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$Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ superconductor: sample preparation and transport properties under hydrostatic pressure

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Abstract. Samples of the $Hg_{1-x}Re_xBa_2Ca_2Cu_3O_{8+\delta}$ superconductor (Hg, Re-1223), with low rhenium (Re) content ($x = 0.05$), have been produced with the help of a novel thermobaric analysis technique which could monitor the total pressure inside the quartz tube during synthesis at high temperature. The sample quality was verified by means of Rietveld analysis of the x-ray diffraction data, and by ac susceptibility measurements. The formation and stability of the Hg, Re-1223 phase has also been investigated by varying the oxygen content of the $Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ precursor, and the mercury filling factor ($ff_{Hg} = 0.00$ to 0.014 g cm^{-3}). It was observed that the reduction of oxygen content in the precursor ($Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$) and the increase of the mercury partial pressure inside the quartz tube enhanced the yield of the superconductor phase.

Resistance measurements as a function of temperature under hydrostatic pressure (0–1.0 GPa) show an increase in the superconducting transition temperature which can be fitted with a parabolic curve. The reduction of the lattice volume induced by external hydrostatic pressure is similar to the one induced by chemical pressure due to rhenium (Re) doping ($0.00 < x < 0.10$); however T_C does not depend on the chemical pressure. This behaviour can be understood on the basis of the pressure-induced charge transfer model (PICTM) modified by Almasan *et al*.

1. Introduction

The families of $HgBa_2Ca_{n-1}Cu_nO_y$ ($n = 1, 2, 3, \ldots$) compounds have been studied intensively since their discovery in 1993 [1], despite the difficulty in their preparation which involves high pressure sintering. These compounds display good superconducting properties with the highest T_C ever reported at ambient pressure [1–3]. The compound with $n = 3$ has a record T_C of 134 K at ambient pressure, and the first pressure measurements [4, 5], in the 0.0–1 GPa range, showed that T_C increases under compression at a rate of 1.7 K GPa^{-1}, which would correspond to the behaviour of an underdoped sample. Other pressure measurements, on optimum doped samples, up to higher pressure values ($\cong$20 GPa) confirm that T_C increases with pressure at a rather high rate, reaching 158 K at 15 GPa [5]. As soon as the optimal doped samples became available, the maximum T_C as a function of pressure ($T_C(P)$) rose to 164 K at 30 GPa [6–8]. The characteristic $T_C(P)$ curve is a parabola, but in the low pressure regime one can consider a linear behaviour as more sensible to sample quality. For pure $n = 3$ superconductor phase (Hg-1223) the linear $\partial T_C/\partial P$ behaviour has a clear dependence on the sample oxygen content. The optimally doped samples have shown a linear $\partial T_C/\partial P$ dependence close to 4 K GPa^{-1} [9, 10] in the 0.0–1.0 GPa range; however this dependence changes to low values (1.7 K GPa^{-1}) [6–8] when one takes into account the whole pressure range (0.0–40 GPa). Therefore, knowledge of the $\partial T_C/\partial P$ value in the low pressure range (0.0–1.0 GPa) can be associated with the oxygen content present in the sample.

The formation process for the $HgBa_2Ca_{n-1}Cu_nO_y$ series of compounds has not been well established yet. It is

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possible to stabilize the pure phase by sintering under pressure of the order of a few GPa and at temperatures close to 850 °C [11, 12], or by substituting Hg for cations with higher valence [13–17]. For example, this is the case for Re substitution at the Hg site, which allows the preparation of $(Hg, Re)Ba_2Ca_{n-1}Cu_nO_y$ under normal pressures in a quartz tube. In this work the preparation of $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ samples has been optimized with the use of a recently developed technique, named thermobaric analysis (TBA) [18]. This technique has been used to optimize the synthesis of $Hg_{0.82}Re_{0.18}Ba_2Ca_2Cu_3O_{8+\delta}$ samples, as was described in our previous paper [19]. In the same way, the oxygen content present in the $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ sample can be optimized by controlling the pressure during synthesis. Resistance versus temperature measurements under hydrostatic pressure, for oxygen optimized samples, are discussed in comparison with the chemical pressure.

