

Patents Granted

12-17-1991

High temperature superconductors comprising Tl-Ca-Ba-O, Tl-Sr-Ba-Cu-O, or Tl-Sr-Cu-O

Zhengzhi Sheng
University of Arkansas, Fayetteville

Allen M. Hermann
University of Arkansas, Fayetteville

Follow this and additional works at: <https://scholarworks.uark.edu/pat>

Citation

Sheng, Z., & Hermann, A. M. (1991). High temperature superconductors comprising Tl-Ca-Ba-O, Tl-Sr-Ba-Cu-O, or Tl-Sr-Cu-O. *Patents Granted*. Retrieved from <https://scholarworks.uark.edu/pat/249>

This Patent is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Patents Granted by an authorized administrator of ScholarWorks@UARK. For more information, please contact scholar@uark.edu.

[54] HIGH TEMPERATURE SUPERCONDUCTORS COMPRISING TL—CA—BA—O, TL—SR—BA—CU—O, OR TL—SR—CU—O

[75] Inventors: Zhengzhi Sheng; Allen M. Herman, both of Fayetteville, Ark.

[73] Assignee: The University of Arkansas, Little Rock, Ark.

[*] Notice: The portion of the term of this patent subsequent to Oct. 9, 2005 has been disclaimed.

[21] Appl. No.: 498,392

[22] Filed: Mar. 26, 1990

Related U.S. Application Data

[63] Continuation of Ser. No. 155,247, Feb. 12, 1988, Pat. No. 4,962,083.

[51] Int. Cl.⁵ C01F 11/02; C01G 3/02; C01G 15/00; H01L 39/12

[52] U.S. Cl. 505/1; 252/521; 423/604; 423/624; 423/635; 501/123; 505/783

[58] Field of Search 505/783, 1; 423/602, 423/624, 635; 501/123; 252/521

[56] References Cited

U.S. PATENT DOCUMENTS

4,755,593	7/1988	Takeuchi et al.	501/134
4,870,052	9/1989	Engler et al.	505/1
4,880,773	11/1989	Itozaki	252/521
4,962,083	10/1990	Hermann et al.	501/123

FOREIGN PATENT DOCUMENTS

0280812	9/1988	European Pat. Off. .
0284062	9/1988	European Pat. Off. .
0286289	10/1988	European Pat. Off. .
0292340	11/1988	European Pat. Off. .
0301952	2/1989	European Pat. Off. .
0301958	2/1989	European Pat. Off. .
0316009	5/1989	European Pat. Off. .

OTHER PUBLICATIONS

Saito "High-Tc superconducting properties in (Y_{1-x}Tl_x)Ba₂Cu₂O_x" *Physica* 148B 1987, pp. 336-338.
 Richert "Atomic Substitution in YBa₂Cu₃O₇₋₂ Modifica-

tion . . ." *American Vac. Soc. Series 3*, Anaheim, CA, Nov. 6, 1987, pp. 377-283.

Hasegawa, T., et al., *High T. Superconductivity of (La_{1-x}Sr_x)CuO₄*—Effect of Substitution . . . Superconductivity, *Japan Journal of Applied Physics*, vol. 26, No. 4, Apr. 20, 1987, L337-L338.

Kishio, K., et al., *Effect of Lanthanide Ion Substitutions for Lanthanum Sites on Superconductivity of (La_{1-x}Sr_x)₂CuO_{4-δ}*, *Japanese Journal of Applied Physics*, vol. 26, No. 4, Apr. 20, 1987, L391-L393.

Ohshima, S., et al., *Superconducting and Structural Properties of the New Ba_{2-x}Ln_xCuO_{3-x} Compound System (Ln=La, Ce, Pr, Nd, Sm, Eu, . . . and Yb)*, *Japanese Journal of Applied Physics*, vol. 26, No. 5, May 1987, L815-L817.

Tsurumi, S., et al., *High T. Superconductivities of A₂Ba₄.Cu₆O_{14+y}*, *Japanese Journal of Applied Physics*, vol. 26, No. 5, May 1987, L856-L857.

Superconductivity News, vol. 1, No. 2, Aug. 1987, pp. 1, 2 and 6-8.

Yang, K. N., et al., *High Temperature Superconductivity in Rare-Earth (R)—Barium Copper Oxides (RBa₂)Cu₃O_{9-δ}*, *Solid State Communications*, vol. 63, No. 6, 1987, pp. 515-519.

Tarascon, J. M., et al., *Oxygen and Rare-Earth Doping of the 90-K Superconducting Perovskite YBa₂Cu₃O_{7-x}*, *Physical Review B*, vol. 36, No. 1, 1987, 226-234.

(List continued on next page.)

