ANNUAL REPORT

1994/1995

High Tc Superconducting Bolometric and Nonbolometric Infrared (IR) Detectors

NASA GRANT: NAG 5-2348

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CONTENTS

ANNUAL REPORT

I. Brief summary of the workplan for 1994/95

The workplan for the period August 1994 through August 1995 includes the following:

1. Expansion of the Applied Superconductivity Laboratory to include stand-alone optical response and noise measurement setups;

2. Pursue studies of the low frequency excess electrical noise in YBCO films; and

3. To enhance the academic support component of the project through increased student and faculty participation.

II. Expansion of the Applied Superconductivity Laboratory at UDC

a) Optical response measurements

As reported in the annual report last year, the pilot Applied Superconductivity Laboratory at UDC is currently well equipped for DC electrical transport measurements in the temperature range 10K to 300K. In the current year, the lab was expanded to include a facility for low frequency optical response measurements. The following additional equipments have been acquired since last year:

- A lock-in amplifier (acquired in '93)
- He-Ne laser source and the necessary optical bench and accessories;
- A light chopper with variable frequency;
- A variable temperature cryostat with optical windows;
- A temperature controller to replace the temperature controller currently on loan from the Center for Superconductivity Research at the University of Maryland; and
- A 25-liter Dewar for supply and storage of liquid nitrogen.

The optical response setup will also be utilized to study photo conductivity and superconductivity in YBCO and other oxide superconductor thin films. A sample optical response measurment result is attached (OPR11.XL chart 1)

b) Electrical noise measurements

This year, the Pilot Applied Superconductivity Laboratory at UDC was expanded to include a stand-alone noise measurement setup. To this end, the following equipments have been

acquired:

- A low noise voltage preamplifier;
- A low noise transformer;
- A spectrum analyzer*; and
- Other miscellaneous accessories.

* Made available by the Department of Engineering and Technology at UDC

Noise measurement can now be carried out in variable temperature optical response cryostat with necessary modifications. Coupled with the transport and optical response measurements and our access to the thin film deposition and characterization facilities at the CSR, this would enable the Applied Superconductivty Laboratory at UDC to carry out state-of-the-art research related to materials and device issues for the development of HTSC based radiation detectors. However, we plan to make the noise measurment apparatus even more reliable by acquring a better stabilized optical bench. Also, the current vacum pump must be replaced by one that provides more vacum stability in order to achieve better noise measurment results.

III Low Frequency Excess Electrical Noise in YBCO films

1. Early results

We have studied the dependence of the excess electrical noise both in the normal state and in the superconducting transition range. Detailed results of our investigation in the normal state were already presented in the semiannual report which covered our work up to Feb. 95. Subsequently we have carried out these measurements in the transition range, the results of which are presented here along with a summary of the results in the normal state. The micro structure is expected to play an important role since the conductance fluctuations which give rise to the excess noise are expected to have a dominant contribution from the defect fluctuations which are coupled to the concentration and mobility of charge carriers. YBCO films with varying micro structures are obtained by depositing the films on different substrates by pulsed laser deposition. We have studied films on three different substrates :

(i) **YBCO / (100) $LaAlO_3$** : The lattice mismatch of YBCO films with (100) $LaAlO_3$ is < 1 % as a result of which the film micro structure is very nearly single crystalline. The thermal expansion coefficient of the substrate and the film are also well matched

(ii) **YBCO / Poly crystalline Yttria Stabilized Zirconia (Poly YSZ)** : The substrate is poly crystalline and hence there is no in-plane alignment of the YBCO film with the substrate resulting in the formation of low angle grain boundaries. Since the film is poly crystalline any strain resulting from thermal expansion mismatch would be relieved via the formation of defects.

(iii) **YBCO / CeO_2 buffered R-plane Sapphire** : In this case, the lattice mismatch between YBCO and the CeO_2 buffer layer is better than 1% as in the case of YBCO / LaAlO3.
Hence structurally the films are nearly single crystalline with no grain boundaries. However, unlike in the case of YBCO / $LaAlO_3$ there is considerable mismatch between the thermal expansion coefficients of YBCO and Sapphire which is expected to result in stresses in the film during the film growth process .

2. Summary of the results in the normal state

a. Structural Analysis by X-ray Diffraction

We have done detailed structural analysis in these films using the 4-circle x-ray diffractometer facility at Univ. of Maryland in order to correlate the micro structural information with the results of our electrical noise measurements. The F scan analysis reveals good in-plane alignment in the case of YBCO/ $LaAlO_3$ as well as YBCO/ Sapphire while no in-plane alignment is observed in the case of YBCO / Poly YSZ as expected. Rocking angle analysis reveals a good degree of c-axis texturing in all the three cases. The rocking angle FWHM is ~0.3^o in the case of YBCO / $LaAlO_3$, 0.7^o in the case of YBCO / Sapphire and ~ 0.9^o in the case of YBCO /Poly YSZ.
Electrical Noise Measurements
The films were patterned into micro bridges for the noise measurements. Contact pads of Ag were thermally evaporated. The contacts were annealed at 500^oC in oxygen to obtain low contact resistances.
We measured the excess electrical noise in these films in the standard 4-probe geometry. The samples were biased with a DC current from a battery operated source. A large ballast resistance was connected in series with the sample to minimize current fluctuations. The sample voltage was capacitively filtered to eliminate the Dc component and transformer coupled to a low noise amplifier. The amplifier output was given to a dynamic signal analyzer to obtain the noise spectral density by Fourier transform .

b. Noise measurements in the normal state

The normal state noise power spectral density has a quadratic dependence on the bias current and $1/f^a$ (a = 1- 1.1) dependence on frequency which are characteristic of conductance fluctuations .
We have analyzed the noise power spectral density in the frame work of HoogeÕs empirical relation given by

$$S_V = g \; V_{DC}^2 / N_c \, f^a \qquad (1)$$

where N_c is the total concentration of charge carriers in the sample volume and g is a constant representing the strength of the noise sources. In fig. (1) we show this quantity as a function of temperature for the films on the three different substrates.
The most striking aspect is the enhancement in the normalized noise power in the films on poly YSZ by nearly 6 orders of magnitude as compared to the single crystalline films on LaAlO3. This clearly indicates that the grain boundaries when present are a dominant source of excess noise. The noise levels in the films on Sapphire are intermediate between the that of the films on $LaAlO_3$

and the films on poly YSZ. While the films on Sapphire are single crystalline, the enhancement of the noise level may be associated with the strain present in the films due to the mismatch of the thermal expansion coefficients. In addition to the three films we have also studied the normal state excess noise in YBCO film on $LaAlO_3$ which has been de-oxygenated there by decreasing T_c below 77 K . This film shows enhanced noise levels close to that of
YBCO / Poly YSZ. This result indicates that oxygen vacancy fluctuations could be a dominant source of noise has been indicated by some other recent studies[2,3] as well.
The results described above were presented at the 94 MRS Fall meeting at Boston. A more detailed paper on this work has been submitted to Applied Physics Letters and is currently under review. A copy of the abstract of the manuscript is attached.