2. Experiment

The first step to synthesize the sample involves the preparation of the $Re_{0.05}Ba_2Ca_2Cu_3O_{7.1+\delta}$ precursor. Initially $Ba_2Ca_2Cu_3O_{7+\delta}$ (99.9% purity—PRAXAIR) and ReO_2 (99% purity—Aldrich) powders were weighed in 1:0.05 molar ratio. The mixture was ground in an agate mortar and the rectangular pellets, with typical size of $4 \times 4 \times 40$ mm^3, were uniaxially compacted under 0.2 GPa pressure. The pellets were crushed and compacted after being heat treated under oxygen flow at 850 °C for 15 h and 930 °C for 12 h. Finally a third heat treatment of the pellets was done in an oxygen poor flux ($p < 0.3$ bar) with heating rate of 120 °K h^{-1} up to 930 °C [20], where they were kept for 12 h, and subsequently cooled at rate of 300 °K h^{-1}. In order to control the low oxygen content of the O_2 (99.9%) and Ar (99.9%) gas mixture, a Quanta Chrome Inc. gas mixer, with controlled flow rate, was utilized.

The $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ sample was synthesized from a stoichiometric mixture of HgO (99%, Aldrich) and a $Re_{0.05}Ba_2Ca_2Cu_3O_{7.1+\delta}$ precursor. The resulting powder was pressed into pellets wrapped in gold foil (99.9% purity) and sealed in a quartz tube, which had a pressure sensor. The optimum filling factor (ff), defined as the ratio between the sample mass and the volume of quartz tube, was ff = 0.70 g cm^{-3} [19]. Liquid Hg was added, before the quartz tube was sealed under a vacuum of 10^{-3} bar, and the ratio between Hg mass and total free volume was defined as the Hg filling factor (ff_{Hg}). In order to avoid the formation of the $CaHgO_2$ impurity phase [21, 22], a high heating rate of 300 °K h^{-1} was used up to 700 °C, while pressure inside the tube (p_T) was monitored with the TBA. Above this temperature the heating rate was decreased to 120 °K h^{-1} until 860 °C was reached and than it was kept for 10 h at this temperature. The samples were cooled at the rate of 120 °K h^{-1}.

Four precursors were prepared at 1 bar (total pressure Ar and O_2) under different partial oxygen pressure: $P_{O_2} = 0.25$ bar for precursor No 1, and $P_{O_2} = 0.1$ bar for precursors Nos 2, 3 and 4. With these precursors, four samples were then prepared, with the same ff = 0.70 g cm^{-3}, varying the oxygen content and the ff_{Hg}, as can be seen in table 1.

Table 1. Samples Nos I and II were prepared with $ff_{Hg} = 0$ from precursors Nos 1 and 2 while samples Nos III and IV were prepared from precursors Nos 3 and 4, with $ff_{Hg} = 0.010$ and 0.014 g cm^{-3}, respectively. In this way samples Nos I and II differ in the oxygen content while samples Nos II, III and IV differ in Hg content.

	I	II	III	IV
ff (g cm^{-3})	0.70	0.70	0.70	0.70
ff_{Hg} (g cm^{-3})	0.000	0.000	0.010	0.014
Precursor	1	2	3	4
O_2 partial pressure of the precursor (bar)	0.25	0.10	0.10	0.10

Powder x-ray diffraction patterns (Cu Kα_1) were recorded with a Rigaku D-MAX 2000 diffractometer and the Rietveld analysis [23, 24] was performed with the DBWS program [25].

The magnetic characterization of the final compounds was performed with the sample in powder form. The pellets were ground in an agate mortar and dried in an oven in N_2 atmosphere, at 105 °C, for 1 h. The powder was than cooled in a dry box, for 1 h, and mechanically sieved to assure that all the material has particle size below 65 μm.

The ac susceptibility was measured with a home-made calibrated and automated device ($H_{ac} = 8$ A m^{-1} and $\nu = 500$ Hz) [26, 27]. The difference between pick-up coils was measured by a dual phase lock-in model 5210 (EG&G) and the heating rate was 0.05 K min^{-1}. Dc magnetization measurements in a SQUID magnetometer confirm the ac susceptibility results.