Primary Examiner—Paul Lieberman

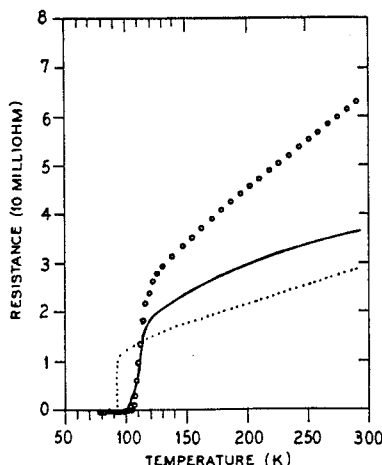
Assistant Examiner—John Boyd

Attorney, Agent, or Firm—Hermann, Ivester, Hill, Van Santen, Steadman & Simpson

[57] ABSTRACT

A new high temperature superconductor with transition temperature above 120 K. is disclosed. The superconductor in a preferred embodiment comprises TlR₂BaCuO wherein R is chosen from Group 2A elements excluding Ba. In another preferred embodiment, the superconductor comprises TlSrCuO. Processes for making high temperature superconductors are also disclosed.

3 Claims, 2 Drawing Sheets



OTHER PUBLICATIONS

- Hor, P. H., et al., *Superconductivity Above 90 K in the Square-Planar Compound System $A\text{Ba}_2\text{Cu}_3\text{O}_{6+x}$ with $A = \text{Y, La, Nd, Sm, Eu, Gd, Ho, Er, and Lu}$* , Physical Review Letters, vol. 58, No. 18, 1987, 1891-1894.
- Khurana, A., *Superconductivity Seen Above the Boiling Point of Nitrogen*, Physics Today, Apr., 1987, 17-23.
- Cava, R. J., et al., *Bulk Superconductivity at 91 K in Single-Phase Oxygen-Deficient Perovskite $\text{Ba}_2\text{YCu}_3\text{O}_{9-\delta}$* , Physical Review Letters, vol. 58, No. 16, 1987, 1676-1679.
- Nagashima, T., et al., *Superconductivity in $\text{Tl}_{1.5}\text{SrCaCu}_2\text{O}_x$* , Japanese Journal of Applied Physics, vol. 27, No. 6, Jun. 1988, L1077-L1079.
- Kondoh, S., et al., *Superconductivity in Tl-Ba-Cu-O System*, Solid State Communications, vol. 65, No. 11, 1988, 1329-1331.
- Sera, M. et al., *On the Structure of High- T_c Oxide System Tl-Ba-Cu-O*, Institute for Molecular Science, Myodaiji, Okazaki 444 Japan, 1988.
- Ihara, H. et al., *Possibility of Superconductivity at 65° C. in Sr-Ba-Y-Cu-O System*, Japanese Journal of Applied Physics, vol. 26, No. 8, Aug. 1987, L1413-L1415.
- Ishida, T., *Compositional Variation of High T_c in $\text{Yb}_x\text{Er}_{1-x}\text{Ba}_2\text{Cu}_3\text{O}_{6+y}$ System*, Japanese Journal of Applied Physics, vol. 26, No. 8, Aug. 1987, L1294-L1295.
- Kijima, T., et al., *Superconductivity in the Bi-Sr-La-Cu-O System*, Japanese Journal of Applied Physics, vol. 27, No. 6, Jun. 1988, L1035-L1037.
- Ferreira, J. M., et al., *Long-range Magnetic Ordering the High- T_c Superconductors $\text{RBa}_2\text{Cu}_3\text{O}_{7-\delta}$ ($R = \text{Nd, Sm, Gd, Dy and Er}$)*, Physical Review B, vol. 37, No. 4, Feb. 1, 1988, 2368-2371.
- Shih, I., et al., *Multilayer Deposition of Thallium Barium Calcium Copper Oxide Films*, Applied Physics Letter 53(6), 1988, 523-525.
- Ginley, D. S., et al., *Sequential Electron Beam Evaporated Films of $\text{Tl}_2\text{CaBa}_2\text{Cu}_2\text{O}_y$ with Zero Resistance at 97 K*, Applied Physics Letters, 53(5), Aug. 1, 1988, 406-408.