c. Noise measurements in the Transition Range

We have also carried out the measurements of the excess noise in the superconducting transition range in the YBCO films on (100) $LaAlO_3$ and poly crystalline YSZ.
In Fig 2 we present the resistance and the noise power spectral density S_V as a function of temperature for YBCO / $LaAlO_3$. The temperature dependence of the noise power follows the resistance behavior and drops to zero below the superconducting transition as expected. The temperature dependence is similar at all bias currents. The bias current dependence is linear and the frequency dependence is 1/f characteristic of the conductance fluctuations as in the normal state.
In Fig. 3 we show similar data for the YBCO films on poly crystalline YSZ. The striking feature in this data is the non monotonic temperature dependence seen at all bias currents. The noise initially starts to drop at the onset of the superconducting transition but rises again at a lower temperature and exhibits a peak at a lower temperature. This behavior is unique to poly crystalline films and is not seen in any of our epitaxial films on lattice matched substrates.
In Fig.4 we present the bias current dependence of $S_V^{1/2}$ in the poly crystalline films at different temperatures. In the normal state at T=94K, $S_V^{1/2}$ shows the expected linear bias current dependence. As the temperature is lowered (T = 85K, 83K, 80K, 78K) we see an oscillatory component superposed on the linear rise. The oscillations become more pronounced at higher currents and lower temperatures`. In an attempt to understand the bias current dependence in relation to the critical currents we studied the temperature dependence of the critical current density of the same poly crystalline sample We find that the bias current range of the noise measurements presented in Fig.4 is well above the measured critical currents at all temperatures. Thus it is not straightforward to associate the observed oscillations of the noise with critical currents.
At present we do not have a clear idea of the origin of the anomalies we observe in the poly crystalline sample. However, it is clear that these are related to the presence of the grain boundaries since such anomalies are not seen in epitaxial films. We are currently working on understanding these results in the frame work of the following qualitative picture. The superconducting path in the poly crystalline film contains grain boundary weak links with a distribution of critical current densities. Earlier work [4] on the noise associated with Josephson weak links has shown that the noise arises basically due to temperature fluctuations resulting in fluctuations of the junction critical currents. The critical current fluctuations in turn result in voltage fluctuations since the junction voltage is a function of the critical current. In the case of a

single junction it can be shown that this would result in a bias current dependence of the noise which has peak when the bias current is equal to the junction critical current. However in the present case since the transport path consists of a series of junctions with different critical currents the measured transport critical current would represent the junction with the lowest critical current. Noise on the other hand will have contributions from all the junctions. The contribution from any one junction would peak when the bias current is equal to the critical current . With a distribution of critical currents that peak at several values corresponding to the distribution of grain boundary angles it is conceivable the that the bias current dependence of the noise power would show oscillations as seen in our experiment. We are currently working on a quantitative model based on this picture.

It may be mentioned here that the anomalous behavior discussed above in the poly crystalline samples occurs only in the transition range. In the normal state the bias current dependence and temperature dependence follow the behavior of conductance fluctuations. frequency dependence of the transition range noise in the poly crystalline samples is of the form S_V a $1/f^a$ with a ~ 1-1.1 as in the normal state. We will present the early results of noise measurment in the bolometric region at the Fall '95 MRS meeting (see abstract attached)

d. Effect of Co and Ni doping in $YBa_2Cu_3O_7$ thin films.

In collaboration with CSR at Univ. of Maryland, we have studied magnetic field induced resistivity broadening and critical current densities in $YBa_2Cu_3O_7$ thin films in which the copper sites are partially substituted by dopants such as Co and Ni. Copper substitutes for the chain copper sites while Ni substitutes for the chain sites. One of the main goals of our present study is to distinguish between the effects of the two types of substitutions. In Fig.5, we show the magnetic field induced broadening of the resistive transitions in the undoped YBCO film as compared to the co doped and Ni doped YBCO films. It is obvious that chain doping by co significantly enhances the field induced broadening. In Fig. 6 we plot the transition width as function of the magnetic field to make this effect clearer. it is obvious that the plane site substitution by Ni does not remarkably change the nature of the field induced broadening unlike the chain site substitution. These results are in agreement with several other experiments [5] which suggest that the chain dopants reduce the inter layer coupling and increase the anisotropy in the YBCO system. The enhanced field induced broadening is a sign of reduced inter layer coupling and increased anisotropy as in systems like Bi:2212 [6].

We have also studied the anisotropic field dependence of the critical currents $J_c(B,T,Q)$ in the Co and Ni doped systems in comparison with undoped YBCO where Q represents the angle between the B field direction and the c-axis. Previous studies have shown that the form of the angular dependence is qualitatively different for the highly anisotropic systems such as Bi:2212 from the behavior seen in YBCO which is less anisotropic. In Fig 7 (a), 7(b) and 7(c) we show we show the behavior of $J_c(B,T,Q)$ in undoped YBCO, Ni doped YBCO and Co doped YBCO. We see that in the case of the undoped YBCO and Ni doped YBCO, $J_c(B,T,Q)$ fits well to the Tachiki and Takahashi model [7]. In the case of Co doped YBCO, this model does not fit the data while the Kes model [8] which has been found to hold in the more anisotropic systems like Bi:2212 gives a good fit. The $J_c(B,T,Q)$ behavior is thus consistent with resistivity broadening data.

Some of the results discussed here were presented at the March 95 meeting of the APS at San Jose California (see abstracts attached). A manuscript based on this work is currently under

preparation.

IV. Academic support

As reported previously, the dissemination among the students and faculty of the UDC community of the theory and application of High Tc superconductivity was primarily achieved through the offering of a course on Applied Superconductivity as part of the technical elective offerings at the Department of Engineering and Technology at UDC. However, this year additional means of involving students in basic research in the characterization of HTSC materials were sought. One such means is the sponsoring of laboratory fellows who under the College of Professional Studies Laboratory Fellowship Program will be allowed to participate in semester long assignments at the Pilot Applied Superconductivity Laboratory. At present, the academic support component of the project includes the following:

- Offering of a course on Applied Superconductivity
  (Textbooks: Introduction to Superconductivity, A. C. Rose-Innes
  Foundations of Applied Superconductivity, Orlando & Delin);

- Sponsoring of Laboratory Fellows
  (see attachment for lab fellow presentation in Fall '94);

- Invited speakers on selected topics on High Tc superconductivity & its applications One such seminar was organized on Monday January 31, 1995 on the topic of "Bolometric Properties and Optical Response of HTSC";

- Participation of senior students of the program of Electrical Engineering in specific projects to be conducted in the pilot laboratory. In fact, the current research assistant, Ms. A. Goyal has worked at the laboratory on a project that fulfilled her Senior Project requirement in the program of Electrical Engineering. She has set up a computer controlled data aquisition system for measuring the optical response of YBCO samples.

V. Proposed research plan for future work

1. Effect of heavy ion induced columnar defects on the optical response and noise in YBCO
This is a problem of particular relevance to space applications since the devices are subject to damaging effects of radiations in space. There has been studies of the effects of ionizing radiation on the transition edge noise [9]. We plan to undertake effects of heavy ion irradiations which produce columnar defects in the normal state and transition edge noise in high T_c materials. We will also study the effects of such irradiation on the resistive transitions and the bolometric optical response to identify damage thresholds which could affect detector performances.

2. Effects of oxygen stoichiometry variations on noise and optical response in YBCO
A problem closely related to possible environmental damage is the effect of changes in the oxygen

content on detector performances. Local heating due to impinging radiation can cause significant loss of oxygen . Since the superconducting properties of YBCO are very sensitive to oxygen content , the oxygen loss may severely degrade detector performances, We will undertake a study of the effects of controlled oxygen content variation on the optical response and noise in YBCO thin films.

3. Studies of optical response and electrical noise in the doped YBCO films

Doped YBCO films in which the copper sites have been partially substituted with different dopants may find potential detector applications where an operating temperature lower than 90 K (T_c of undoped YBCO) is desired. The T_c of the doped systems can be controlled by adjusting the dopant concentration. We wil! study the optical response of systems which different dopants to identify those that are suitable for potential detector applications.

Studies of the electrical noise in the doped films is of relevance both for the applications mentioned above as well as for understanding the effect of doping on the defect dynamics such as motion of the oxygen vacancies. We plan to undertake detailed studies of electrical noise in the doped YBCO films both in the normal state and in the transition range.

4. Microstructure dependence of the noise in the transition range

In continuation with the on going study presented in this report we plan to conduct detailed studies of the transition edge noise in YBCO films on substrates such as Sapphire and Si which are used for bolometric applications.

