Superconducting transition in polycrystalline $YBa_2Cu_3O_{7-x}$: diving into the meaning of T_c and the excess of electrical conductivity in the normal state

Author: Anna Planella Vidal
*Facultat de Física, Universitat de Barcelona, Diagonal 645, 08028 Barcelona, Spain.**

Advisor: Antoni García-Santiago

Abstract: *Superconductivity is the property of certain materials to conduct direct current electricity without energy loss when they are cooled below a critical temperature T_c. The transition at this temperature is driven by thermal fluctuations, so deciding the exact value of T_c is not a trivial matter. In this work we show different methods that have been used to estimate this temperature and deepen our understanding of the excess conductivity due to fluctuations. We can detect the mean-field, fluctuations, and full critical regions as they change with temperature.*

I. INTRODUCTION

Superconductors are those materials which present a particular set of electric and magnetic properties at low temperatures, mainly the rapid decrease of their electrical resistance down to almost negligible values at a certain critical temperature. This behaviour has been intensely studied ever since it was first coined, and there are still advances that further our understanding of these metals to this day.[1]

Superconductivity by itself is a phase of matter and, therefore, it is mostly studied and observed with electric measurements that show the phase transition. Adding the variable of a magnetic field to these measurements can also give us important information, such as how the critical temperature shifts value.

Depending on their magnetic behaviour during the transition between the normal and superconducting state, superconductors can be categorized into two groups: type-I or type-II. Type-I superconductors can enter an intermediate state when subjected to a critical magnetic field, in which both the superconductor and normal states coexist in different regions of the material. It must be specified that the appearance of this state depends on the shape of the body and its demagnetizing factor. This is the category for most pure metal superconductors.

Here, however, we will focus on type-II superconductors, mostly alloys and impure metals, and specifically $YBa_2Cu_3O_{7-x}$. These materials enter the mixed state instead, splitting into a fine-scale mixture of the superconducting and normal regions with its boundaries parallel to the applied field.[2] Being energetically favourable, this state is an intrinsic feature of the type-II superconductors. This type also encompasses high-temperature superconductors, which transition at much higher temperatures than the other type.[3] Such is the material we will be analysing in this work.

The superconductor material will revert into the normal state if it is driven above its critical temperature, critical magnetic field, or critical current. This is a true phase transition that can be characterized by critical exponents, as will be seen later.

The actual phenomenon of superconductivity is understood through the free electrons in the material, or "superelectrons". One of the main theories in superconductivity is that of Ginzburg-Landau (GL). The GL theory introduces a wave-function for the superconducting electrons and uses it as an order parameter in Landau's theory of second-order phase transitions.[4] This wave-function achieves a Schrödinger-like equation once derived its differential equation, which makes it possible to treat in ways unconceived at the time (1950).

Another basis of this study are the thermodynamic fluctuations.[4] The presence of thermal energy in any material gives a finite probability that it will fluctuate into other states besides the lowest energy. This means that a finite resistance can appear even in the superconducting state and vice versa, that some superconductivity can remain above the critical temperature, giving rise to the so-called excess conductivity, which will be one of the main subjects of study in this work.

The main motivation behind this study is to gain a deeper understanding on the properties of $YBa_2Cu_3O_{7-x}$. This interest stems from my internship last summer in the University of Girona, where I joined the Research Group in Materials and Thermodynamics (GRMT) in their project about thermic growth of superconductor films $REBa_2Cu_3O_{7-x}$ (RE: rare earth). I was able to participate and watch the creation of such films from the binary solutions and thought it convenient to take this as an opportunity to continue the investigation process, doing the required experimentation to determine some of the properties of this material.

In the Laboratory of Modern Physics at the University of Barcelona there is a set-up that was already in use to study the superconducting transition of $YBa_2Cu_3O_{7-x}$. Therefore, it seemed appropriate to make use of that equipment to make our own experimentation and analysis, which consist in studying the shape of the drop of resistance with temperature and determine the critical temperature of the material according to different criteria. Afterwards, we will discuss

* Electronic address: annaplanella@yahoo.es

the validity of all values obtained and proceed with the study of the excess of conductivity during the transition.

This work will consist of the following parts: a brief explanation of the experimental set-up (section II) to set the foundation of our study, the results and discussion (section III) of both the critical temperature and the excess of conductivity and, lastly, the conclusions (section IV) and acknowledgments.

II. EXPERIMENTAL

What follows is a brief explanation of the experiment to contextualize the main body of this study.

The sample we are working with is a solid square pellet of $YBa_2Cu_3O_{7-x}$ whose oxygen content is currently unknown. Whichever used to be in the past, the time it has been on use plus different maintenance of the hardware that caused it to be outside the equipment have affected it. This only implies that the critical temperature of this sample will have changed slightly over time.

The main piece of equipment is a cryostat, which allows us to cool down the sample with liquid nitrogen in a vacuum chamber. Opening and closing a valve, we can control the nitrogen flow and, therefore, the cooling rate. However, the precision of this valve is rather low, and measures must be taken quickly, if possible, since closing the valve can cause the risk of warming the sample again. The temperature of the sample is known feeding a platinum resistance with a current of 1 mA and measuring its voltage drop with a *Hewlett Packard 3435A* voltmeter (with a resolution of 0.01 mV, or 0.03 K). [5] This resistance has a linear relation with temperature and will be located inside the cryostat, close to the sample.

We measure the voltage drop in the sample, which at a fixed intensity of 10 mA is practically equivalent to measuring its resistance. This is done using the 4-point probe method, selected specifically to avoid the most electrical noise and parasite resistance during the measurement by the contacts and other elements of the set-up. Since we plan to reach very low levels of resistance, this is strictly necessary.

No configuration is perfect though, and some voltage drop will be added due to the thermoelectric effect. This voltage drop is independent of the way of the current, unlike the voltage we plan to record. Therefore, by switching the sign of the current between two subsequent data records and proceeding with the following subtraction,

$$V_{i'} = \frac{V_i - V_{i-1}}{2} \tag{1}$$

we get rid of the non-desired voltage drop. This voltage is measured with a *Keithley 2000* microvoltmeter (with a resolution of 0.0001 mV).

Using the software provided by [5], it is possible to quickly record the voltage drop and temperature of the sample at any given time during the procedure. Therefore, what was done was take data of these two magnitudes from ambient temperature to 84 K, in varying intervals (from 1.00 K at room temperature down to 0.01 K below 86 K), to suit the shape and precision necessary.

III. RESULTS AND DISCUSSION

The current in a conductor is carried by the conduction electrons, which are scattered by the thermal vibrations and impurities of the material. Such is the origin of electrical resistance. The fact that superconductors experience an elimination of resistance is lightly explained as some electrons becoming *superelectrons*, which cannot be scattered, and the fraction of which keeps increasing as temperature lowers.[2]

The Bardeen–Cooper–Schrieffer (BCS) theory is the most common microscopic explanation for the superelectrons. The idea is that an electron polarizes the medium by attracting the positive ions, which in turn attract a second electron. Since this interaction, seemingly between the electrons, is considered attractive, their energy is decreased.[4]

This theory, however, does not apply when considering inhomogeneous spaces, as is the mixed state of type II superconductors, for example. For these cases, we use the macroscopic Ginzburg-Landau (GL) theory, which is valid at temperatures near T_c and smooth spatial variations.