- Qiu, C. X., et al., *Formation of Tl-Ca-Ba-Cu-O Films by Diffusion of Tl into rf-sputtered Ca-Ba-Cu-O*, Applied Physics Letters, 53(12), Sep. 19, 1988, 1122-1124.
- Gopalakrishnan, I. K., et al., *Synthesis and Properties of a 125 K Superconductor in the Tl-Ca-Ba-Cu-O System*, Applied Physics Letters, 53(5), Aug. 1, 1988, 414-416.
- Parkin, S. S. P., et al., *Bulk Superconductivity at 125 K in $\text{Tl}_2\text{Ca}_2\text{Ba}_2\text{Cu}_3\text{O}_x$* , Physical Review, 1988, 2539-2542.
- Sheng, Z. Z., et al., *Superconductivity in the Rare-Earth-Free Tl-Ba-Cu-O System Above Liquid-Nitrogen Temperature*, Nature, vol. 332, Mar. 3, 1988, 55-58.
- Sheng, Z. Z., et al., *Superconductivity at 90 K in the Tl-Ba-Cu-O System*, Physical Review Letters, vol. 60, No. 10, Mar. 7, 1988, 937-940.
- Sheng, Z. Z., et al., *Bulk Superconductivity at 120 K in the Tl-Ca/Ba-Cu-O System*, Nature, vol. 332, Mar. 10, 1988, 138-139.
- Ihara, H., et al., *A New High- T_c $\text{TlBa}_2\text{Ca}_3\text{Cu}_4\text{O}_{11}$ Superconductor with $T_c > 120$ K.*, Nature, vol. 334, Aug. 11, 1988, 510-511.
- Sheng, Z. Z., et al., *Tl_2O_3 Vapor Process of Making Tl-Ba-Ca-Cu-O Superconductors*, Appl. Phys. Lett. 53(26), Dec. 26, 1988, 2686-2688.
- Hazen, R. M., et al., *100-K Superconducting Phases in the Tl-Ca-Ba-Cu-O System*, Physical Review Letters, vol. 60, No. 16, Apr. 18, 1988, 1657-1660.
- Sheng, Z. Z., et al., *New 120 K Tl-Ca-Ba-Cu-O Superconductor*, Appl. Phys. Lett., vol. 52, No. 20, May 16, 1988, 1738-1740.
- Lin, R. J., et al., *Forming Superconducting Tl-Ca-Ba-Cu-O Thin Films by the Diffusion Method*, Japanese Journal of Applied Physics, vol. 28, No. 1, Jan. 1989, L85-L87.
- Thompson, B. J., et al., *Preparation of High T_c Tl-Ba-Ca-Cu-O Thin Films by Pulsed Laser Evaporation and Tl_2O_3 Vapor Processing*, Appl. Phys. Lett. 54(18), May 1, 1989, 1810-1811.
- Sugise, R., et al., *Preparation of $\text{Tl}_2\text{Ba}_2\text{Ca}_2\text{Cu}_3\text{O}_y$ Thick Films from Ba-Ca-Cu-O Films*, Japanese Journal of Applied Physics, vol. 27, No. 12, Dec. 1988, L2314-L2316.
- Hatta, S., et al., *Pt-coated Substrate Effect on Oxide Superconductive Films in Low-Temperature Processing*, Appl. Phys. Lett. 53(2), Jul. 11, 1988, 148-150.
- Lee, W. Y., et al., *Superconducting Tl-Ca-Ba-Cu-O Thin Films with Zero Resistance at Temperatures of up to 120 K*, Appl. Phys. Lett. 53(4), Jul. 25, 1988, 329-331.
- Oota, A., et al., *Electrical, Magnetic and Superconducting Properties of High- T_c Superconductor (Y, Sc)-(Ba,*