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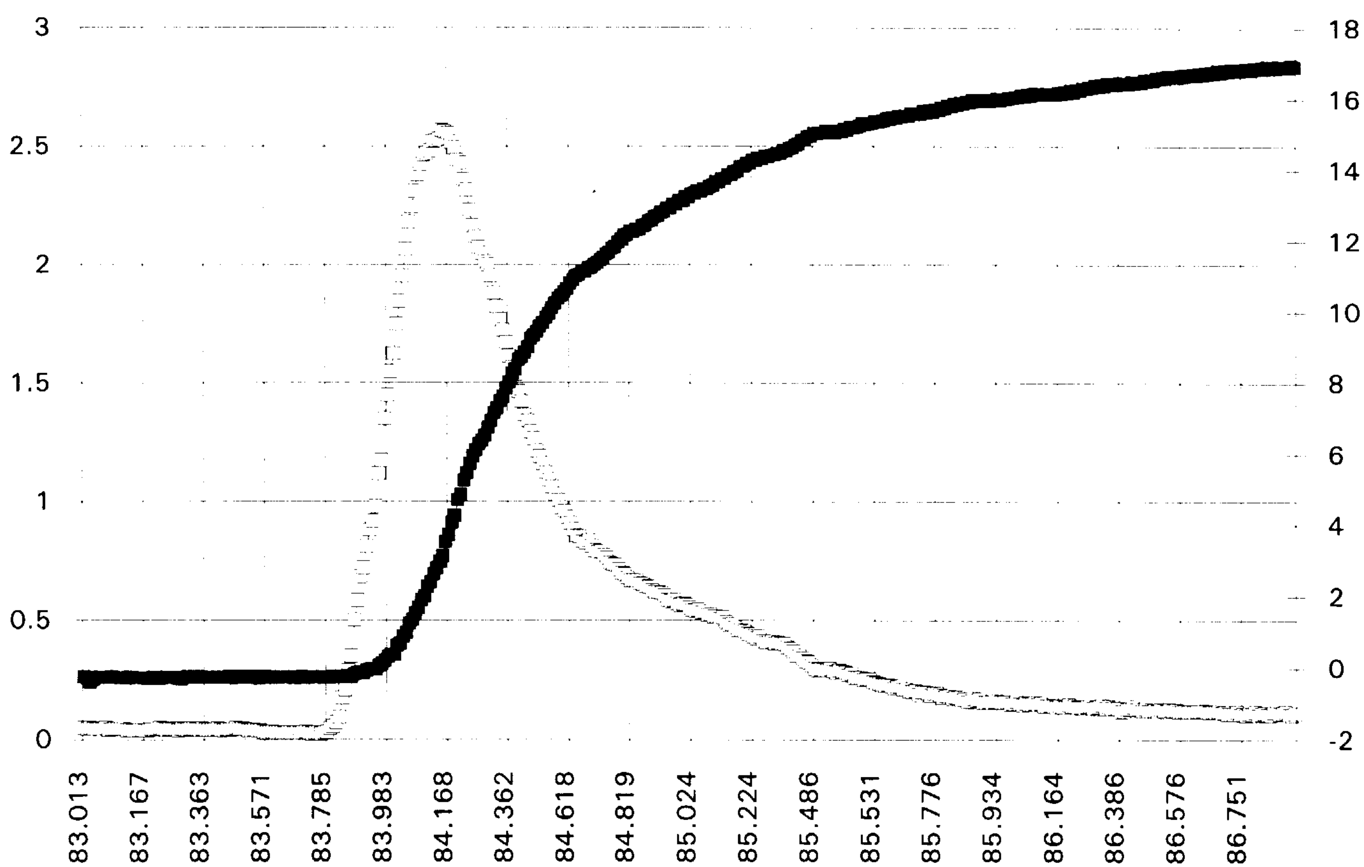
ATTACHMENTS

OPTICAL RESPONSE & RESISTANCE OF YBCO SAMPLE



Abstract Submitted
for the 1995 March Meeting of the
American Physical Society
20-24 March, 1995

Suggested Session Title:
Electrical and magneto transport in superconducting thin films.

March Sorting
Category: *32(C)*

ELECTRICAL AND MAGNETO-TRANSPORT IN THE NORMAL STATE AND SUPERCONDUCTING STATE OF EPITAXIAL THIN FILMS OF $YBa_2Cu_{3-x}M_xO_{7-\delta}$.

M. Rajeswari,* D.D. Choughule,+ S.B.Ogale,+ P. Warburton, E.A.Wood, S. Lakeou,* and T. Venkatesan, Department of Physics, University of Maryland, College Park, MD 20742,
+ Department of Physics, University of Poona, Pune, India,
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We will present our studies of the normal state and superconducting transport properties of epitaxial thin films of $YBa_2Cu_{3-x}M_xO_{7-\delta}$ where M represents Cu(1) site dopants (eg. Co, Fe, Ga) as well as Cu(2) site dopants (eg. Ni, Zn, Mn). Previous studies , based largely on bulk samples have shown that doping the Cu(2) sites results in enhanced Tc suppression while Cu(1) site doping is characterized by broadening of the transition. We will discuss electrical resistivity, Hall coefficients, critical current densities and electrical noise characteristics in the context of examining the effects of dopants on the normal state transport, suppression of superconducting transition temperatures as well as possible effects on interlayer coupling in the superconducting state.
Partially supported by NASA grant G-5 2348 at Univ. of DC.

Prefer Standard Session

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APS membership # M60012136

Abstract Submitted
for the 1995 March Meeting of the
American Physical Society
20-24 March, 1995

Suggested Session Title:
Superconducting materials - Films.

March Sorting
Category: *30(a)*

DOPANT INCORPORATION IN EPITAXIAL THIN FILMS OF $YBa_2Cu_{3-x}M_xO_{7-\delta}$ by pulsed laser deposition.
D.D. Choughule,* M. Rajeswari,+ S.B.Ogale,* L. Senapati**, R.P. Sharma, I. Takeuchi, S. Lakeou+ and T. Venkatesan, Department of Physics, University of Maryland, College Park MD 20742, * Department of Physics, University of Poona, Pune, India, +Department of Engineering and Technology, University of District of Columbia, Washington DC -20008, **Nuclear Science Center, New Delhi, India.

We have studied the systematics of the dopant incorporation during the pulsed laser deposition of epitaxial thin films of $YBa_2Cu_{3-x} M_x O_{7-\delta}$ where M represents Cu(1) site dopants (eg. Co, Fe, Ga) as well as Cu(2) site dopants (eg. Ni, Zn, Mn).. We find that the complete incorporation of dopants in several cases is not achieved under deposition conditions which are optimal for the preparation of high quality $YBa_2Cu_{3-x}O_{7-\delta}$ films. Further, the sensisitvity to deposition conditions is dopant- specific. We will discuss the effect of the deposition parameters on the dopant incorporation as revealed by RBS, X-ray, AFM and electrical transport measurements of films prepared under different conditions.
Partially supported by NASA grant G-5 2348 at Univ. of DC.

Prefer Standard Session

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Pune,
India.

Membership # m60013732

Submitted To Symposium___F___

ELECTRICAL NOISE IN THE SUPERCONDUCTING TRANSITION RANGE OF $YBa_2Cu_3O_7$ THIN FILMS. M. Rajeswari, A. Goyal, A. Kidane and S. Lakeou, Department of Engineering and Technology, University of the District of Columbia, 4200 Connecticut Ave. Washington DC 20008, E. A. Wood and T. Venkatesan, Center for Superconductivity Research, University of Maryland, College Park MD 20742, K.S. Harshavardhan and Z. Shi, Neocera Inc., 10000 Virginia Manor Road, Suite 300, Beltsville, Maryland 20705 - 4215.

We have measured low frequency excess electrical noise with 1/f-like frequency dependence in the superconducting transition range of $YBa_2Cu_3O_7$ thin films. We find that the bias current dependence and temperature dependence of the noise in the films on poly crystalline substrates is characteristically different from those of the epitaxial films on lattice matched substrates. The epitaxial films exhibit dependences characteristic of conductance fluctuations. In the poly crystalline films however we see anomalies and non monotonic behavior of the noise as a function of temperature and bias current. Possible role of grain boundaries as the source of such anomalies will be discussed.