The GL theory introduces a pseudowavefunction $\psi(\vec{r})$ as a complex order parameter, where $|\psi(\vec{r})|^2 = n_s(\vec{r})$ represents the local density of superconducting electrons. We start by postulating the free-energy density, [4]

$$f = \left(f_{n0}(0) - \frac{1}{2}\gamma T^2 + \frac{h^2}{8\pi}\right) + \alpha|\psi|^2 + \frac{\beta}{2}|\psi|^4 + \frac{1}{2m^*}\left|\left(\frac{\hbar}{i}\nabla - \frac{e^*}{c}\vec{A}\right)\psi\right|^2 \tag{2}$$

where $\psi = 0$ gives us the free energy of the normal state. Minimizing this energy, the volume integral of Eq.(2), when fields, currents or gradients are imposed gives us the GL differential equations:

$$\alpha\psi + \beta|\psi|^2\psi + \frac{1}{2m^*}\left(\frac{\hbar}{i}\nabla - \frac{e^*}{c}\vec{A}\right)^2\psi = 0, \tag{3}$$

$$\vec{J} = \frac{e^*}{m^*}|\psi|^2\left(\hbar\nabla\varphi - \frac{e^*}{c}\vec{A}\right) = e^*|\psi|^2\vec{v}_s, \tag{4}$$

where $e^* = 2e$ and $m^* = 2m$.

The characteristic length for variation of ψ, or coherence length, $\xi(T)$, is defined by considering a simplified case with no fields at Eq.(3). Along with the penetration depth $\lambda(T)$, which indicates how the currents and the flux density reach beyond the surface of the material, these lengths define the dimensionless GL parameter $\kappa = \frac{\lambda(T)}{\xi(T)}$. This parameter separates the superconductors' type at $\kappa = 1/\sqrt{2}$, being $\kappa \ll 1$ for pure (type I) superconductors and vice versa for type II.

Despite knowing $\psi(\vec{r})$ will strive to reach minimum free energy, thermodynamic fluctuations allow the system to present an array of other functions, especially those that raise the energy by only $\sim kT$. As we have stated before, this can give a finite resistance below T_c as well as superconducting effects above T_c (because $\langle\psi^2\rangle \neq 0$).

If we consider a bulk sample far above from T_c, so we can neglect the quartic term in Eq.(2), we can reach a solution of the linearized GL equation (Eq.(3)) such as

$$\left|\psi_{\vec{q}}\right|^2 = \frac{kT}{\alpha + \hbar^2 q^2/2m^*} = \frac{2m^*}{\hbar^2}\frac{kT}{q^2 + 1/\xi^2}. \quad (5)$$

We apply a cutoff at $q \approx 1/\xi(0)$ to give a finite value for $\langle\psi^2\rangle = \sum_{\vec{q}}\left|\psi_{\vec{q}}\right|^2$, which complements the GL theory's range of validity. Superconducting properties will be given by phases of $\psi(\vec{r})$ with coherent spatial variation. Therefore, we look at the two-point correlation function:

$$g(\vec{r},\vec{r}') = \langle\psi^*(\vec{r})\,\psi(\vec{r}')\rangle = \frac{m^* kT}{2\pi\hbar^2}\frac{e^{-\frac{R}{\xi(T)}}}{R} \quad (6)$$

which depends only on the magnitude $\vec{R} = \vec{r}' - \vec{r}$. This function shows how, in the fluctuation regime, the local values of ψ are correlated over a distance ξ, as expected.

Conductivity can usually be defined by $\sigma_n = ne^2\tau/m$ where τ is the mean scattering time of the electrons and n is the density of electrons. When fluctuations arise, they contribute an extra term to this expression.

Using the Kubo formalism [4] for a case with uniform fields and currents and taking q as a continuous variable in bulk samples, we can obtain an exact expression for the excess conductivity in a three-dimensional case:

$$\sigma'_{3D} = \frac{1}{32}\frac{e^2}{\hbar\,\xi(0)}\left(\frac{T_c}{T - T_c}\right)^{1/2}. \quad (7)$$

Eq. (7) takes on similar shapes for two and one-dimensional cases, where the temperature term's exponent changes to 1 for 2D and $3/2$ for 1D. [6]

However, during the critical transition, the GL theory does not hold up anymore. For high-temperature superconductors such as these, the GL theory should break down within 0.1 K or more of the transition temperature.[7]

An important difference between critical and GL behaviour is the correlation length, $\xi(T) \sim (T - T_c)^{-\nu}$, with $\nu = 2/3$ for the first and $\nu = 1/2$ for the latter. If the electrical conductivity increases as $\sigma' \propto \xi(T)$ due to fluctuations [6], the excess conductivity should vary as $(T - T_c)^{-1/2}$ in the mean-field regime and $(T - T_c)^{-2/3}$ in the critical region. It should change again closer to T_c to $(T - T_c)^{-1/3}$ if a dynamical scaling approach is considered.[7] In the end, we are left with the following equation:

$$\sigma' \cong \frac{e^2}{\hbar\,\xi(0)}\left(\frac{T_c}{T - T_c}\right)^{a(T)} \;;\; a(T) \in \left[\frac{1}{2}, \frac{2}{3}, \frac{1}{3}\right]. \quad (8)$$

A. Criteria for the determination of T_c

The raw data used in these studies will be found in the appendix of this report, Table II.

We start by presenting the data in almost its raw form, only applying $R[\Omega] = V[\text{mV}]/10[\text{mA}]$, where V is already the semi-difference of voltage.

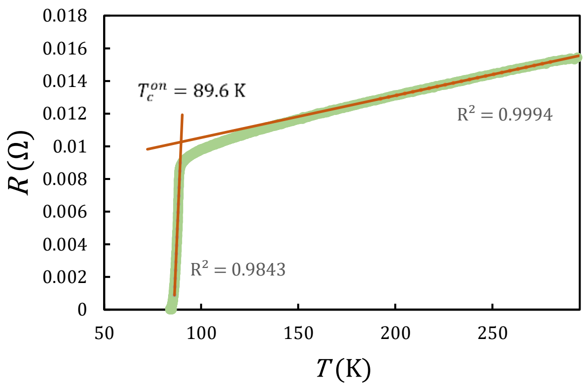

FIG. 1: Dependence of the electrical resistance of the sample with temperature. Two main areas have been adjusted to a trendline: the metallic region and the transition region.

We will use different criteria to estimate the temperature at which the superconducting transition takes place. [8][9]

The first step in determining the critical temperature with this information is to consider the intersection point of these two trendlines. It is clear to see, however, that this will correspond to an onset for when the transition begins as it is approached from the normal state.

The intersection happens at $T_c^{on} = 89.6 \pm 1.3$ K.

Another way of determining when the transition happens is to take the metallic trendline above and extend it to all temperatures. We then assume this is the behaviour the material would have if the transition never happened, R_m. This criterion tells us that the transition will take place when this "metallic resistance" is halved, $R(T_{cR}) = \frac{1}{2}R_m(T_{cR})$.[8]

As seen in Fig. 2, this criterion can be used to find more than just the 50% mark of the transition. We have determined the other two points (see Fig. 2) to also obtain an estimate of the width of this transition. In this case, however, since the deviation from the metallic behaviour starts slowly, we can take the width from the 10% mark only and make it $\Delta T_{cR} =$

$2(T_{cR} - T_{c10})$, since the 90% one gives us little information, being so far away from T_{cR}.

According to this criterion, $T_{cR} = 87.91 \pm 0.02$ K with $\Delta T_{cR} = 2.01$ K. We can see from Fig. 2 that this interval is still valid despite our dismissal of the right mark.