(List continued on next page.)

OTHER PUBLICATIONS

- Sr*-*Cu* Oxide, Japanese Journal of Appl. Physics, vol. 26, No. 8, Aug. 1987, L1356-L1358.
- Iwazumi, T., et al., *Identification of a Structure with Two Superconducting Phases in L-Ba-Cu-O System (L=La or Y)*, Japanese Journal of Applied Physics, vol. 26, No. 5, May 1987, L621-L623.
- Capone, Il., D. W., et al., *Super Critical Fields and High Superconducting Transition Temperatures of $La_{1.85}Sr_{0.15}CuO_4$ and $La_{1.85}Ba_{0.15}CuO_4$* , Appl. Phys. Lett 50(9), Mar. 2, 1987, 543-544.
- Johnson, D. W., et al., *Fabrication of Ceramic Articles from High T_c Superconducting Oxides*, Materials Research Society, Symposium S Proceedings (High Temperature Superconductors), Apr. 1987, 193-195.
- Garwin, L., *Superconducting Conference Yields New Temperature Record*, Nature, vol. 332, Mar. 10, 1988.
- Suzuki, A., et al., *Rare-Earth (RE)-Barium Solubility Behavior in $Y(Ba_{2-x}RE_x)Cu_3O_{7+\delta}$ and $Sm(Ba_{2-x}RE_x)Cu_3O_{7+\delta}$* , Japanese Journal of Applied Physics, vol. 27, No. 5, May 1988, L792-L794.
- Nagashima, T., et al., *Improving Superconducting Characteristics of Tl-Sr-Ca-Cu-O by Doping with Pb and/or Rare-Earth Elements*, Japanese Journal of Applied Physics, vol. 28, No. 6, Jun. 1989, L930-L933.
- Vijayaraghavan, R., et al., *Investigations of Novel Cuprates of the $TlCa_{1-x}Ln_xSr_2Cu_2O_{7-\delta}$ ($Ln=rare\ earth$) Series Showing Electron- or Hole-superconductivity Depending on the Composition*, Superconducting Science and Technology, vol. 2(3), Sep. 1989, 195-201.
- Inoue, O., et al., *Superconductivity in a Tl-Sr-Y-Cu-O System*, Japanese Journal of Applied Physics, vol. 28, No. 8, Aug. 1989, L1375-L1377.
- Peters, P. N., et al., *Observation of Enhanced Properties in Samples of Silver Oxide Doped $YBa_2Cu_3O_x$* , Appl. Phys. Lett 52(24), Jun. 13, 1988, 2066-2067.
- S. Natarajan et al., *Superconductivity Studies on $(Y_{1-x}Ln_x)Ba_2Cu_3O_7$, $Ln=La, Pr, Tb$* , Physica C, vols. 153-155, Feb. 1988, 926-927.
- D. D. Sarma, et al., *Electronic Structure of High- T_c Superconductors from Soft-x-ray Absorption*, Physical Review B, vol. 37, No. 16, Jun. 1988, 9784-9787.
- K. Kishio, et al., *Superconductivity Achieved at Over Liquid Nitrogen Temperature by (Mixed Rare Earths)-Ba-Cu Oxides*, Japanese Journal of Applied Physics, vol. 26, No. 5, May 1987, L694-L696.
- Waldrop, M. Mitchell, *Thallium Superconductor Reaches 125K*, Research News, Mar. 1988, 1243.
- Qadri, S. B., et al., *X-ray Identification of the Superconducting High- T_c Phase in the Y-Ba-Cu-O System*, Physical Review B, vol. 35, No. 13, 1987.
- Murphy, D. W., et al., *New Superconducting Cuprate Perovskites*, Physical Review Letters, vol. 58, May 1987, 1888-1890.