* Partially supported by NASA grant NAG5-2348 at Univ.of DC

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ABSTRACT SUBMITTED TO THE FALL '95
MRS Meeting

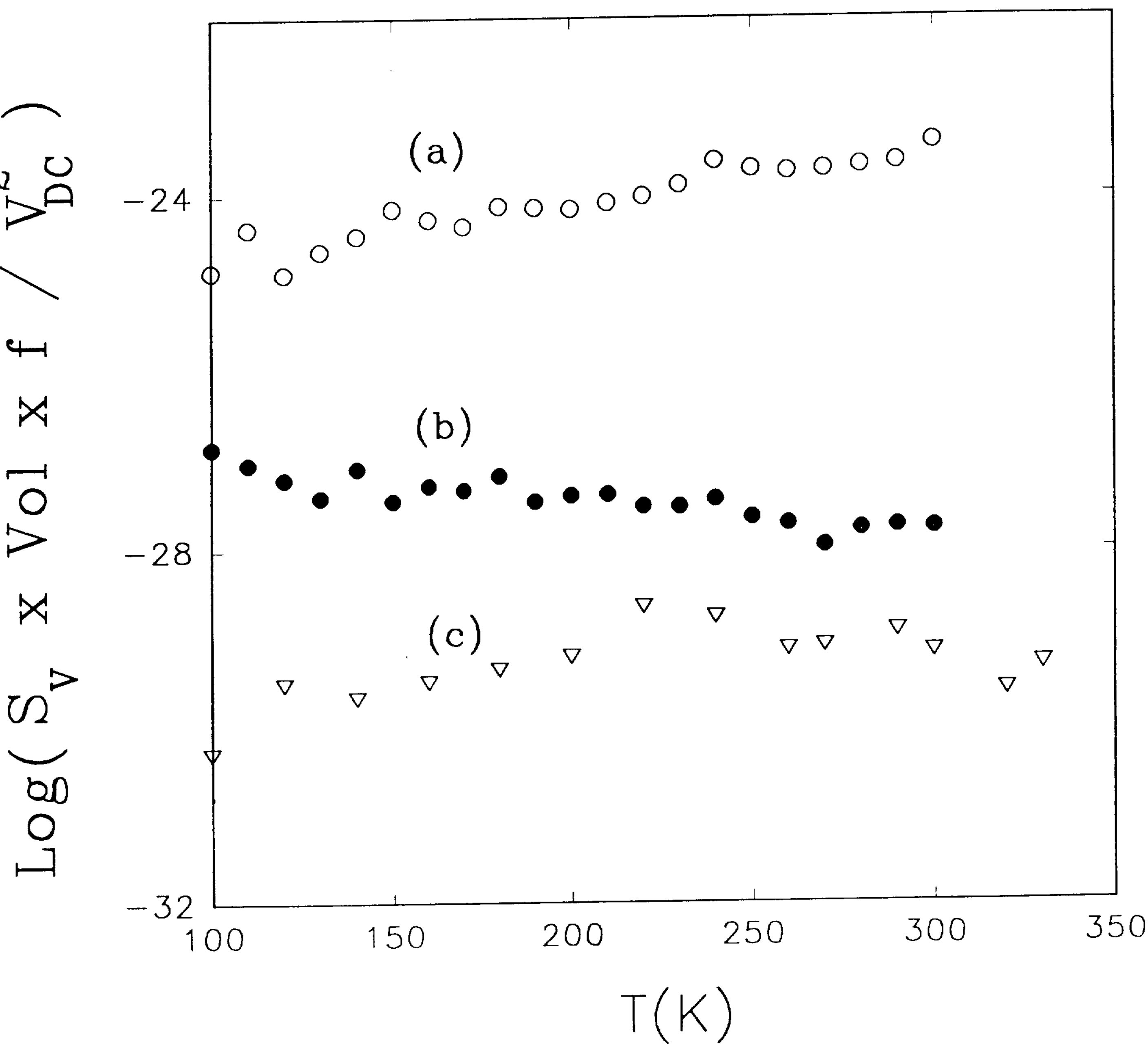


Fig.1

Comparison of the normalized noise power spectral density as a function of temperature for the films on different substrates.

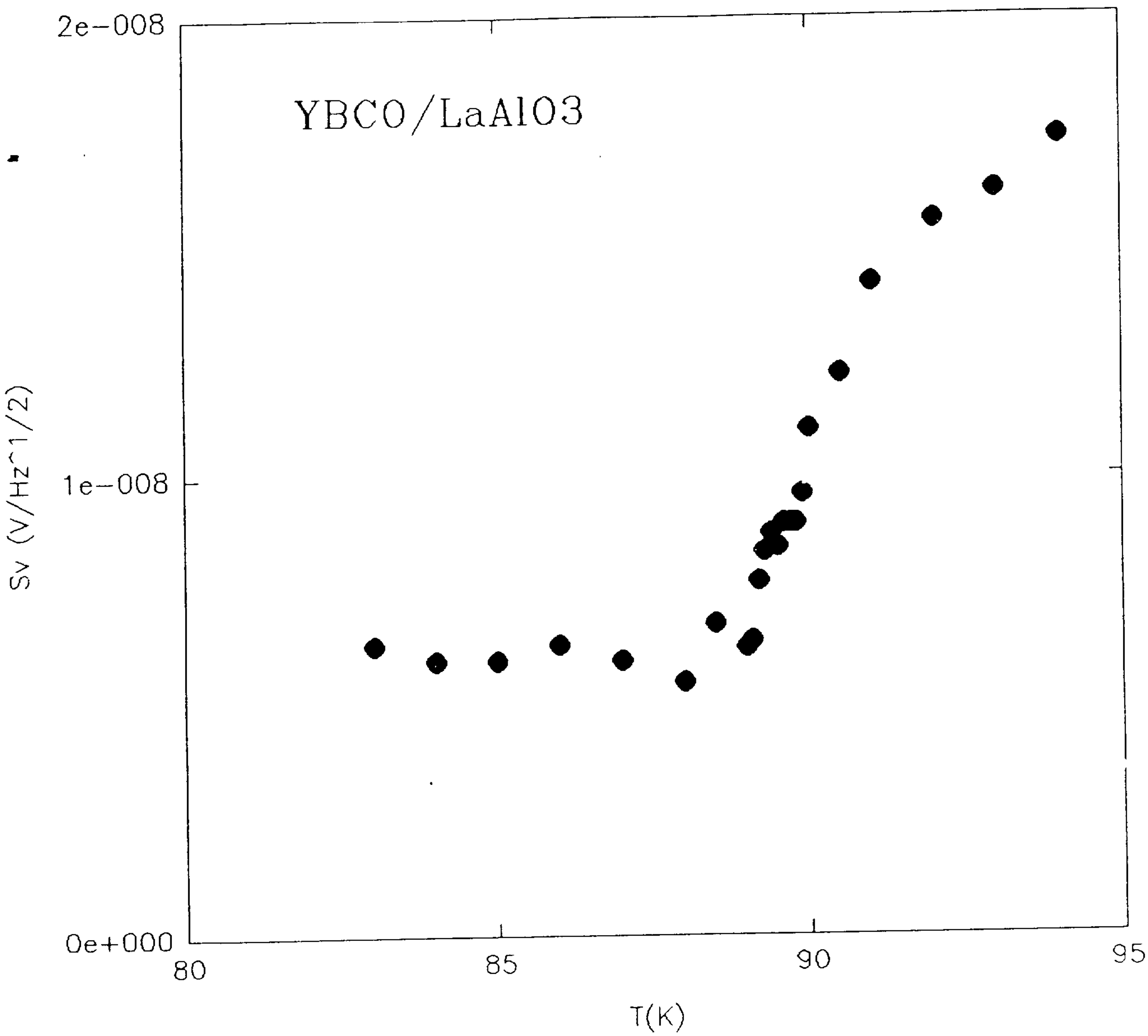


Fig.2

Square root of the noise power spectral density ($S_v^{1/2}$) as a function of temperature at the superconducting transition for YBCO / $LaAlO_3$.