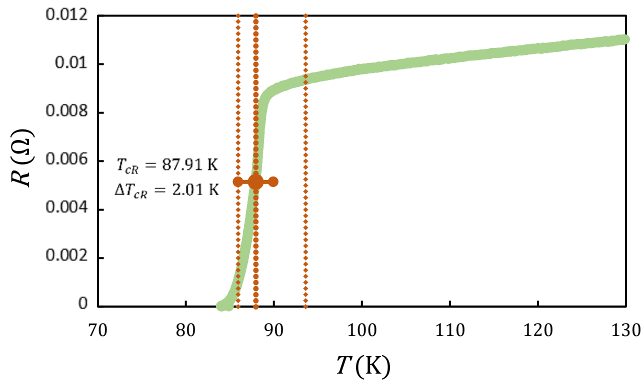

FIG. 2: Visual representation of the halved resistance criterion, including also the 10% and 90% points and ΔT_{cR}.

There is yet another point of view. We can say that a superconductor material will only have transitioned when its resistance falls to a very small value and the fluctuations have diminished. We can arbitrarily decide this is the 5% mark, according to the previous criterion.

If we do this, the approximate critical temperature is $T_{c5} = 85.37 \pm 0.02$ K.

With the data presented so far, a last definition of T_c can be found. We might say the critical temperature of a superconductor is that at which the electrical resistance reaches zero. This is evidently not a perfect definition. The measured values at this range are so small that fluctuations of many types, as well as the equipment used and its precision, can make the zero point quite arbitrary (a zero will always be, in actuality, a very small non-zero number).

Despite all that, in our case, we find $T_{c0} = 84.2 \pm 0.2$ K.

Aside from the electrical resistance itself, we can also study its variation. In other words, we can use the derivative of the resistance with respect to temperature to set some other criteria for determining T_c.[8]

Firstly, to have a rough estimate of the onset, we follow the same procedure as we did in Fig. 1, finding in this case the intersection between the baseline and the trendline of Fig. 3.[10] Here is when the resistance starts diminishing.

The intersection happens at $T_c^{on,d} = 88.94 \pm 0.02$ K.

Lastly, we could define the transition as “the point after the biggest change” or, in other words, the highest point in the derivative. This inflection point is $T_{cI} = 88.25 \pm 0.02$ K.

We summarize our results in Table I. Looking at these results, firstly we can see that both onsets are in the range set by ΔT_{cR}, which further validates the way we determined it. We also see how T_{c5} and T_{c0}, on the other hand, are not in this range. This also makes sense since these temperatures rather led to find the end of the transition.

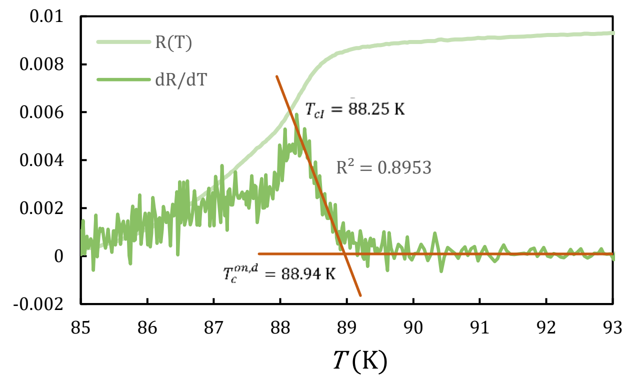

FIG. 3: Derivative of the electrical resistance with respect to temperature, along with the resistance itself in the background. The descend of the derivative has been adjusted to a trendline. A ground baseline has also been added.

Criterion	Critical temperature
T_c^{on}	89.6 ± 1.3 K
$T_c^{on,d}$	88.94 ± 0.02 K
T_{cI}	88.25 ± 0.02 K
T_{cR}	87.91 ± 0.02 K
T_{c5}	85.37 ± 0.02 K
T_{c0}	84.2 ± 0.2 K

TABLE I: Different values of the critical or onset temperature according to different criteria.

B. Critical behaviour of excess conductivity

As we have just seen, T_c can be interpreted in many ways. This leads to the lingering question, is there a best criterion? Which is the most important point in the transition? These questions probably do not have a unique answer.

We have, however, encountered a theory in which T_c appears in a mathematically determined equation. Such is the excess conductivity. Therefore, attempting to find T_c through this equation would seem to lead us to a “truer” result.

We define the crossover critical temperature T_{cC} as the temperature for which, when using Eq. (8), the critical exponent result is the one predicted, $\alpha = 2/3$. Therefore, we impose this exponent, find the region where it is valid, and find this temperature. To see this region with ease we use the variation of Eq. (8) that follows, Eq. (9), where we have noticed $\frac{e^2}{\hbar\,\xi(0)}$ has conductivity units and we can relate a constant conductivity to its value in the normal state, σ_0.

$$\left(\frac{\sigma_0}{\sigma'}\right)^{-3/2} = \left(\frac{T}{T_{cC}} - 1\right) \qquad (9)$$

Since we do not have measures of conductivity, we will use $R = \frac{1}{\sigma}\frac{L}{S}$ to obtain it, assuming the dimensions of the sample remain unchanged during the transition.

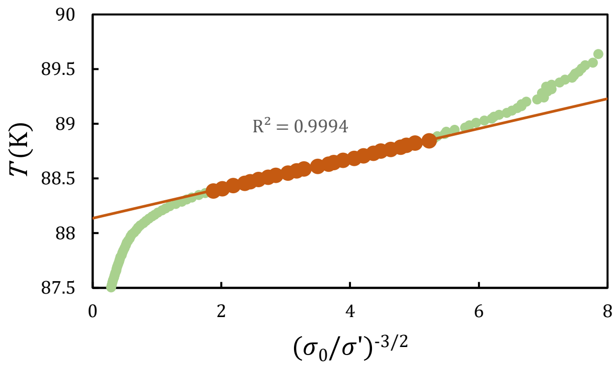

FIG. 4: Dependence of temperature with respect to the excess conductivity $(\sigma_0/\sigma')^{-3/2}$. The points that show a linear dependence, marking where Eq. (9) is valid, have been adjusted to a trendline.

According to Fig. 4, $T_{cC} = 88.137 \pm 0.003$ K, which corresponds to the ordinate of the origin. This might as well be the result with the most underlying physics we have found so far, since it comes from taking the actual expression for the excess conductivity and imposing the range in which fluctuations and the phase transition begin.

We continue the study of excess conductivity by attempting to find the three different exponents theorized by Lobb.[7] We now modify Eq. (8) once again to easily detect the different exponents:

$$\ln\frac{\sigma'}{\sigma_0} = -a(T) \cdot \ln\left(\frac{T}{T_{cC}} - 1\right). \qquad (10)$$

This is shown in Fig. 5. We already know the points (orange region, exponent -0.6632) that fit into the $a = 2/3$ from Fig. 4 and we can see that we are also able to detect $a = 1/3$ with much accuracy (green region, exponent -0.338). The mean-field exponent (blue region, exponent -0.43), however, does not reach the $1/2$ expected, even though what we find matches perfectly with other published results. The explanation for this discrepancy could be the inhomogeneities and defects of the sample, tampering with the idealized sample the GL theory was based upon.[9]

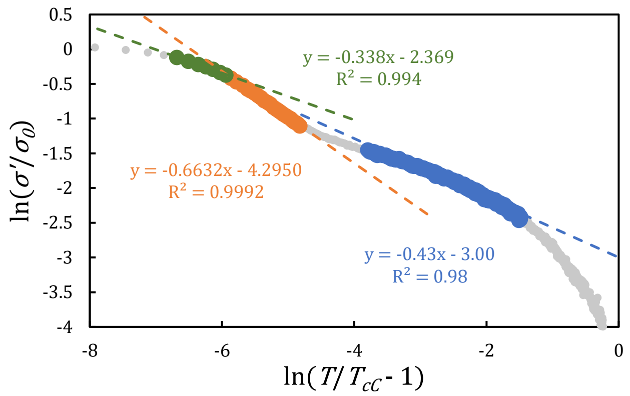

FIG. 5: Dependence of the excess conductivity $\ln(\sigma'/\sigma_0)$ with respect to temperature $\ln\left(\frac{T}{T_{cC}} - 1\right)$ with the tree regions detected: mean-field (blue), transitional (orange) and full critical (green).