FIG. 1

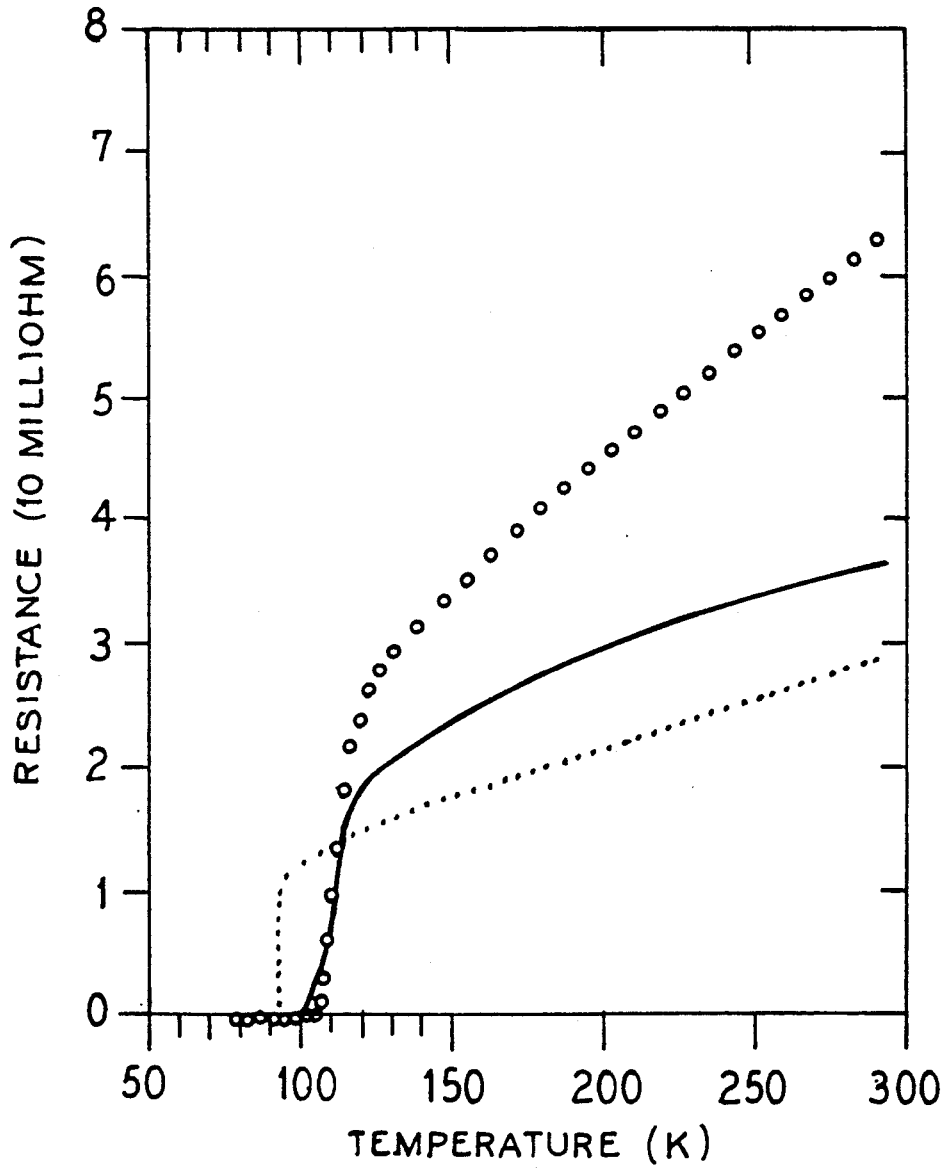
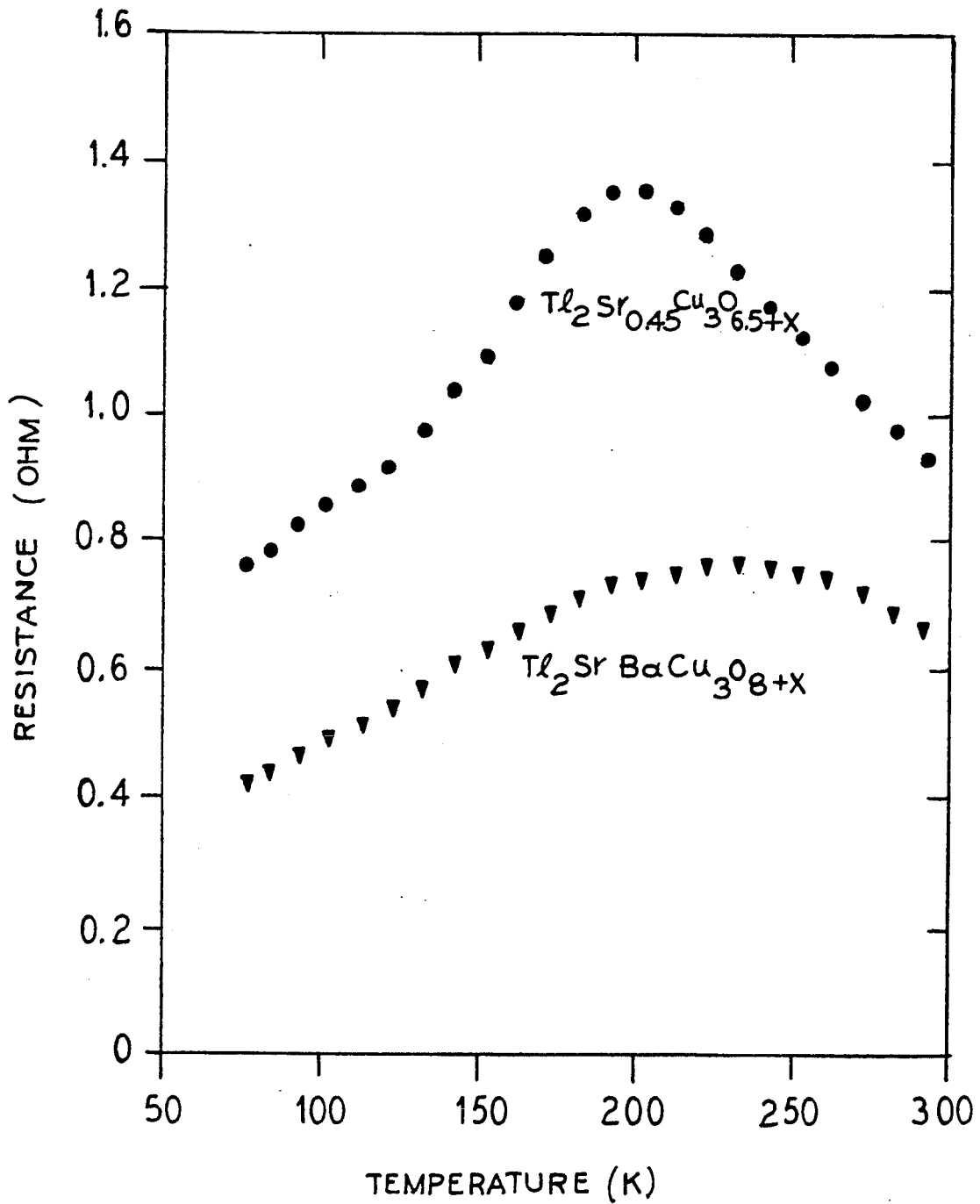


FIG. 2



**HIGH TEMPERATURE SUPERCONDUCTORS
COMPRISING TL—CA—BA—O,
TL—SR—BA—CU—O, OR TL—SR—CU—O**

This is a continuation of application Ser. No. 155,247, filed Feb. 12, 1988, now U.S. Pat. No. 4,962,083.