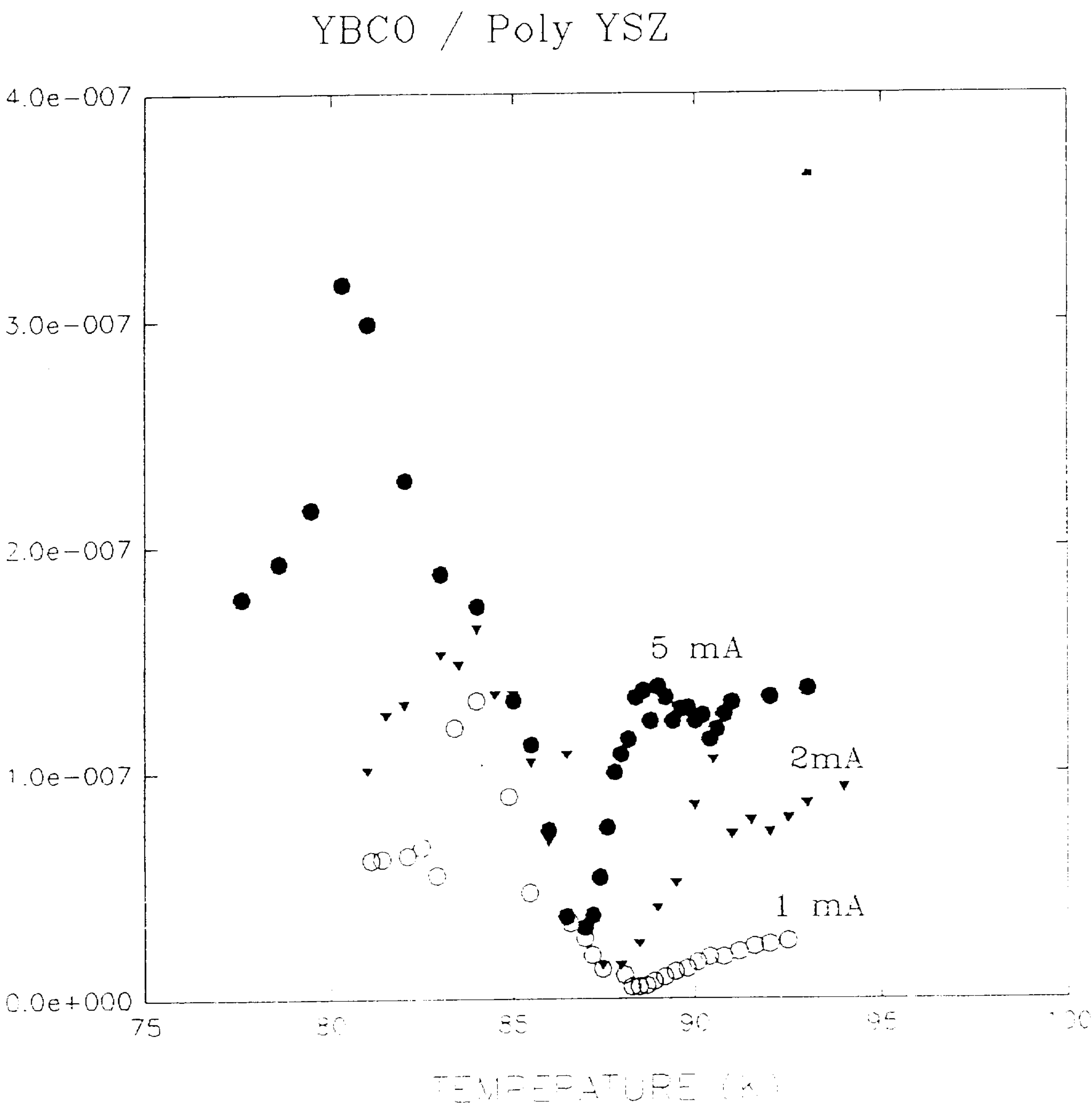


Fig.3

Square root of the noise power spectral density $(S_V^{1/2})$ as a function of temperature at the superconducting transition for YBCO / Poly YSZ for different bias currents.

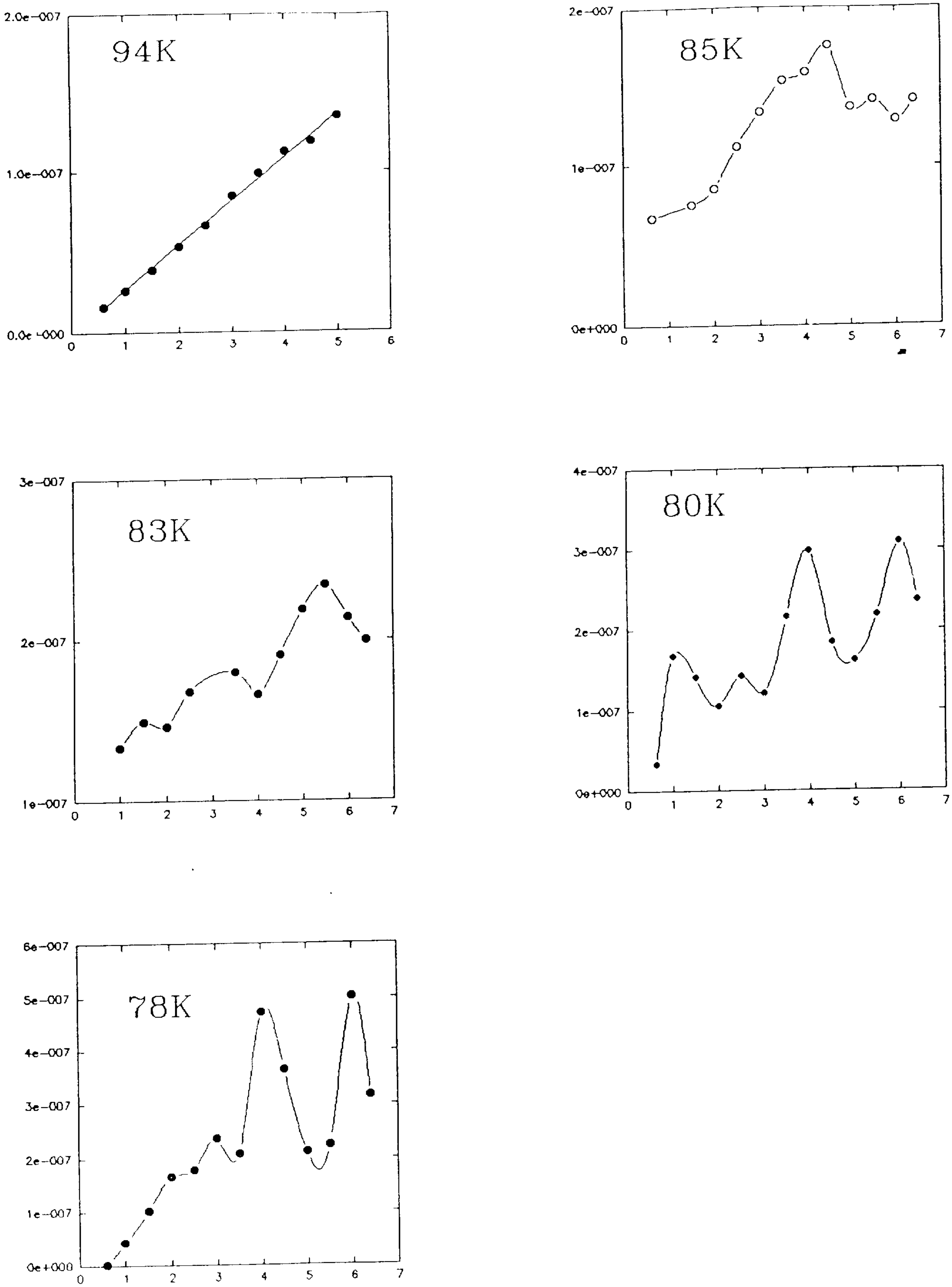


Fig.4

Bias current depedence of $S_V^{1/2}$ at different temperatures for YBCO / Poly YSZ.