IV. CONCLUSIONS

Observing all the different values we have gathered, we can distinguish three clear groups: the onsets, the offsets, and more importantly, T_{cR} and T_{cI} which fall in the middle of the transition and have very similar values both to each other and to T_{cC}. This leads to the conclusion that this middle section, where the critical exponent would change, marks the true transition point. We can rely on the corresponding theory since we have also been able to experimentally verify the different exponents.

This project could be further expanded by studying the behaviour of other magnitudes, such as the temperature and magnetic field dependence of the magnetization via magnetometry measurements.

V. AKNOWLEDGMENTS

I sincerely give my thanks to my advisor Antoni García-Santiago for all his constant support, kindness, and supervision. I have felt guided and reassured during every step of this project. I also thank my family and friends for their patience and my colleagues for their encouragement.

[1] O'Mahony S. M. *et al*. On the electron pairing mechanism of copper-oxide high temperature superconductivity. *PNAS*, Vol.**119**, 37 (2022).

[2] Rose-Innes A. C. and Rhoderick E. H. *Introduction to Superconductivity*. 2nd edition. Oxford: Pergamon Press plc, 1978.

[3] Cava R. J. *et al*. Bulk Superconductivity at 91 K in Single-Phase Oxygen-Deficient Perovskite $Ba_2YCu_3O_{9-\delta}$. *Physical Review Letters*, Vol.**58**, 16 (1987).

[4] Tinkham, M. *Introduction to Superconductivity*. 2nd edition. New York: Dover Publications INC., 1996.

[5] Morguí, O. Improvement of the superconducting transition lab experiment (LFM). *Final Year Assignment*. Barcelona: Dipòsit Digital de la Universitat de Barcelona, 2016. [http://hdl.handle.net/2445/102943].

[6] Aslamazov L. G. and Larkin A. I. Effect of fluctuations on the properties of a superconductor above the critical temperature. *Soviet Physics - Solid State*, Vol.**10**, 4 (1968).

[7] Lobb C. J. Critical fluctuations in high-T_c superconductors. *Physical Review B*, Vol.**36**, 7 (1987).

[8] Vidal, F. *et al*. superconducting order parameter fluctuations above T_c in polycristalline $Ho_1Ba_2Cu_3O_{7-\delta}$ compunds. *Physica C*, Vol.**157** 165-172 (1988).

[9] Carrera M. *et al*. Twins, electron-phonon coupling and fluctuations in $Y_{0.5}Sm_{0.5}Ba_2Cu_3O_{7-y}$. *Physica C*, Vol.**157** 285-292 (1989).

[10] Petrenko E.V. *et al*. Temperature dependence of upper critical fields and coherence lengths for optimally-doped $YBa_2Cu_3O_{7-\delta}$ thin films. *Low Temperature Physics*, Vol.**48**, 755-762 (2022).

VI. APPENDIX

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
293.86	0.1573	**265.17**	-0.1472	**232.02**	-0.1401
293.86	0.1574	**264.10**	0.1483	**231.50**	0.1385
293.87	0.1577	**263.12**	-0.1466	**231.03**	-0.1398
293.87	0.1576	**262.09**	0.1480	**230.53**	0.1384
293.87	0.1578	**260.99**	-0.1460	**230.01**	-0.1397
293.87	0.1574	**260.03**	0.1473	**229.51**	0.1377
293.86	0.1576	**259.20**	-0.1459	**229.03**	-0.1396
293.87	0.1574	**258.24**	0.1468	**228.51**	0.1372
293.87	0.1574	**257.27**	-0.1452	**228.02**	-0.1392
293.87	0.1577	**256.18**	0.1461	**227.54**	0.1371
293.87	0.1576	**255.27**	-0.1450	**227.05**	-0.1395
293.87	-0.1511	**254.17**	0.1452	**226.53**	0.1368
290.76	0.1549	**253.29**	-0.1446	**226.04**	-0.1389
290.60	-0.1521	**252.25**	0.1453	**225.53**	0.1362
290.59	-0.1521	**251.27**	0.1451	**225.04**	-0.1391
290.57	-0.1523	**250.96**	-0.1439	**224.52**	0.1362
290.44	0.1552	**250.28**	0.1447	**224.04**	-0.1388
289.68	-0.1522	**249.25**	-0.1435	**223.54**	0.1358
289.52	0.1544	**248.28**	0.1439	**223.03**	-0.1386
288.90	-0.1522	**247.18**	-0.1430	**222.53**	0.1355
286.14	0.1535	**246.26**	0.1434	**222.02**	-0.1381
285.98	-0.1522	**245.17**	-0.1425	**221.51**	0.1354
285.02	0.1532	**244.19**	0.1428	**221.02**	-0.1380
283.76	-0.1516	**243.06**	-0.1424	**220.46**	0.1354
282.41	0.1524	**242.21**	0.1421	**220.03**	-0.1368
281.06	-0.1517	**241.21**	-0.1417	**219.53**	0.1348
280.19	0.1515	**240.24**	0.1417	**219.03**	-0.1374
278.88	-0.1514	**239.48**	-0.1414	**218.52**	0.1347
278.86	-0.1514	**238.95**	0.1412	**218.01**	-0.1368
278.28	0.1508	**238.48**	-0.1412	**217.50**	0.1345
277.22	-0.1499	**237.97**	0.1408	**217.02**	-0.1366
276.29	0.1511	**237.53**	-0.1408	**216.51**	0.1342
275.30	-0.1493	**236.99**	0.1406	**216.03**	-0.1365
274.27	0.1509	**236.47**	0.1403	**215.52**	0.1338
273.26	-0.1489	**236.01**	-0.1407	**215.00**	-0.1359
272.23	0.1504	**235.52**	0.1401	**214.51**	0.1336
271.31	-0.1482	**234.99**	-0.1405	**214.04**	-0.1356
270.12	0.1500	**234.51**	0.1395	**213.52**	0.1336
269.21	-0.1478	**234.01**	-0.1404	**213.01**	-0.1356
268.17	0.1494	**233.51**	0.1392	**212.53**	0.1334
267.21	-0.1477	**232.99**	-0.1402	**212.02**	-0.1353
266.28	0.1488	**232.51**	0.1389	**211.51**	0.1332

