by a custom mount which allowed variable angle measurements. Since the photoelectron energy analyzer has a solid angle of acceptance of 30°, these data should be viewed as angle-integrated measurements centered at the specified angle, rather than as angle-resolved measurements.

The 0.1s spectra measured from orthorhombic YBaCuO, Tetragonal YBaCuO, and the N—YBaCuO weak link film were compared in FIG. 10. All three spectra exhibited peaks at higher binding energy associated with residual nonsuperconducting surface species, which will not be considered here. The lower binding energy peaks in the tetragonal YBaCuO and N—YBaCuO spectra are narrower than that of o-YBaCuO, and the tetragonal YBaCuO peak is shifted to higher binding energy. The o-YBaCuO spectrum had a clear shoulder on the low binding energy side of the main peak and a less obvious shoulder on the high binding energy side which is evident when comparison is made to the N—YBaCuO, which can be fitted with a single peak.

The second derivatives, in which peak positions appear as troughs and weak structure is enhanced, of the spectra from FIG. 10 are shown in the top three curves in FIG. 11. These data confirm that the tetragonal YBaCuO and N—YBaCuO spectra consist of single peaks at 528.8 eV and 528.1 eV, respectively, and that the previously unresolved three peaks comprising the o-YBaCuO spectrum now appear as well-resolved components. The peaks at 527.1 and 528.0 eV are believed to be intrinsic to o-YBaCuO, corresponding to...
Cu—O chains and Cu—O planes, respectively. The peak at 528.7 eV is surface related, evident in its enhanced relative intensity at grazing angles (compare the bottom two curves in Fig. 11). The occurrence of this peak at the same position as that of t-YBaCuO suggests that it may correspond to some residual t-YBaCuO due to incomplete oxidation or oxygen loss at the surface in vacuum. However, no other spectral features associated with t-YBaCuO were observed. As subsequently discussed, a possible origin of this peak is reconstruction of the Cu—O planes which terminate chemically-etched o-YBaCuO surfaces. The absence of this feature and the peak associated with Cu—O in the N—YBaCuO may indicate a simple perovskite crystal structure in which Cu—O planes and chains do not exist.

Within experimental error, the Cu 2p core level and Cu LMM Auger signals for N—YBaCuO are identical to those for o-YBaCuO. The intensity of the satellite peak in the Cu 2p spectrum, characteristic of Cu in the +2 oxidation state was 43% of the intensity of the main peak for both o-YBaCuO and N—YBaCuO, while it is 0.29 for t-YBaCuO, and the Cu\(^{+}\) signal evident in t-YBaCuO is absent in N—YBaCuO. This observation suggests that N—YBaCuO is not simply an oxygen deficient YBaCuO. The other core level signals from N—YBaCuO and the Cu\(^{+}\) signal evident in t-YBaCuO are also very similar to those from o-YBaCuO. The Y 3d\(_{5}/2\) is observed at 155.8 eV, 155.9 eV, and 156.4 eV for o-YBaCuO, N—YBaCuO, and t-YBaCuO, respectively, and the corresponding Ba 3d\(_{5}/2\) (4d\(_{5}/2\)) peaks were observed at 777.6 eV (872 eV), 777.8 eV (874 eV) and 776.8 eV (882 eV), respectively. The Ba MNN Auger signals from N—YBaCuO and o-YBaCuO are identical within experimental error. These data imply that the potentials at the Y, Ba, and Cu sites may be similar in o-YBaCuO and N—YBaCuO.

The overall shape of the valence band spectrum from N—YBaCuO is similar to that from o-YBaCuO, as shown in Fig. 12, but is slightly narrower, primarily on the low binding energy side, and with less intensity at the Fermi level. A Fermi edge is evident in the o-YBaCuO spectrum, reflecting the normal state metallic conductivity and providing evidence of a high quality surface. The valence band spectrum from t-YBaCuO differs significantly from the spectra in Fig. 12, in having negligible intensity at the Fermi level and also significantly different features. The lower intensity in the N—YBaCuO spectrum in the 0–2 eV range is consistent with a lack of Cu 3d\(_{5}/2\) 2p π-bonding states from Cu—O chains, and is thus consistent with expectations from a possible simple perovskite crystal structure.

In summary, XPS characterization of a nonsuperconducting N—YBaCuO SNS weak link barrier material shows that the spectral features are distinct from those of the o-YBaCuO and t-YBaCuO phases, especially in the O 1s region. Features associated with Cu—O chains and surface-reconstructed Cu—O planes are absent in the N—YBaCuO spectra, consistent with a possible, simple perovskite crystal structure.

Those skilled in the art will appreciate that various adaptations and modifications of the just-described preferred embodiments can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

I claim:

1. A method of producing a high temperature superconductor Josephson element comprising the steps of:
   - providing a substrate;
   - depositing a weak superconducting electrode film layer of YBaCuO on the substrate;
   - depositing a weak link barrier layer of a nonsuperconducting film of N—YBaCuO on the lower film layer, and
   - depositing an upper superconducting counter-electrode film layer of YBaCuO on the barrier layer.

2. The method of claim 1 wherein the lower superconducting film layer has an exposed edge of a c-axis oriented Ba\(_{x}\)Cu\(_{y}\)O\(_{z}\) film layer and the weak link barrier layer of nonsuperconducting film is deposited over the exposed edge.

3. The method of claim 1 wherein the lower electrode superconducting film and upper electrode superconducting film are deposited at approximately a temperature range of 790° C. to 830° C. and the nonsuperconducting film is deposited at a temperature range of 520° C. to 540° C. in 100 to 200 m Torrs of oxygen.