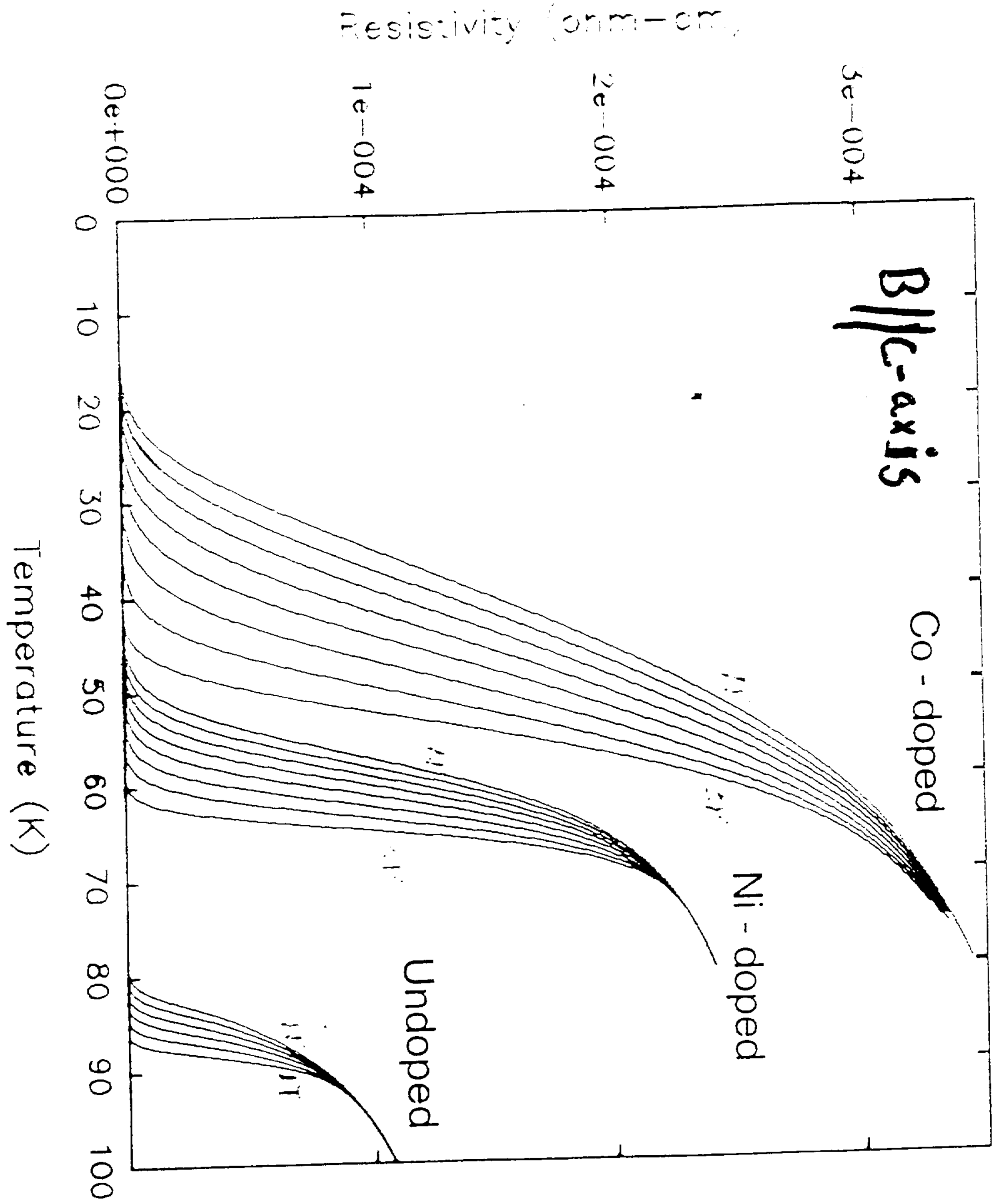


Fig.5

Field induced broadening of the resistive transition for undoped YBCO, Ni doped YBCO and Co doped YBCO.

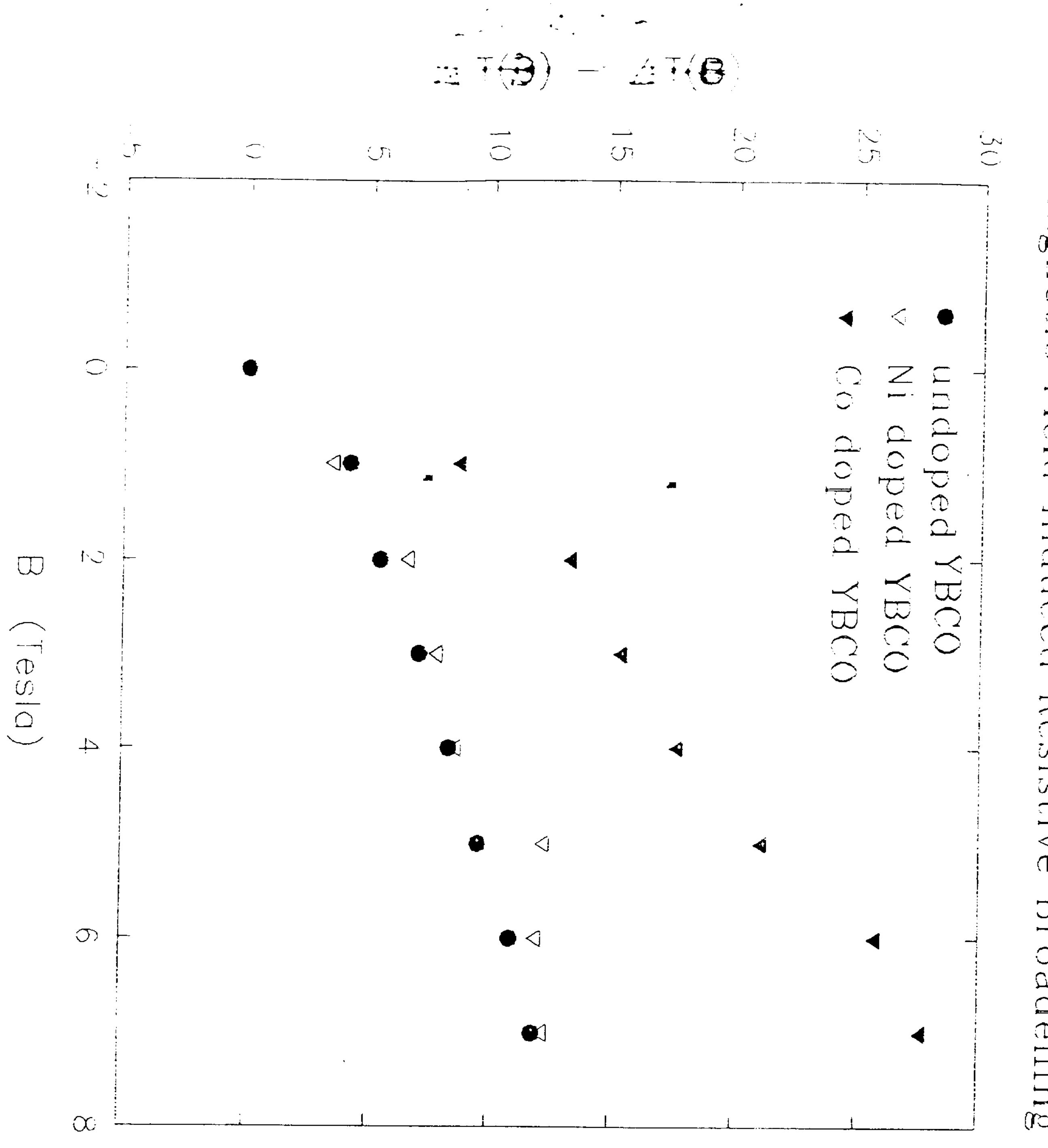


Fig.6

Increase in the transition width as a function of magnetic field for undoped YBCO, Ni doped YBCO and Co doped YBCO.