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
211.04	-0.1350	**189.07**	-0.1301	**172.16**	-0.1260
210.53	0.1328	**188.54**	0.1257	**171.88**	0.1204
210.03	-0.1347	**188.04**	-0.1297	**171.58**	-0.1256
209.53	0.1324	**187.56**	0.1255	**171.28**	0.1203
209.04	-0.1343	**187.06**	-0.1297	**170.98**	-0.1257
208.52	0.1321	**186.55**	0.1249	**170.68**	0.1197
208.03	-0.1344	**186.06**	-0.1297	**170.38**	-0.1256
207.51	0.1319	**185.55**	0.1246	**170.08**	0.1196
207.03	-0.1341	**185.05**	-0.1291	**169.78**	-0.1252
206.51	0.1318	**184.55**	0.1243	**169.47**	0.1194
206.03	-0.1338	**184.06**	-0.1288	**169.18**	-0.1253
205.48	0.1314	**183.54**	0.1244	**168.89**	0.1191
205.04	-0.1334	**183.05**	-0.1285	**168.55**	-0.1255
204.54	0.1311	**182.55**	0.1238	**168.28**	0.1190
204.04	-0.1332	**182.06**	-0.1284	**167.98**	-0.1250
203.51	0.1306	**181.53**	0.1236	**167.68**	0.1188
203.02	-0.1329	**181.06**	-0.1281	**167.35**	-0.1252
202.54	0.1303	**180.56**	0.1232	**167.00**	0.1181
202.03	-0.1326	**180.04**	-0.1279	**166.75**	-0.1248
201.46	0.1300	**179.68**	0.1228	**166.44**	0.1190
201.02	-0.1327	**179.38**	-0.1277	**166.17**	-0.1237
200.53	0.1295	**179.06**	0.1226	**165.87**	0.1189
200.04	-0.1327	**178.76**	-0.1276	**165.57**	-0.1236
199.52	0.1295	**178.47**	0.1225	**165.27**	-0.1235
199.03	-0.1325	**178.16**	-0.1275	**164.89**	0.1182
198.53	0.1289	**177.86**	0.1224	**164.67**	-0.1241
198.02	-0.1324	**177.56**	-0.1271	**164.37**	0.1172
197.62	0.1286	**177.26**	0.1222	**164.06**	-0.1241
197.04	-0.1320	**176.96**	-0.1271	**163.74**	0.1170
196.49	0.1282	**176.67**	0.1216	**163.41**	-0.1242
196.04	-0.1317	**176.36**	-0.1270	**163.15**	0.1169
195.56	0.1281	**176.07**	0.1216	**162.86**	-0.1239
195.03	-0.1315	**175.76**	-0.1268	**162.56**	0.1166
194.54	0.1276	**175.46**	0.1212	**162.21**	-0.1242
194.05	-0.1312	**175.16**	-0.1266	**161.96**	0.1164
193.54	0.1272	**174.85**	0.1213	**161.66**	-0.1242
193.03	-0.1312	**174.56**	-0.1266	**161.36**	0.1158
192.53	0.1268	**174.27**	0.1213	**161.06**	-0.1242
192.02	-0.1308	**173.96**	-0.1263	**160.74**	0.1154
191.54	0.1267	**173.68**	0.1209	**160.45**	-0.1244
191.04	-0.1305	**173.37**	-0.1261	**160.08**	0.1159
190.55	0.1263	**173.08**	0.1206	**159.86**	-0.1241
190.05	-0.1300	**172.78**	-0.1259	**159.54**	0.1150
189.55	0.1260	**172.47**	0.1205	**159.26**	-0.1246

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
159.05	0.1140	**145.42**	-0.1207	**137.48**	0.1040
158.66	-0.1245	**145.09**	0.1089	**137.38**	-0.1210
158.35	0.1139	**144.73**	-0.1208	**137.27**	0.1039
158.07	-0.1246	**144.41**	0.1086	**137.16**	-0.1208
157.76	0.1134	**144.13**	-0.1208	**137.08**	0.1037
157.47	-0.1241	**143.77**	0.1083	**136.97**	-0.1214
157.16	0.1134	**143.51**	-0.1205	**136.86**	0.1034
156.87	-0.1237	**143.20**	0.1081	**136.77**	-0.1212
156.65	0.1134	**142.92**	-0.1206	**136.68**	0.1034
156.26	-0.1239	**142.61**	0.1079	**136.56**	-0.1213
156.07	0.1131	**142.34**	-0.1203	**136.48**	0.1030
155.78	-0.1236	**142.05**	0.1076	**136.37**	-0.1215
155.46	0.1124	**141.77**	-0.1200	**136.27**	0.1026
155.18	-0.1241	**141.44**	0.1071	**136.18**	-0.1217
154.76	0.1114	**141.12**	-0.1203	**136.07**	0.1027
154.48	-0.1244	**140.83**	0.1065	**135.96**	-0.1215
154.16	0.1110	**140.51**	-0.1207	**135.86**	0.1023
153.88	-0.1241	**140.22**	0.1062	**135.77**	-0.1217
153.59	0.1109	**139.95**	-0.1207	**135.67**	0.1020
153.29	-0.1245	**139.84**	0.1062	**135.57**	-0.1216
153.00	0.1104	**139.69**	-0.1208	**135.46**	0.1019
152.69	-0.1242	**139.56**	0.1058	**135.36**	-0.1220
152.39	0.1112	**139.46**	-0.1204	**135.27**	0.1017
151.98	-0.1222	**139.36**	0.1054	**135.17**	-0.1218
151.71	0.1121	**139.25**	-0.1205	**135.06**	0.1014
151.39	-0.1220	**139.15**	0.1053	**134.95**	-0.1222
151.10	-0.1219	**139.06**	-0.1206	**134.85**	0.1013
150.77	0.1112	**138.94**	0.1052	**134.77**	-0.1221
150.49	-0.1220	**138.86**	-0.1206	**134.66**	0.1011
150.20	0.1111	**138.75**	0.1052	**134.55**	-0.1224
149.87	-0.1216	**138.67**	-0.1208	**134.44**	0.1006
149.58	0.1111	**138.60**	0.1053	**134.37**	-0.1224
149.29	-0.1217	**138.54**	0.1052	**134.27**	0.1001
148.94	0.1109	**138.49**	-0.1206	**134.16**	-0.1227
148.59	-0.1212	**138.38**	0.1047	**134.07**	0.0997
148.31	0.1108	**138.31**	-0.1210	**133.97**	-0.1230
148.00	-0.1213	**138.21**	0.1045	**133.86**	0.1000
147.69	0.1105	**138.13**	-0.1208	**133.77**	-0.1231
147.41	-0.1209	**138.07**	0.1045	**133.67**	0.0997
147.10	0.1101	**137.97**	-0.1207	**133.56**	-0.1231
146.74	-0.1209	**137.88**	0.1043	**133.46**	0.0996
146.43	0.1097	**137.77**	-0.1210	**133.37**	-0.1233
146.11	-0.1211	**137.67**	0.1044	**133.27**	0.0991
145.75	0.1093	**137.58**	-0.1208	**133.16**	-0.1236