The resistance measurements under pressure were performed in a BeCu pressure cell, similar to the one used in other works [28, 29], under hydrostatic conditions with an *n*-pentane–isoamyl alcohol mixture (1:1) as pressure medium. Room temperature pressure was measured by a manganin manometer. The pressure change upon cooling due to thermal contraction effects was calibrated considering the Thompson [30] procedure. The temperature dependence of the resistance at several pressures (0.0–1.0 GPa) was measured by a standard four probe method on slabs of $0.7 \times 1.5 \times 5$ mm^3 dimensions. The resistance measurements were made using a Linear Research Inc. LR-700 AC resistance bridge, at $\nu = 16$ Hz and with $I_{ac} = 100$ μA. A calibrated GaAlAs sensor (GAL8957) and a Lake Shore temperature controller, model 340, were used to control and monitor the temperature. The resistance at room temperature shows the same value on thermal cycling confirming the good quality of the contacts. The temperature T_{cd} was used as the criterion to determine the transition temperature from the variation of resistance with temperature for all the pressure values. The T_{cd} was defined as the intersection of the tangent through $\partial R/\partial T$, where $\partial^2 R/\partial T^2$ has the highest negative value, with the extrapolation of the normal state behaviour just above $T_{C\,onset}$ [31].

In order to compare the hydrostatic external pressure and the chemical pressure we used the $T_{C\,onset}$ (ac susceptibility) and lattice parameter (x-ray pattern) data for a sample with $x = 0.10$, prepared by the same method as reported in [19].

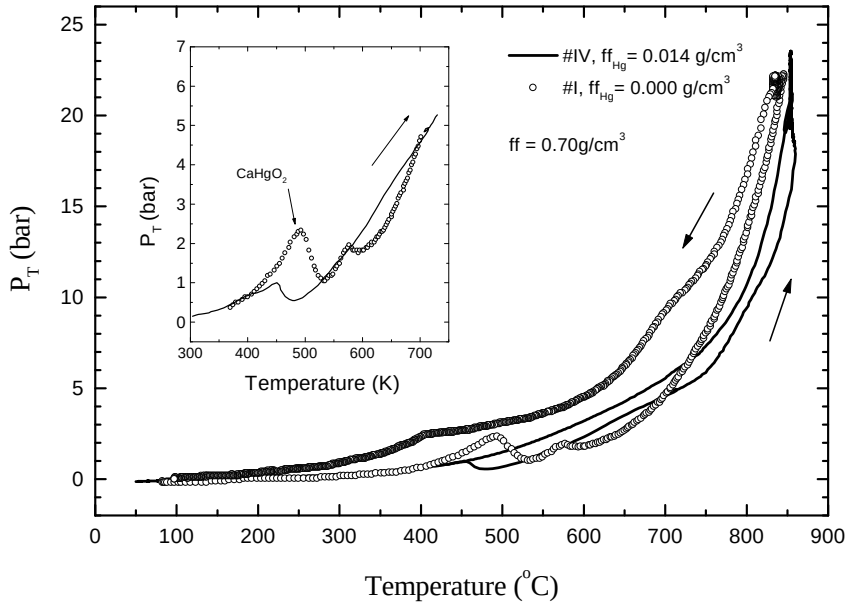

Figure 1. Diagram of pressure in the sealed quartz tube (P_T) versus temperature for the $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ synthesis. Sample No I was prepared with ff $= 0.70$ g cm^{-3} and a precursor obtained with a partial pressure of $P_{O_2} = 0.25$ bar. Sample No IV was prepared with ff $= 0.70$ g cm^{-3} and a precursor obtained with a partial pressure of $P_{O_2} = 0.1$ bar.

3. Results and discussion

3.1. Sample characterization

Figure 1 displays the experimental curves for the variation of pressure P_T (inside the sealed quartz tube) with the temperature following the formation of $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$, in two batches with different filling factors of mercury and oxygen content at the precursor preparation. For both samples the pressure inside the quartz tube was registered in the warming up and cooling down process: it increases up to 23 bar when the compound is heated and kept at 850 °C. There is a special interest in the heating process because the pressure variation displays peaks (see insert) that announce the appearance of $CaHgO_2$ in the final synthesis of the composition [19, 21]. When the first peak becomes more flat and moves to lower temperatures there is a reduction of $CaHgO_2$ [20] fraction in the sample.

Sample No IV with ff$_{Hg} = 0.014$ g cm^{-3} displays one pressure peak in $P_T(T)$, while sample No I with ff$_{Hg} =$ 0.000 g cm^{-3} shows two peaks. In both cases the first peak of each curve occurs with different intensities and at different temperatures (sample No I at 490 °C and sample No IV at 450 °C): it is more intense for sample No I (ff$_{Hg} =$ 0.000 g cm^{-3}) than for sample No IV (ff$_{Hg} = 0.014$ g cm^{-3}). The intensity of the second peak, with an origin still to be determined, is an indication that a spurious phase will appear in the sample.