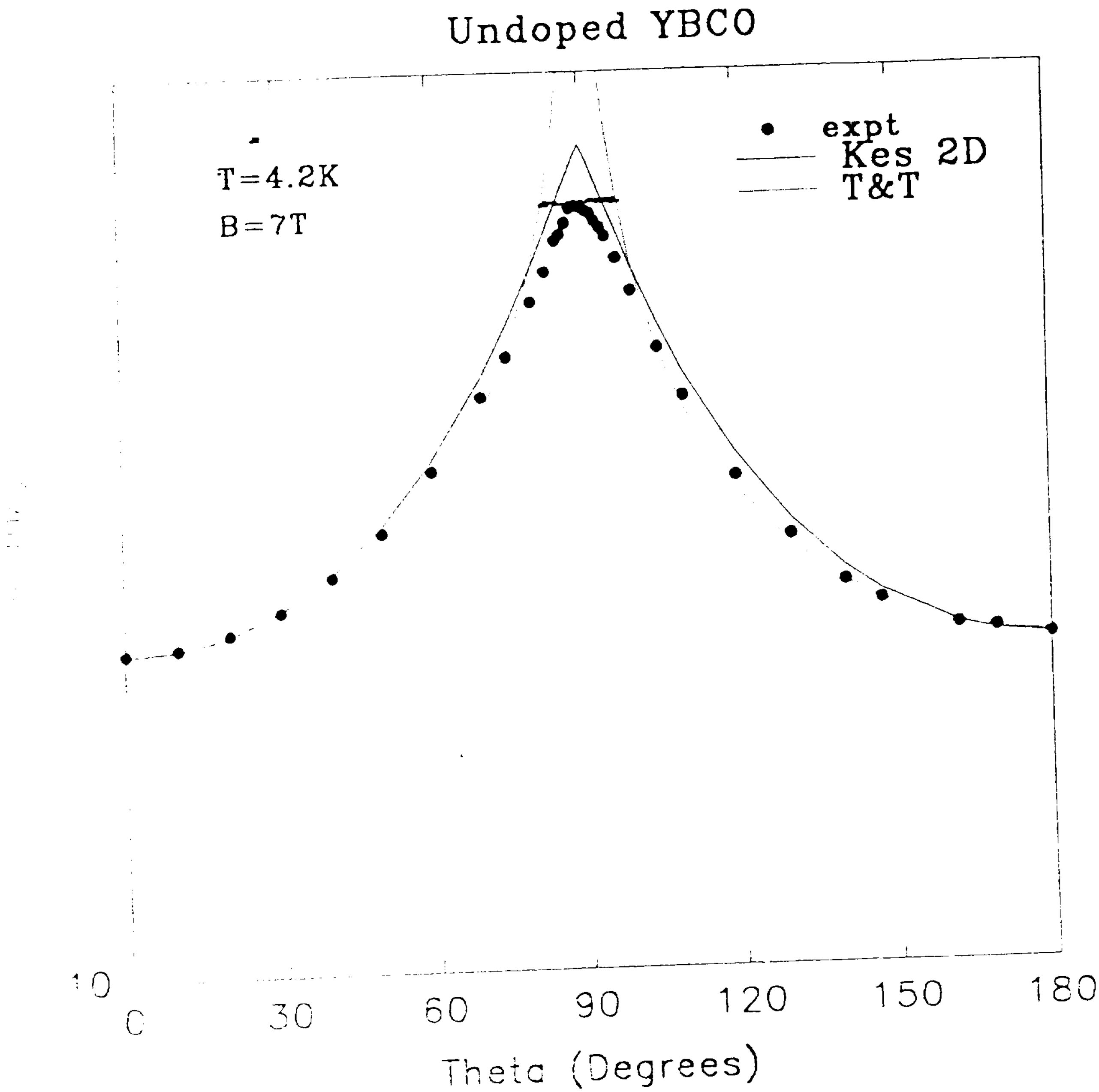


Fig.7

Angular dependence of the critical current density $J_c(B,T,\theta)$ and the model calculations for undoped YBCO

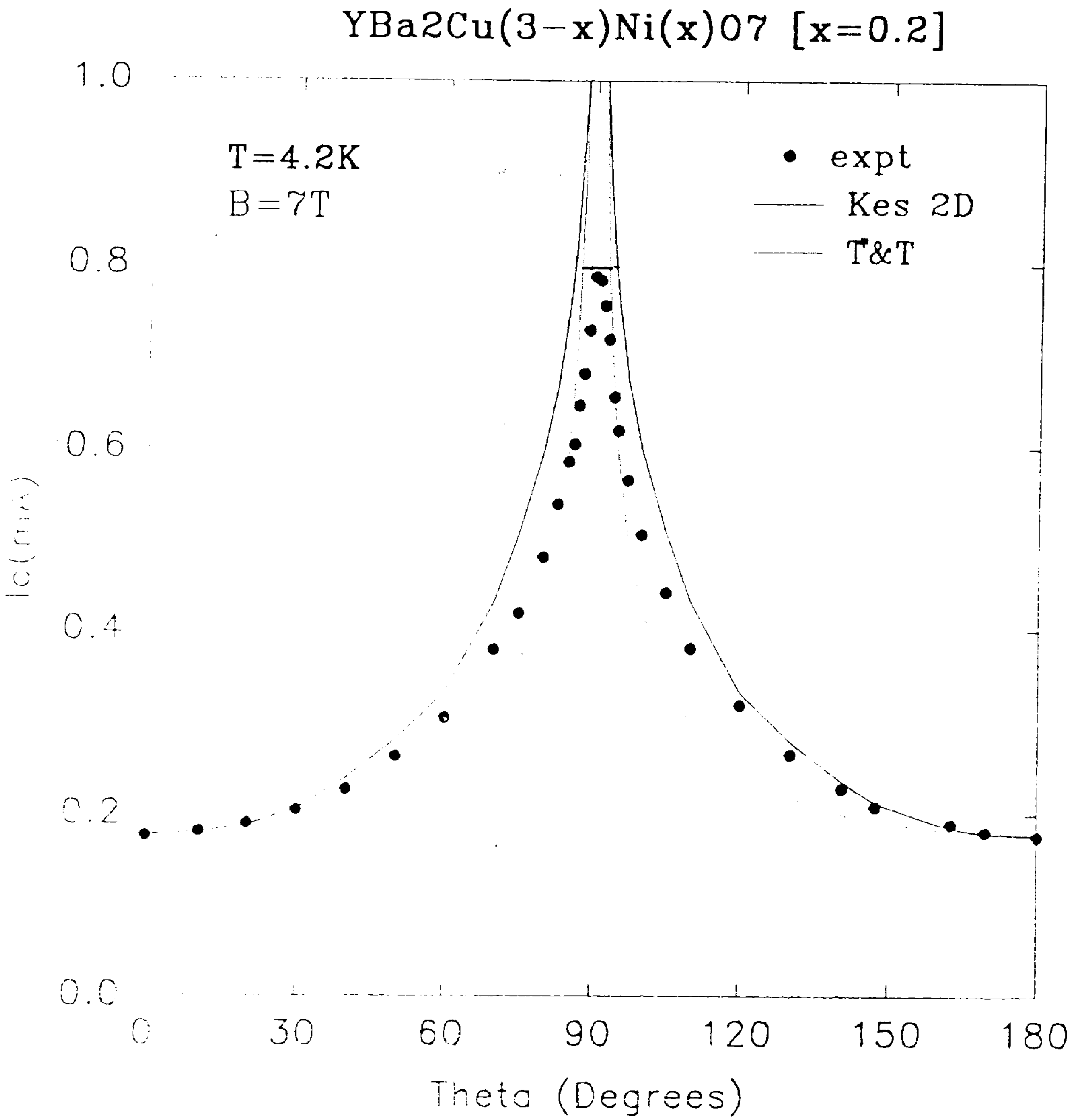


Fig.7a

Angular dependence of the critical current density $J_c(B,T,\theta)$ and the model calculations for Ni doped YBCO