$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)
133.06	0.0985	**128.64**	0.0950	**124.14**	0.0928
132.96	-0.1238	**128.54**	-0.1240	**124.03**	-0.1233
132.87	0.0982	**128.43**	0.0949	**123.93**	0.0926
132.77	-0.1236	**128.35**	-0.1243	**123.83**	-0.1232
132.67	0.0979	**128.27**	0.0946	**123.72**	0.0928
132.58	-0.1237	**128.16**	-0.1240	**123.61**	-0.1230
132.46	0.0978	**128.07**	0.0945	**123.54**	0.0925
132.37	-0.1239	**127.96**	-0.1237	**123.44**	-0.1231
132.27	0.0979	**127.86**	0.0945	**123.34**	0.0922
132.16	-0.1242	**127.77**	-0.1243	**123.24**	-0.1228
132.07	0.0976	**127.63**	0.0944	**123.13**	0.0922
131.96	-0.1241	**127.55**	-0.1243	**123.04**	-0.1228
131.87	0.0972	**127.43**	0.0940	**122.93**	0.0923
131.76	-0.1242	**127.35**	-0.1241	**122.83**	-0.1231
131.66	0.0967	**127.23**	0.0939	**122.73**	0.0921
131.56	-0.1244	**127.15**	-0.1243	**122.64**	-0.1227
131.45	0.0967	**127.05**	0.0938	**122.50**	0.0918
131.35	-0.1244	**126.94**	-0.1241	**122.40**	-0.1225
131.26	0.0966	**126.83**	0.0937	**122.30**	0.0918
131.15	-0.1243	**126.74**	-0.1241	**122.24**	-0.1227
131.06	0.0963	**126.62**	0.0938	**122.14**	0.0916
130.95	-0.1243	**126.48**	-0.1240	**122.06**	-0.1224
130.85	0.0962	**126.33**	0.0936	**121.93**	0.0916
130.74	-0.1245	**126.23**	-0.1239	**121.84**	-0.1224
130.65	0.0962	**126.15**	0.0933	**121.74**	0.0915
130.55	-0.1241	**126.03**	-0.1239	**121.64**	-0.1222
130.46	0.0962	**125.93**	0.0934	**121.54**	0.0915
130.34	-0.1241	**125.81**	-0.1239	**121.44**	-0.1222
130.24	0.0959	**125.71**	0.0932	**121.34**	0.0915
130.15	-0.1243	**125.62**	-0.1239	**121.28**	-0.1221
130.08	0.0959	**125.53**	0.0932	**121.18**	0.0915
129.93	-0.1246	**125.43**	-0.1237	**121.05**	-0.1220
129.83	0.0958	**125.34**	0.0929	**120.91**	0.0910
129.75	-0.1245	**125.24**	-0.1238	**120.82**	-0.1223
129.65	0.0955	**125.12**	0.0928	**120.72**	0.0909
129.56	-0.1245	**125.02**	-0.1236	**120.63**	-0.1222
129.45	0.0957	**124.92**	0.0927	**120.52**	0.0912
129.38	-0.1244	**124.83**	-0.1235	**120.43**	-0.1215
129.25	0.0954	**124.76**	0.0929	**120.36**	0.0910
129.14	-0.1245	**124.66**	-0.1234	**120.27**	-0.1218
129.04	0.0952	**124.57**	0.0930	**120.14**	0.0910
128.94	-0.1242	**124.47**	-0.1235	**120.04**	-0.1219
128.85	0.0952	**124.37**	0.0929	**119.94**	0.0912
128.75	-0.1242	**124.24**	-0.1233	**119.87**	-0.1216

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
119.69	-0.1217	**115.23**	-0.1196	**110.84**	-0.1175
119.59	0.0907	**115.14**	0.0893	**110.75**	0.0881
119.49	-0.1216	**115.05**	-0.1197	**110.65**	-0.1172
119.37	0.0910	**114.93**	0.0893	**110.54**	0.0879
119.24	-0.1212	**114.84**	-0.1197	**110.43**	-0.1169
119.14	0.0908	**114.75**	0.0894	**110.34**	0.0881
119.01	-0.1213	**114.66**	-0.1197	**110.27**	-0.1170
118.89	0.0907	**114.57**	0.0888	**110.16**	0.0878
118.83	-0.1214	**114.48**	-0.1195	**110.05**	-0.1170
118.73	0.0906	**114.39**	0.0890	**109.94**	0.0878
118.64	-0.1210	**114.30**	-0.1193	**109.84**	-0.1165
118.57	0.0905	**114.13**	0.0889	**109.75**	0.0878
118.48	-0.1212	**114.04**	-0.1191	**109.65**	-0.1166
118.35	0.0903	**113.92**	0.0889	**109.54**	0.0882
118.26	-0.1211	**113.83**	-0.1191	**109.46**	-0.1165
118.16	0.0901	**113.69**	0.0887	**109.35**	0.0879
118.04	-0.1210	**113.60**	-0.1190	**109.28**	-0.1165
117.94	0.0904	**113.54**	0.0889	**109.19**	0.0877
117.85	-0.1207	**113.43**	-0.1189	**109.09**	-0.1159
117.75	0.0903	**113.34**	0.0888	**108.95**	0.0879
117.66	-0.1207	**113.26**	-0.1187	**108.85**	-0.1157
117.57	0.0902	**113.17**	0.0886	**108.77**	0.0875
117.45	-0.1204	**113.06**	-0.1186	**108.65**	-0.1158
117.32	0.0900	**112.94**	0.0887	**108.54**	0.0877
117.23	-0.1205	**112.83**	-0.1185	**108.44**	-0.1157
117.14	0.0903	**112.74**	0.0888	**108.33**	0.0882
117.05	-0.1207	**112.63**	-0.1183	**108.23**	-0.1153
116.95	0.0898	**112.54**	0.0887	**108.15**	0.0878
116.83	-0.1204	**112.43**	-0.1184	**108.05**	-0.1152
116.74	0.0899	**112.34**	0.0884	**107.92**	0.0882
116.65	-0.1205	**112.26**	-0.1185	**107.82**	-0.1150
116.52	0.0896	**112.15**	0.0886	**107.75**	0.0879
116.43	-0.1203	**112.03**	-0.1182	**107.64**	-0.1152
116.34	0.0897	**111.95**	0.0884	**107.57**	0.0881
116.25	-0.1204	**111.86**	-0.1178	**107.47**	-0.1148
116.13	0.0895	**111.75**	0.0886	**107.34**	0.0873
116.04	-0.1201	**111.64**	-0.1179	**107.24**	-0.1149
115.95	0.0895	**111.53**	0.0883	**107.17**	0.0875
115.83	-0.1200	**111.45**	-0.1177	**107.04**	-0.1146
115.74	0.0893	**111.33**	0.0881	**106.97**	0.0875
115.62	-0.1199	**111.25**	-0.1177	**106.85**	-0.1146
115.53	0.0894	**111.14**	0.0884	**106.75**	0.0875
115.44	-0.1199	**111.03**	-0.1178	**106.65**	-0.1142
115.34	0.0894	**110.92**	0.0879	**106.55**	0.0873