In order to compare the influence of ff$_{Hg}$ on the synthesis process two samples with the same oxygen treatment were heated under different mercury partial pressure. Figure 2 shows, in detail, the region including the first peak, and a clear reduction of its intensity can be seen, for samples with the same oxygen content, when the ff$_{Hg}$ is increased.

X-ray diffraction patterns have shown that the fraction of $CaHgO_2$ is higher in sample No I and sample No II than

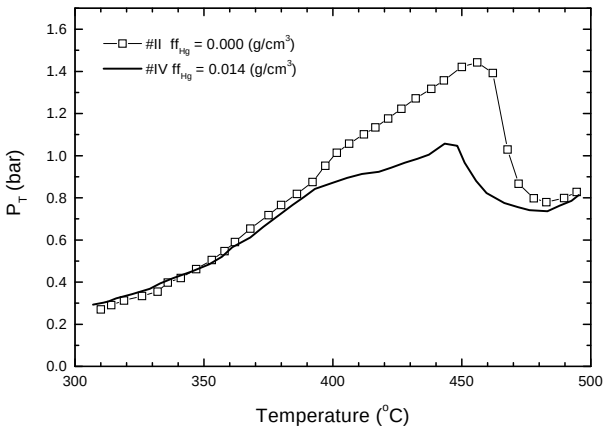

Figure 2. Detail of the diagram of pressure inside the quartz tube (P_T) versus temperature for the $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ synthesis. Sample No II was prepared with ff $= 0.70$ g cm^{-3} an ff$_{Hg} = 0.00$ g cm^{-3} and a precursor obtained with a partial oxygen pressure of 0.1 bar while sample No IV was prepared under the same preparation conditions however with different ff$_{Hg}$, as indicated in the figure.

in sample No IV. This suggests that the reduction of oxygen content of the precursor ($Re_{0.05}Ba_2Ca_2Cu_3O_{7.1+\delta}$) and the increase of the mercury partial pressure reduces $CaHgO_2$, improving the yield of the superconductor phase.

Figure 3 shows the ac susceptibility for several samples obtained with different oxygen and mercury contents. Samples No I and No II differ in the oxygen content while samples Nos II, III and IV differ in the Hg filling factor. The different behaviour displayed for samples Nos II and III is due to the ff$_{Hg}$ (0.000 and 0.010), as can be seen in table 1. The best results were obtained with samples Nos III and IV and the low T_C of sample No I indicates that excess of oxygen in the precursor treatment is detrimental to superconductivity.

Table 2. The relative proportion of different phase distribution as obtained from the Rietveld analysis.

$Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$	$CaHgO_2$	$Ba_4CaCu_2O_y(CO_3)_{0.5}$	$Ca_{0.85}CuO_2$	$BaCuO_{2+x}$
86(5)%	6.6(5)%	3.9(4)%	2.3(6)%	1.1(5)%

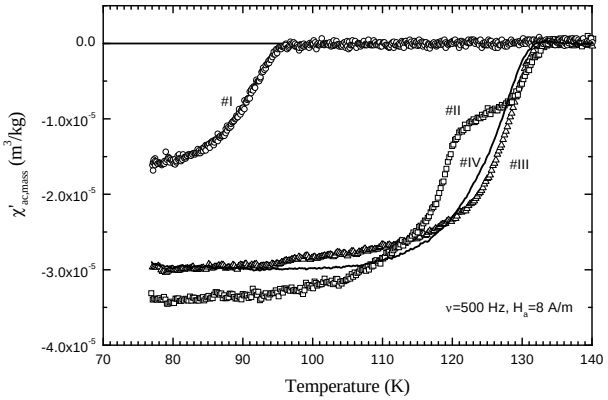

Figure 3. χ_{ac} as a function of temperature for samples Nos I, II, III and IV prepared with ff $= 0.70$ g cm^{-3}. Sample No I was prepared from a precursor obtained with oxygen partial pressure of $P_{O_2} = 0.25$ bar while samples Nos II, III and IV were prepared with $P_{O_2} = 0.1$ bar. For samples Nos I, II, III and IV the $ff_{Hg} = 0.000$, 0.000, 0.010 and 0.014 g cm^{-3} were used respectively.