BACKGROUND OF THE INVENTION

The present invention relates to high temperature superconductors.

Recently, there has been much work done on the development of high temperature superconductors. Recent developments have indicated that certain combinations of elements are superconducting. However, these compositions typically do not maintain their superconductive attributes at temperatures that exceed approximately 90K. For example, recently, much work has centered on the use of ternary oxides containing rare earth elements, barium, and copper for superconductivity above the temperature of liquid nitrogen. But, these systems have limited transition temperatures, at or below 93K, and thus their applications are limited.

U.S. patent application Ser. Nos. 082,222, 089,067, and 144,114, filed on Aug. 6, 1987, Aug. 25, 1987, and Jan. 15, 1988, respectively, in the name of the inventors of the present invention disclose superconductor systems. U.S. patent application Ser. No. 089,067 discloses, in part, a superconductor based on a R—Ba—Cu—O wherein R is chosen from the group of rare earth metals excluding praseodymium, cerium, and terbium. U.S. patent application Ser. No. 082,222 discloses, in part, a superconductor based on a Tb—R—Ba—Cu—O system wherein R is chosen from the group of rare earth metals excluding praseodymium, cerium, and terbium. U.S. patent application Ser. No. 144,114 discloses, in part, a superconductor based on a TlBaCuO system.

Although superconductors prepared pursuant to the systems disclosed in the above-identified patent applications have produced "high-temperature" superconductors and yielded optimistic test results, superconductors prepared pursuant to the present invention have yielded higher transition temperatures. Indeed, based on the knowledge of the inventors, superconductors produced pursuant to the present invention have yielded the highest transition temperatures to date for any superconductor.

A superconductor with a higher transition temperature would be desirable for many reasons. Such a superconductor would: (1) facilitate the discovery of the correct theory on oxide superconductivity; (2) provide a framework for the search of higher temperature, even room temperature superconductors; (3) allow superconducting components to operate at higher temperatures with lower cost; and (4) provide low cost processing and manufacturability.

Furthermore, many of the superconductor compositions that have been proposed to date are based on rare earth metals. Due to the short supply and cost of these rare earth metals, the compositions constructed therefrom can be quite expensive.

Accordingly, there is a need for improved superconductors with higher transition temperatures.

SUMMARY OF THE INVENTION

The present invention provides improved superconductors with transition temperatures above 120K. Fur-

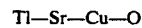
thermore, the present invention provides superconductors that contain no rare earth elements.

In an embodiment, the present invention preferably comprises a system comprising:

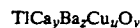


wherein: R is a Group 2A element, excluding barium. Preferably, R is chosen from the group of elements consisting of strontium (Sr) and calcium (Ca).

In another embodiment, the system of the present invention comprises:



In a preferred embodiment, the superconductive system of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0 and less than or equal to 5;

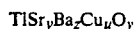
z is greater than or equal to 0 and less than or equal to 5;

y+z is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to z+y+u and less than or equal to 2+z+y+u.

In another preferred embodiment, the superconductive system of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0 and less than or equal to 5;

z is greater than or equal to 0 and less than or equal to 5;

y+z is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to z+y+u and less than or equal to 2+z+y+u.

In another preferred embodiment, the superconductive system of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to y+u and less than or equal to 2+y+u.

A method of producing the high temperature superconductor system of the present is also provided. In an embodiment, the method allows the superconductor to be prepared at temperatures of between approximately 850° to about 950° C. in flowing oxygen. The method

further allows the superconductor to be produced rapidly in about 30 minutes.

Accordingly, an advantage of the present invention is to provide a new superconductor with high transition temperatures.

A further advantage of the present invention is to provide a material system that may produce higher temperature superconductors, possibly even room temperature superconductors.

A still further advantage of the present invention is that it provides a new high temperature superconductor that is formed at a relatively low temperature, and allows for rapid production.

Furthermore, an advantage of the present invention is that it provides a method for making a new high temperature superconductor.

Still another advantage of the present invention is that it provides a method for rapidly making a high temperature superconductor.

Yet another advantage of the present invention is that it provides a method for making a superconductor having a transition temperature above 120K.

Moreover, another advantage of the present invention is that it provides a superconductor system that does not include rare earth metals.

Another advantage of the present invention is that the high temperature superconductor can be used at temperatures near the boiling point of liquid nitrogen where higher critical currents are to be expected.