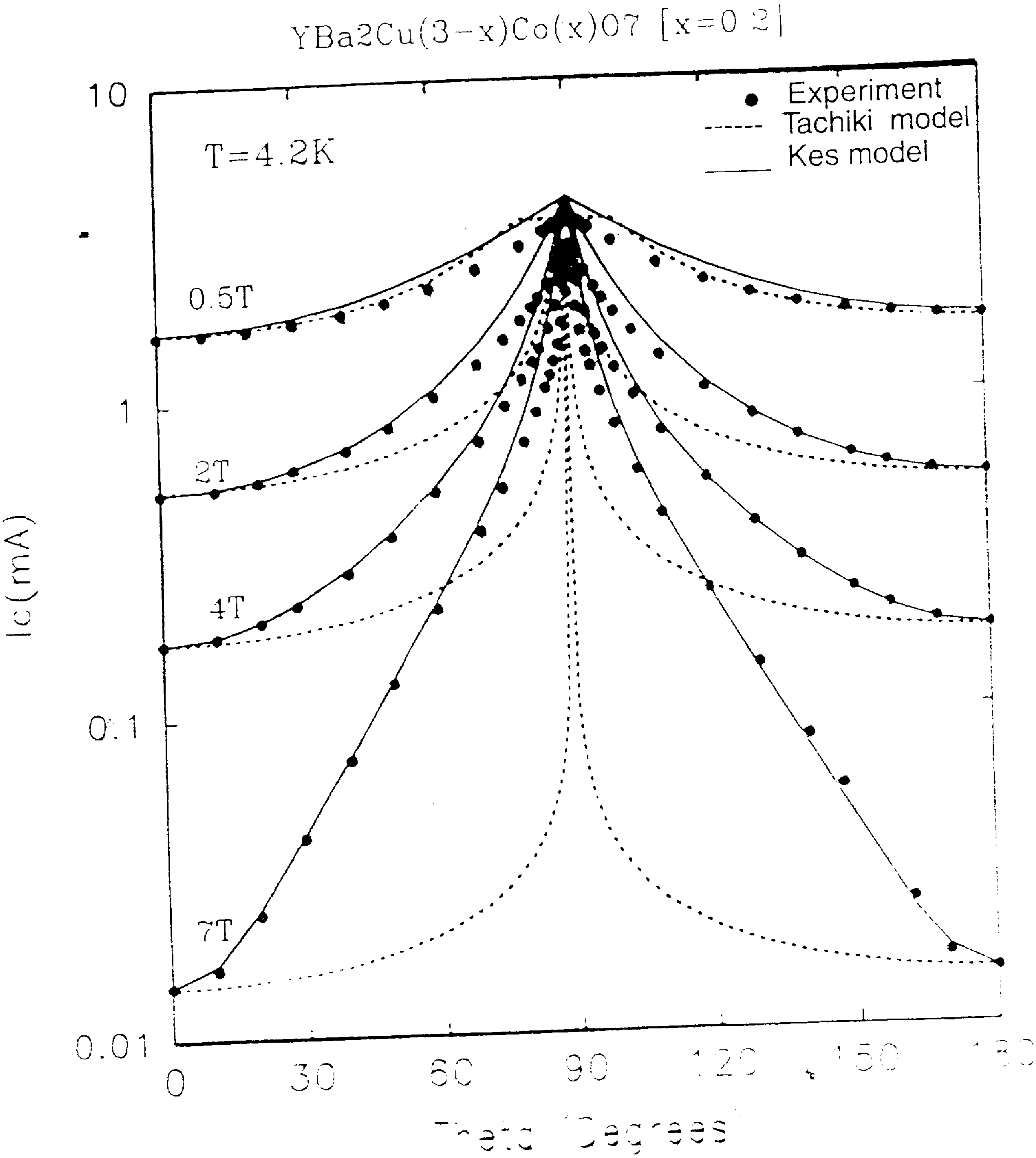


Fig.7b

Angular dependence of the critical current density $J_c(B,T,\theta)$ and the model calculations for Co doped YBCO.

UNIVERSITY OF THE DISTRICT OF COLUMBIA

COLLEGE OF PROFESSIONAL STUDIES

Presents the

FALL 1994

LABORATORY FELLOWS

SEMINAR

Wednesday, December 14, 1994
10:00 a.m. to 12:00 Noon
Building 52 - Faculty Lounge

Tilden J. LeMelle, President
Julius F. Nimmons, Jr., Provost/VPAA
Philip L. Brach, Dean

Presentations

EVALUATION OF THE CRITICAL CURRENT J_c IN YBCO SUPER CONDUCTORS

Labaratory Fellow - Andryas Kidane

Mentor - Dr. Samuel Lakeou

FINANCIAL MANAGEMENT OF WATER AND SEWER IN BALTIMORE

Laboratory Fellow - Teresina Kiragu

Mentor - Dr. Yearn Choi

RE: APPLICATION OF *MAPLE* SOFTWARE TO MAGNETOSTATIC PROBLEMS

Laboratory Fellow - Medoune Seye

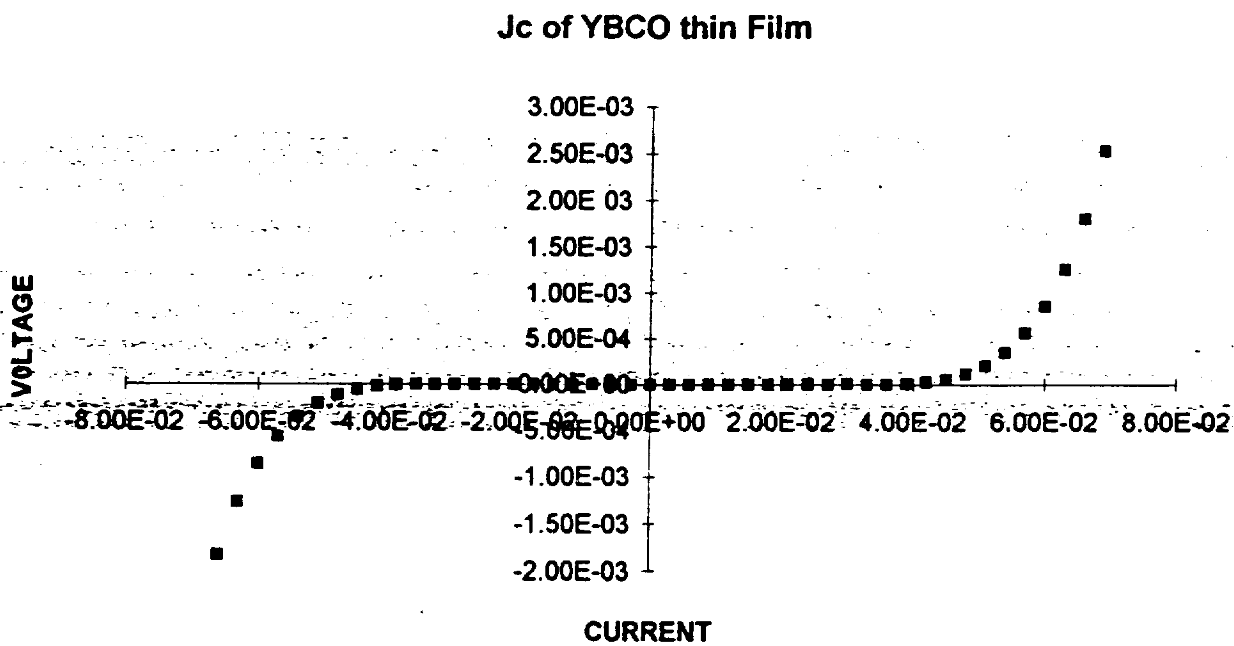
Mentor - Dr. Bing Liu

CONDUCTING A SEARCH THROUGH UDC AND ITS CONSORTIUM LIBRARIES

Laboratory Fellow - John Blunt

Mentor - Dr. Carlyle Hughes

Sample Jc Measurement Results from the work of the Lab Fellow



Temperature(K)	Critical Current (mA)	Critical Current density(A/m^2)
90	1	1.33×10^8
89	10	1.33×10^9
85	18	2.39×10^9
82	29	3.86×10^9
80	39	5.19×10^9
79	60	7.98×10^9
77	72	9.58×10^9
76	75	9.98×10^9

Influence of Substrate on the Excess Electrical Noise in the Normal State of $YBa_2Cu_3O_{7-\delta}$ Thin Films.

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College Park, MD 20742

K.S. Harshavardhan and Z.Shi
Neocera Inc.,
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Abstract

We present our studies of the low frequency excess electrical noise in $YBa_2Cu_3O_{7-\delta}$ thin films in the normal state. We have studied films with varying microstructure deposited on different substrates. The frequency dependence and bias current dependence of the noise power spectral density agree with the behavior expected for noise due to conductance fluctuations. Comparison between films on different substrates shows that the presence of defects such as grain boundaries in the film correlate with significantly enhanced noise levels . The noise levels in our good quality epitaxial films are several orders of magnitude lower than the anomalously large noise magnitudes reported for $YBa_2Cu_3O_{7-\delta}$ in most of the earlier studies.

Submitted to APL, May 3, 95.