Table 3. Refined structural parameters for the best $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ sample. The space group is $P4/mmm$ (No 123). The values obtained for the lattice parameters are $a = 3.8534(6)$ Å and $c = 15.742(4)$ Å. The final agreement factors are $R_{wp} = 18.6\%$, $R_{exp} = 9.42\%$, ($S = R_{wp}/R_{exp} = 1.97$) and CuK$\alpha$ wavelength was used.

Atom	x	y	z	n
Hg	0.000	0.000	0.000	0.88(6)
Re	0.000	0.000	0.000	0.12(3)
Ba	1/2	1/2	0.169(4)	1
Ca	1/2	1/2	0.44(6)	1
Cu_1	0.000	0.000	1/2	1
Cu_2	0.000	0.000	0.324(4)	1
O_1	1/2	0.000	1/2	1
O_2	1/2	0.000	0.297(9)	1
O_3	0.000	0.000	0.105(9)	1
O_{Re}	0.42(4)	0.42(4)	0.000	0.11(5)
O_{Hg}	1/2	1/2	0.000	0.05(3)

Based on the magnetic characterization, sample No IV has been chosen for detailed x-ray data analysis. The result reveals that there were small amounts of polycrystalline impurity phases such as $CaHgO_2$, $Ba_4CaCu_2O_y(CO_3)_{0.5}$, $Ca_{0.85}CuO_2$ and $BaCuO_{2+x}$. They have been considered in the Rietveld analysis and the typical fractions for those phases, which are on the limit of detection by x-ray diffraction, are given in table 2. The structural parameters obtained from the refinement are shown in table 3.

The Re ion in fact does substitute the Hg ion in the $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ compound and it is surrounded by the usual four oxygen ions located in the HgO plane and two extra oxygen neighbours, above and below, completing the octahedral coordination. Such a structural analysis has been already done by Kishio *et al* [32] for an

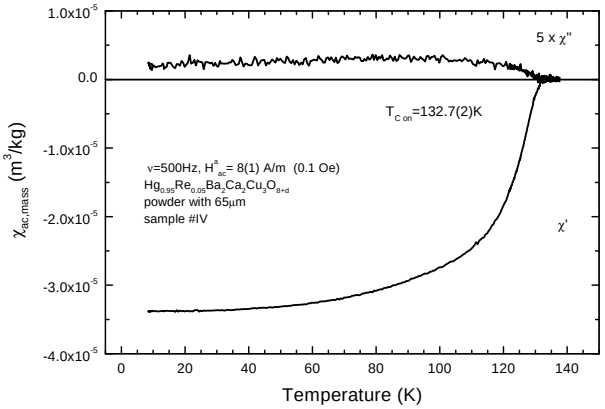

Figure 4. The magnetic shielding showed by the sample powder with 65 μm average diameter particles. χ''_{ac} shows a small effect. The intragrain effect is proportional to 80% of the maximum magnetic shielding.

$Hg_{0.75}Re_{0.25}Ba_2Ca_2Cu_3O_{8+\delta}$ sample, and both analyses are in agreement concerning the oxygen coordination number for the Re ion. The effect of Re doping is more effective on the c parameter, which is bigger for an Re content $x = 0.05$ than for $x = 0.25$, while the a and b parameters remain almost constant. This means that the chemical pressure acts mainly along the c axis as almost uniaxial strain.

The phase content determined for sample No IV is shown in table 2. Taking into account the other phases present and the conservation of the reaction stoichiometry, it is expected that the Re content present in the superconductor phase is closer to $x \approx 0.06$. This increase of the Re content is in agreement with the experiments of Reder *et al* [33]; however in our samples no signature of Hg-1212 phase was observed in the susceptibility curve and in the x-ray patterns. Therefore, we can conclude that Hg, Re-1223 phase is optimized when the sample is produced by the quartz tube method with an $ff_{Hg} > 0.01$ g cm^{-3} and the precursor has been treated with low oxygen partial pressure.

3.2. Ac susceptibility and resistance

Figure 4 shows the temperature dependence of the ac magnetic susceptibility data for a powder sample with controlled size smaller than 65 μm, chosen in order to reduce the influence of intergrain magnetic shielding. The maximum shielding for this powder occurs close to 40 K.