Additional advantages and features of the present invention are described in, and will be apparent from, the detailed description of the presently preferred embodiments and the drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 illustrates a graph of electrical resistance versus temperature for three superconductor samples, the dashed line represents a Eu—Ba—Cu—O superconductor and the solid line and line represented by "O" depict samples based on a Tl—Ca—Ba—Cu—O superconductor system.

FIG. 2 illustrates a graph of electrical resistance versus temperature for two superconductor samples. "●" represents a superconductor based on TlSrCuO, while "▼" represents a superconductor based on TlSrBaCuO.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

The present invention provides a new superconductor with transition temperature above 120K. The present invention also provides a superconductor system that may produce higher temperature superconductors, even room temperature superconductors by further elemental substitution and variation of preparation procedures. In addition, the present invention provides a method for making these new high temperature superconductors.

To date, the inventors of the present invention are not aware of any superconductors that have transition temperatures above 100K. Of course, low transition temperatures limit the applications of the superconductors. The inventors of the present invention have discovered a superconductor system that has a transition temperature above 120K; which is at least 20K higher than that of any known high temperature superconductor. Because of its higher transition temperature, the present invention provides a superconductor that can be oper-

ated at higher temperatures with lower cost. Furthermore, the inventors of the present invention have found that the high temperature superconductor system of the present invention can be rapidly produced at relatively low temperatures.

In an embodiment of the present invention, the system comprises:



wherein:

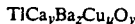
R is an element chosen from Group 2A elements excluding barium.

Preferably, R is chosen from the group of elements consisting of calcium (Ca) and strontium (Sr).

In another embodiment of the present invention, the system comprises:



In a preferred embodiment, a superconductor based on the new superconductive system of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0 and less than or equal to 5;

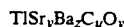
z is greater than or equal to 0 and less than or equal to 5;

y+z is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to z+y+u and less than or equal to 2+z+y+u.

In another preferred embodiment, a superconductor based on the new superconductive system of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0 and less than or equal to 5;

z is greater than or equal to 0 and less than or equal to 5;

y+z is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to z+y+u and less than or equal to 2+z+y+u.

In an embodiment, the superconductor of the present invention has the following approximate stoichiometry:



wherein:

y is greater than or equal to 0.2 and less than or equal to 5;

u is greater than or equal to 0.5 and less than or equal to 15; and

v is greater than or equal to y+u and less than or equal to 2+y+u.

By way of example, and not limitation, examples of the new high temperature superconductors of the present invention will now be given.

EXAMPLE 1

A. To create the superconductor of Example 1, the following reagents were utilized:

1. Tl_2O_3
2. CaO
3. $BaCO_3$
4. CuO

B. The following procedure was followed using the above reagents to create a superconductor:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle. The ground mixture was heated in air at approximately $925^\circ C.$ for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resultant $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and CaO to obtain a mixture with a nominal composition of $Tl_{1.86}CaBaCu_3O_{7.8+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of between approximately 850° to about $950^\circ C.$ with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was then taken out of the furnace and quenched in air to room temperature.

The samples prepared by this procedure had an onset temperature of above 120K, a midpoint of about 110K, and a zero resistance temperature of about 100K. Qualitative magnetic examinations of the superconductor of this example demonstrate a strong Meissner effect, indicating a large volume fraction of superconducting phase.

EXAMPLE 2

A. In this example, the following reagents were utilized:

1. Tl_2O_3
2. CaO
3. $BaCO_3$
4. CuO

B. To produce a superconductor with these reagents, the following procedure was followed:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at approximately $925^\circ C.$ for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resulting $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and CaO to obtain a mixture with a nominal composition of $Tl_{1.86}CaBaCu_3O_{7.8+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of approximately 850° to about $950^\circ C.$ with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was taken out of the furnace and quenched in air to room temperature.

6. The pellet was then annealed at approximately $450^\circ C.$ in flowing oxygen for 6 hours.

The samples prepared by this procedure had an onset temperature of above 120K, a midpoint of about 110K, and a zero resistance temperature of about 100K. FIG. 1 illustrates the resistance-temperature dependence for a superconductor sample prepared pursuant to this example. The sample is indicated by a solid line. By way of comparison, a superconductor based on Eu-Ba-Cu-O system is illustrated by dashed lines. Qualitative magnetic examinations of the samples demonstrated a strong Meissner effect, indicating a large volume fraction of superconducting phase.

EXAMPLE 3

A. The following reagents were utilized in this example:

1. Tl_2O_3
2. CaO
3. $BaCO_3$
4. CuO

B. The following procedure was followed:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at $925^\circ C.$ for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resulting $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and CaO to obtain a mixture with a nominal composition of $Tl_2Ca_{1.5}BaCu_3O_{8.5+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of approximately 850° to about $950^\circ C.$ with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was then taken out of the furnace and quenched in air to room temperature.