4. The method of claim 1 wherein the weak link barrier layer is deposited to form a layer thickness within a range of 25 Å to 100 Å.

5. The method of claim 1 wherein the respective lower and upper superconducting film layers are deposited to form film thicknesses within the range of 1000 Å to 3500 Å.

6. The method of claim 1 wherein the formation of the respective layers occurred in a deposition step with an oxygen pressure of 100 to 200 m Torrs.

7. The method of claim 1 wherein the formation of the respective film layers occurred by exposing a YBa\(_{x}\)Cu\(_{y}\)O\(_{z}\) target to a pulsed excimer laser at 248 nm and an energy density of 1 to 2 J/cm\(^2\).

8. The method of claim 7 wherein the formation of the respective film layers occurred by depositing the lower and upper superconducting film layer at a deposition rate of approximately 1–2 Å/pulse at a pulse rate of 5–10 Hz and the barrier layer at a deposition rate of approximately 1–2 Å/pulse rate of 1 Hz.

9. The method of claim 8 wherein the weak link barrier layer has a thickness of approximately 5 Å to 200 Å.

10. The method of claim 1 wherein the weak link barrier layer is deposited to form a layer thickness of 50 Å.

11. The method of claim 1 further including the step of providing a clean normal metal/superconductor interface between said lower layer and said barrier layer with any damage to said lower layer being approximately less than one coherence length thick.

12. A method of producing a high temperature superconductor Josephson junction comprising the steps of:
   - providing a substrate;
   - depositing a lower superconducting electrode film layer of YBaCuO on the substrate;
   - depositing a weak link barrier layer of a nonsuperconducting film of N—YBaCuO on the lower film layer to form a layer having a thickness within a range of 5 Å to 200 Å, and
   - depositing an upper superconducting counter-electrode film layer of YBaCuO on the barrier layer,

   wherein the lower electrode superconducting film and upper electrode superconducting film are deposited at a temperature range of 790° C. to 830° C. and the nonsuperconducting barrier layer is deposited at a temperature range of 520° C. to 540° C.;

   wherein the formation of each of the respective lower, barrier, and upper layers occurs in a deposition step with an oxygen pressure of 100 to 200 m Torrs; and

   wherein the formation of the respective upper, lower, and barrier film layers is achieved by exposing a
YBa$_2$Cu$_3$O$_{7-x}$ target to a pulsed excimer laser and depositing the lower and upper superconducting films layer at a deposition rate of approximately 1-2 Å/pulse at a pulse rate of 5-10 Hz and the barrier layer at a deposition rate of approximately 1-2 Å/pulse at a pulse rate of 1 Hz.

13. The method of claim 12 wherein the thickness of the weak link barrier is 50 Å.

14. The method of claim 12 further including the step of providing a clean normal metal/superconductor interface between said lower layer and said barrier layer with any damage to said lower layer being approximately less than one coherence length thick.

15. The method of claim 12 wherein the lower superconducting film layer has an exposed edge of a c-axis oriented YBa$_2$Cu$_3$O$_{7-\delta}$ film layer and the weak link barrier layer of nonsuperconducting film is deposited over the exposed edge.

16. A method of producing a high temperature superconductor Josephson junction comprising the steps of:
   - providing a substrate;
   - depositing a lower superconducting electrode film layer of YBaCuO on the substrate;
   - depositing a weak link barrier layer comprising a nonsuperconducting film of N—YBaCuO on the lower film layer; and
   - depositing an upper superconducting counter-electrode film layer of YBaCuO on the barrier layer.

17. The method of claim 16 wherein the lower electrode superconducting film and upper electrode superconducting film are deposited at approximately a temperature range of 790°C to 830°C and the nonsuperconducting film is deposited at a temperature range of 520°C to 540°C in 100 to 200 m Torrs of oxygen.

18. The method of claim 17 wherein the weak link barrier layer is deposited to form a layer thickness of 50 Å.

20. The method of claim 19 wherein the lower electrode superconducting film and upper electrode superconducting film are deposited at approximately a temperature range of 790°C to 830°C and the nonsuperconducting film is deposited at a temperature range of 520°C to 540°C in 100 to 200 m Torrs of oxygen.

21. The method of claim 20 wherein the weak link barrier layer is deposited to form a layer thickness of 50 Å.

22. The method of claim 17 wherein the formation of the upper and lower superconducting films occurs in a deposition step with an oxygen pressure of 100 to 200 m Torrs.

23. The method of claim 20 wherein the formation of the upper and lower superconducting films occurs in a deposition step with an oxygen pressure of 100 to 200 m Torrs.

24. The method of claim 22 wherein the Y—Ba—Cu—O barrier deposition is immediately followed by a ramp to the higher growth temperature, the counter-electrode is then deposited, and the upper, lower and barrier layers are then annealed in 50 Torrs of oxygen at 500°C for 12 minutes.

25. The method of claim 23 wherein the Y—Ba—Cu—O barrier deposition is immediately followed by a ramp to the higher growth temperature, the counter-electrode is then deposited, and the upper, lower and barrier layers are then annealed in 50 Torrs of oxygen at 500°C for 12 minutes.

26. The method of claim 22 wherein the Y—Ba—Cu—O barrier deposition is immediately followed by a ramp to the higher growth temperature, the counter-electrode is then deposited, and the upper, lower and barrier layers are then annealed in 50 Torrs of oxygen at 500°C for 12 minutes.

27. The method of claim 23 wherein the lower superconducting film layer has an exposed edge of a c-axis oriented YBa$_2$Cu$_3$O$_{7-\delta}$ film layer and the weak link barrier layer of nonsuperconducting film is deposited over the exposed edge.