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
106.46	-0.1141	**101.98**	0.0861	**98.89**	0.0852
106.36	0.0876	**101.89**	-0.1117	**98.84**	-0.1092
106.26	-0.1140	**101.80**	0.0856	**98.79**	0.0851
106.14	0.0874	**101.68**	-0.1113	**98.74**	-0.1090
106.04	-0.1140	**101.59**	0.0857	**98.69**	0.0848
105.94	0.0873	**101.48**	-0.1115	**98.64**	-0.1093
105.85	-0.1137	**101.37**	-0.1112	**98.59**	0.0851
105.78	0.0875	**101.32**	-0.1109	**98.55**	-0.1092
105.68	-0.1139	**101.29**	0.0858	**98.49**	0.0850
105.54	0.0872	**101.19**	-0.1112	**98.44**	-0.1091
105.45	-0.1135	**101.09**	0.0855	**98.38**	0.0849
105.35	0.0870	**101.03**	-0.1110	**98.33**	-0.1090
105.26	-0.1139	**100.91**	0.0855	**98.29**	0.0848
105.14	0.0872	**100.80**	-0.1108	**98.23**	-0.1085
105.02	-0.1131	**100.70**	0.0859	**98.19**	0.0851
104.93	0.0871	**100.59**	-0.1107	**98.14**	-0.1089
104.91	0.0870	**100.59**	-0.1107	**98.08**	0.0846
104.82	-0.1132	**100.50**	0.0855	**98.04**	-0.1089
104.68	0.0869	**100.40**	-0.1104	**97.99**	0.0847
104.63	-0.1131	**100.29**	0.0860	**97.94**	-0.1087
104.54	0.0867	**100.19**	-0.1103	**97.89**	0.0847
104.45	-0.1131	**100.09**	0.0856	**97.83**	-0.1086
104.34	0.0870	**100.00**	-0.1100	**97.79**	0.0847
104.24	-0.1127	**99.94**	0.0857	**97.74**	-0.1084
104.09	0.0868	**99.89**	-0.1099	**97.69**	0.0844
103.96	-0.1127	**99.83**	-0.1098	**97.64**	-0.1083
103.87	0.0865	**99.79**	0.0859	**97.60**	0.0845
103.78	-0.1124	**99.75**	-0.1096	**97.54**	-0.1083
103.67	0.0864	**99.70**	0.0861	**97.49**	0.0845
103.56	-0.1124	**99.64**	-0.1099	**97.44**	-0.1084
103.47	0.0868	**99.59**	0.0859	**97.39**	0.0845
103.36	-0.1123	**99.54**	-0.1094	**97.33**	-0.1081
103.28	0.0865	**99.50**	0.0855	**97.30**	0.0841
103.19	-0.1124	**99.45**	-0.1093	**97.24**	-0.1082
103.06	0.0866	**99.39**	0.0857	**97.20**	0.0843
102.97	-0.1120	**99.34**	-0.1093	**97.15**	-0.1079
102.87	0.0862	**99.27**	0.0857	**97.10**	0.0842
102.77	-0.1118	**99.23**	-0.1092	**97.04**	-0.1081
102.68	0.0864	**99.19**	0.0856	**97.00**	0.0843
102.56	-0.1117	**99.13**	-0.1094	**96.94**	-0.1078
102.43	0.0863	**99.08**	0.0855	**96.89**	0.0842
102.28	-0.1117	**99.04**	-0.1090	**96.85**	-0.1077
102.17	0.0860	**98.98**	0.0853	**96.79**	0.0843
102.08	-0.1114	**98.93**	-0.2272	**96.75**	-0.1077

$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)
96.69	0.0838	**94.54**	0.0829	**92.34**	0.0810
96.65	-0.1075	**94.49**	-0.0032	**92.29**	-0.1035
96.59	0.0837	**94.44**	0.0831	**92.24**	0.0811
96.55	-0.1077	**94.39**	-0.1058	**92.19**	-0.1035
96.49	0.0839	**94.33**	0.0827	**92.13**	0.0810
96.43	-0.1074	**94.29**	-0.0794	**92.08**	-0.1034
96.39	0.0839	**94.24**	0.0827	**92.05**	0.0811
96.35	-0.1073	**94.19**	-0.1055	**91.99**	-0.1034
96.29	0.0840	**94.14**	0.0825	**91.94**	0.0807
96.22	0.0838	**94.10**	-0.1053	**91.88**	-0.1033
96.18	-0.1072	**94.04**	0.0828	**91.84**	0.0807
96.14	0.0837	**93.98**	-0.1054	**91.79**	-0.1030
96.10	-0.1073	**93.94**	0.0824	**91.74**	0.0804
96.04	0.0840	**93.89**	-0.1052	**91.69**	-0.1029
96.01	-0.1069	**93.84**	0.0825	**91.64**	0.0802
95.95	0.0836	**93.80**	-0.1050	**91.59**	-0.0149
95.91	-0.1072	**93.74**	0.0822	**91.54**	0.0803
95.84	0.0834	**93.68**	-0.1055	**91.50**	-0.1027
95.80	-0.1068	**93.63**	0.0825	**91.43**	0.0802
95.74	-0.1069	**93.59**	-0.1046	**91.38**	-0.1024
95.70	-0.1067	**93.54**	0.0822	**91.33**	0.0798
95.64	0.0836	**93.49**	-0.1048	**91.29**	-0.1022
95.58	0.0833	**93.44**	0.0821	**91.24**	0.0799
95.54	0.0836	**93.40**	-0.1048	**91.20**	-0.1024
95.49	-0.1067	**93.34**	0.0821	**91.13**	0.0799
95.44	0.0835	**93.29**	-0.1045	**91.10**	-0.1023
95.43	0.0835	**93.25**	0.0821	**91.05**	0.0796
95.38	-0.1064	**93.20**	-0.1042	**91.00**	-0.1021
95.34	0.0834	**93.14**	0.0820	**90.94**	0.0798
95.29	-0.1062	**93.08**	-0.1042	**90.90**	-0.1017
95.25	0.0836	**93.04**	0.0817	**90.84**	0.0795
95.20	-0.1062	**92.99**	-0.1043	**90.80**	-0.1017
95.15	-0.0366	**92.94**	0.0816	**90.76**	0.0792
95.09	-0.1062	**92.88**	-0.1042	**90.70**	-0.1014
95.05	0.0833	**92.84**	0.0815	**90.66**	0.0793
94.99	-0.1061	**92.81**	-0.1040	**90.60**	-0.1013
94.95	0.0831	**92.75**	0.0814	**90.55**	0.0790
94.89	-0.1062	**92.70**	-0.1039	**90.49**	-0.1010
94.85	0.0830	**92.65**	0.0814	**90.44**	0.0791
94.79	-0.1059	**92.60**	-0.1040	**90.40**	-0.1015
94.75	0.0831	**92.55**	0.0815	**90.35**	0.0788
94.69	-0.1056	**92.49**	-0.1036	**90.30**	-0.1005
94.65	0.0831	**92.44**	0.0813	**90.25**	0.0787
94.59	-0.1057	**92.39**	-0.1036	**90.19**	-0.1007