The samples prepared by this procedure had an onset temperature of above 123K, a midpoint of about 112K, and a zero resistance temperature of about 103K. Qualitative magnetic examinations of the samples showed a strong Meissner effect, indicating a large volume fraction of superconducting phase.

EXAMPLE 4

A. The following reagents were utilized in this example:

1. Tl_2O_3
2. CaO
3. $BaCO_3$
4. CuO

B. The following procedure was followed in this example:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at $925^\circ C.$ for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resulting $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and CaO to obtain a mixture with a nominal composition of $Tl_2Ca_{1.5}BaCu_3O_{8.5+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of between approximately 850° to about 950° C. with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was then furnace-cooled to room temperature.

The samples prepared by this procedure had an onset temperature of above 123K, a midpoint of about 112K, and a zero resistance temperature of about 103K. FIG. 1 illustrates the resistance-temperature dependence for a superconductor sample prepared pursuant to this example. The sample is indicated by the line defined by "0" in the figure. Qualitative magnetic examinations of these samples demonstrated a strong Meissner effect, indicating a large volume fraction of superconducting phase.

EXAMPLE 5

A. In this example, the following reagents were utilized:

1. Tl_2O_3
2. CaO
3. $BaCO_3$
4. CuO

B. In this example, the following procedure was followed:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at 925° C. for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resulting $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and CaO to obtain a mixture with a nominal composition of $Tl_{1.5}Ca_{0.5}BaCu_3O_{6.8+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of approximately 850° to about 950° C. with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was then taken out of the furnace and quenched in air to room temperature.

The samples prepared by this procedure had an onset temperature of about 120K, a midpoint of about 110K, and a zero resistance temperature of above liquid nitrogen temperature.

EXAMPLE 6

A. The following reagents were utilized in this example:

1. Tl_2O_3
2. $SrCO_3$
3. CuO

B. The following procedure was followed in this example:

1. A mixture of a 0.45 molar portion of $SrCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at 925° C. for more than 24 hours (with several intermediate grindings) to obtain a uniform black $Sr_{0.45}Cu_3O_{3.5}$ powder.

2. The resulting $Sr_{0.45}Cu_3O_{3.5}$ powder was mixed with appropriate amount of Tl_2O_3 to obtain a mixture with a nominal composition of $Tl_2Sr_{0.45}Cu_3O_{6.5+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of between approximately 1000° to about 1050° C. with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

5. The pellet was then taken out of the furnace and quenched in air to room temperature.

Resistance-temperature dependence for a sample prepared pursuant to this example is illustrated in FIG. 2 as represented by the "●" line. Although resistance did not reach zero above liquid nitrogen temperature, it may reach zero at lower temperatures. In particular, a decrease in the resistance at about 200K may originate from the onset of a high temperature superconducting phase of the sample.

EXAMPLE 7

A. In this example, the following reagents were utilized:

1. Tl_2O_3
2. $SrCO_3$
3. $BaCO_3$
4. CuO

B. In this example, the following procedure was followed:

1. A mixture of a one molar portion of $BaCO_3$ and a three molar portion of CuO was ground with an agate mortar and pestle, heated in air at 925° C. for more than 24 hours (with several intermediate grindings) to obtain a uniform black $BaCu_3O_4$ powder.

2. The resulting $BaCu_3O_4$ powder was mixed with appropriate amounts of Tl_2O_3 and $SrCO_3$ to obtain a mixture with a nominal composition of $Tl_2SrBaCu_3O_{8+x}$, which was completely ground, and pressed into a pellet.

3. A tube furnace was heated to a temperature of between approximately 900° to about 950° C. with oxygen flowing therein.

4. The pellet was placed in the tube furnace maintaining the temperature and oxygen flow for approximately 2 to about 5 minutes.

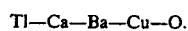
5. The pellet was then taken out of the furnace and quenched in air to room temperature.

Resistance-temperature dependence for the sample prepared pursuant to this example is illustrated in FIG. 2 as the "▼" line. Although the resistance did not reach zero above liquid nitrogen temperature, it may reach zero at lower temperatures. In particular, a decrease in resistance at about 250K may originate from onset of a high temperature superconducting phase of the sample.

It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made without departing from the spirit and scope of the present invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be covered by the appended claims.

We claim:

1. A composition having superconductor properties comprising:



2. A composition having superconductor properties comprising:

Tl—Sr—Ba—Cu—O.

3. A composition having superconductor properties comprising:

Tl—Sr—Cu—O.

5

* * * * *

10

15

20

25

30

35

40

45

50

55

60

65