$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)	$\boldsymbol{T \pm 0.03}$ (K)	$V \pm 0.0001$ (mV)
90.14	0.0784	**88.96**	0.0744	**88.08**	0.0466
90.09	-0.1002	**88.94**	-0.0959	**88.06**	-0.0676
90.04	0.0783	**88.92**	0.0740	**88.04**	0.0451
90.00	-0.1001	**88.90**	-0.0958	**88.02**	-0.0662
89.95	0.0785	**88.88**	0.0736	**88.00**	0.0432
89.93	-0.1001	**88.86**	-0.0956	**87.98**	-0.0645
89.89	0.0780	**88.84**	0.0733	**87.96**	0.0421
89.85	-0.1002	**88.82**	-0.0947	**87.94**	-0.0634
89.81	0.0777	**88.80**	0.0727	**87.92**	0.0407
89.74	-0.0997	**88.78**	-0.0943	**87.90**	-0.0622
89.68	0.0778	**88.76**	0.0720	**87.87**	0.0396
89.65	-0.0994	**88.75**	-0.0936	**87.86**	-0.0608
89.63	0.0772	**88.72**	0.0714	**87.83**	0.0382
89.60	-0.0997	**88.69**	-0.0928	**87.81**	-0.0598
89.57	0.0772	**88.68**	0.0707	**87.79**	0.0374
89.55	-0.0992	**88.66**	-0.0918	**87.77**	-0.0584
89.52	0.0770	**88.64**	0.0698	**87.75**	0.0366
89.49	-0.0990	**88.63**	-0.0913	**87.73**	-0.0576
89.47	0.0769	**88.60**	0.0687	**87.70**	0.0352
89.45	-0.0989	**88.58**	-0.0898	**87.69**	-0.0563
89.43	0.0768	**88.56**	0.0678	**87.66**	0.0344
89.41	-0.0988	**88.54**	-0.0888	**87.65**	-0.0558
89.39	0.0765	**88.52**	0.0662	**87.62**	0.0333
89.37	-0.0986	**88.50**	-0.0877	**87.60**	-0.0546
89.35	0.0762	**88.48**	0.0647	**87.58**	0.0323
89.33	-0.0984	**88.46**	-0.0863	**87.56**	-0.0531
89.30	0.0764	**88.45**	0.0638	**87.54**	0.0312
89.29	-0.0982	**88.42**	-0.0842	**87.52**	-0.0522
89.27	0.0762	**88.40**	0.0615	**87.49**	0.0299
89.25	-0.0983	**88.38**	-0.0821	**87.48**	-0.0515
89.23	0.0762	**88.36**	0.0595	**87.46**	0.0291
89.21	-0.0980	**88.34**	-0.0804	**87.44**	-0.0504
89.19	0.0758	**88.32**	0.0575	**87.41**	0.0278
89.17	-0.0978	**88.30**	-0.0787	**87.39**	-0.0493
89.15	0.0758	**88.28**	0.0559	**87.38**	0.0270
89.13	-0.0976	**88.26**	-0.0765	**87.36**	-0.0485
89.11	0.0755	**88.24**	0.0534	**87.34**	0.0258
89.09	-0.0974	**88.22**	-0.0749	**87.31**	-0.0469
89.07	0.0752	**88.20**	0.0517	**87.29**	0.0247
89.05	-0.0971	**88.18**	-0.0730	**87.27**	-0.0460
89.04	0.0751	**88.16**	0.0500	**87.25**	0.0238
89.02	-0.0968	**88.15**	-0.0715	**87.23**	-0.0448
89.00	0.0747	**88.12**	0.0483	**87.21**	0.0227
88.98	-0.0964	**88.10**	-0.0698	**87.19**	-0.0444

$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)
87.17	0.0219	**86.31**	0.0046	**85.46**	-0.0055
87.16	-0.0438	**86.30**	-0.0267	**85.44**	-0.0166
87.13	0.0208	**86.27**	0.0042	**85.42**	-0.0057
87.11	-0.0422	**86.25**	-0.0257	**85.40**	-0.0162
87.09	0.0203	**86.24**	0.0034	**85.38**	-0.0060
87.07	-0.0413	**86.21**	-0.0253	**85.36**	-0.0160
87.05	0.0193	**86.19**	0.0032	**85.34**	-0.0063
87.04	-0.0402	**86.17**	-0.0247	**85.32**	-0.0156
87.01	0.0179	**86.15**	0.0025	**85.30**	-0.0067
87.00	-0.0397	**86.14**	-0.0245	**85.28**	-0.0151
86.97	0.0169	**86.11**	0.0018	**85.26**	-0.0071
86.95	-0.0388	**86.09**	-0.0237	**85.24**	-0.0151
86.94	0.0164	**86.07**	0.0009	**85.22**	-0.0077
86.92	-0.0380	**86.05**	-0.0233	**85.20**	-0.0149
86.88	0.0152	**86.04**	0.0008	**85.18**	-0.0075
86.87	-0.0370	**86.02**	-0.0227	**85.17**	-0.0147
86.85	0.0146	**86.00**	0.0006	**85.14**	-0.0078
86.83	-0.0362	**85.98**	-0.0221	**85.12**	-0.0145
86.81	0.0136	**85.96**	-0.0002	**85.10**	-0.0079
86.80	-0.0355	**85.94**	-0.0216	**85.08**	-0.0142
86.77	0.0132	**85.92**	-0.0006	**85.06**	-0.0081
86.76	-0.0347	**85.90**	-0.0214	**85.05**	-0.0142
86.74	0.0127	**85.88**	-0.0016	**85.04**	-0.0083
86.72	-0.0340	**85.86**	-0.0209	**85.03**	-0.0138
86.69	0.0115	**85.84**	-0.0019	**85.01**	-0.0085
86.67	-0.0330	**85.82**	-0.0203	**85.00**	-0.0138
86.66	0.0110	**85.81**	-0.0022	**84.98**	-0.0086
86.63	-0.0326	**85.79**	-0.0201	**84.97**	-0.0135
86.62	0.0102	**85.77**	-0.0029	**84.96**	-0.0086
86.59	-0.0313	**85.76**	-0.0195	**84.94**	-0.0135
86.57	0.0095	**85.74**	-0.0028	**84.92**	-0.0088
86.55	-0.0307	**85.72**	-0.0195	**84.90**	-0.0136
86.54	0.0085	**85.70**	-0.0033	**84.87**	-0.0090
86.51	-0.0300	**85.69**	-0.0191	**84.85**	-0.0131
86.50	0.0079	**85.66**	-0.0036	**84.85**	-0.0131
86.48	-0.0292	**85.63**	-0.0182	**84.85**	-0.0130
86.47	0.0076	**85.60**	-0.0043	**84.82**	-0.0093
86.45	-0.0291	**85.59**	-0.0180	**84.80**	-0.0130
86.43	0.0067	**85.56**	-0.0048	**84.78**	-0.0092
86.41	-0.0283	**85.55**	-0.0173	**84.76**	-0.0127
86.40	0.0061	**85.52**	-0.0052	**84.74**	-0.0095
86.37	-0.0275	**85.51**	-0.0172	**84.71**	-0.0126
86.36	0.0055	**85.50**	-0.0054	**84.69**	-0.0097
86.34	-0.0273	**85.48**	-0.0168	**84.67**	-0.0124

$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)	$T \pm 0.03$ (K)	$V \pm 0.0001$ (mV)
84.65	-0.0097	**84.32**	-0.0116	**84.11**	-0.0108
84.63	-0.0126	**84.31**	-0.0107	**84.10**	-0.0116
84.61	-0.0100	**84.29**	-0.0118	**84.09**	-0.0113
84.59	-0.0123	**84.28**	-0.0109	**84.08**	-0.0115
84.57	-0.0099	**84.27**	-0.0117	**84.08**	-0.0110
84.55	-0.0119	**84.25**	-0.0108	**84.07**	-0.0115
84.53	-0.0101	**84.24**	-0.0115	**84.06**	-0.0110
84.52	-0.0118	**84.23**	-0.0109	**84.05**	-0.0113
84.51	-0.0098	**84.21**	-0.0116	**84.05**	-0.0111
84.48	-0.0120	**84.19**	-0.0111	**84.04**	-0.0113
84.45	-0.0101	**84.18**	-0.0117	**84.03**	-0.0109
84.43	-0.0122	**84.17**	-0.0109	**84.02**	-0.0111
84.42	-0.0105	**84.16**	-0.0114	**84.01**	-0.0113
84.39	-0.0118	**84.15**	-0.0110	**84.01**	-0.0113
84.37	-0.0105	**84.14**	-0.0114	**83.99**	-0.0109
84.35	-0.0117	**84.13**	-0.0109		
84.34	-0.0106	**84.13**	-0.0112		

TABLE II: Lab raw data for the temperature of the sample and the voltage drop on it when fed a current of 1 mA.