The ac susceptibility has two components, $\chi_{ac} = \chi'_{ac} + i\chi''_{ac}$. χ'_{ac} corresponds to the magnetic shielding and χ''_{ac} is related to a dissipation process. Considering the dissipation component χ''_{ac}, the intragrain region is associated with the low angle discordance defects between crystal planes while the intergrain one is associated with junctions between the grain regions. The reduced value of the χ''_{ac} signal indicates the small influence of the intergrain component. Considering the χ''_{ac} signal value and the Kramers–Kronig relations [34]

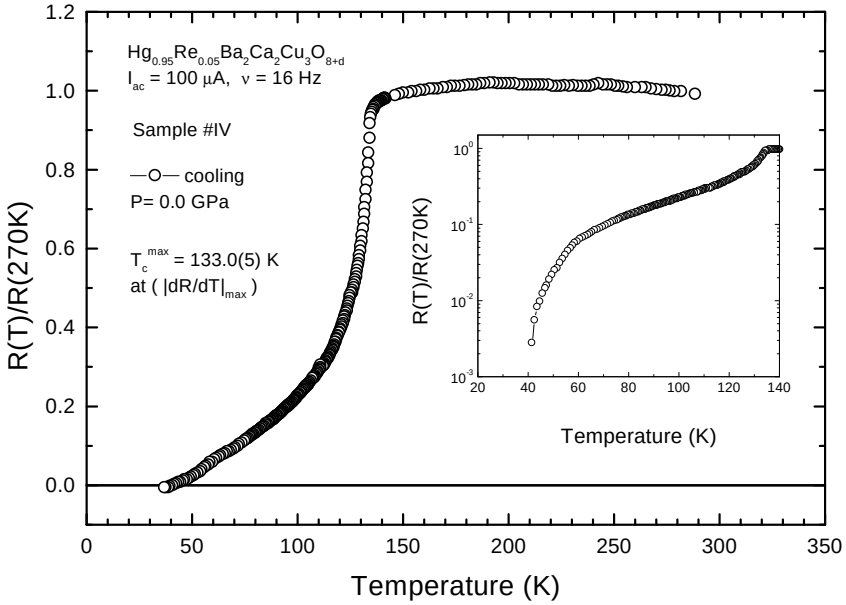

Figure 5. The pellet (sample No IV) resistance behaviour as a function of temperature measured by the four-probe ac method. The long tail represents a distribution of the different types of junction. The insert shows a logarithmic plot enhancing the drop at 40 K.

it can be estimated that only 20% of the maximum magnetic shielding, shown in χ'_{ac} at 10 K, is due to the intergrain effect.

Figure 5 shows the variation of the resistance with temperature at ambient pressure. The derivative $\mathrm{d}R/\mathrm{d}T$ shows a maximum at 133 K, despite a long tail remaining in R(T)/R(270) down to 40 K, which is attributed to the intergrain type of junction distribution. Zero resistance is only established at 40 K in agreement with the complete magnetic shielding accomplished at the same temperature in the ac susceptibility measurement. As can be seen, 60% of the resistance drop occurs in an interval of 10 K and there is no linear term of the resistance above T_C. The inset with a logarithm-scale plot shows more clearly the abrupt drop in the resistance close to 40 K.

3.3. Resistance under pressure

The typical temperature variation of resistance for zero and 0.92 GPa for sample No IV is shown in figure 6, indicating the expected increase of T_C with hydrostatic pressure. The inset with $\mathrm{d}R/\mathrm{d}T$ versus temperature displays two peaks that have been attributed to grain superconductivity (intragrains) and percolation between the grains (intergrains). The determination of the half width of the transition was made here with the criterion based on the different sensitivities displayed by the intergrain and intragrain $\mathrm{d}R/\mathrm{d}T$ under external pressure [35]. Following this argument, we decided to use only the half width found in the intragrain $\mathrm{d}R/\mathrm{d}T$ curve, resulting in a transition width of $\Delta \approx 5$ K. This value was determined from the fits of $\mathrm{d}R/\mathrm{d}T$ with two Lorentzian curves.

From the set of measurements, under similar conditions and different hydrostatic pressures, the variation of critical transition temperature can be determined as shown in figure 7. Analysing these data with a parabolic behaviour, already known for the Hg family, the maximum $T_C(P)$ would be expected between 2.5 GPa and 41 GPa, which are out of the pressure range available in our present experimental conditions. The fit quality is 0.98 733 as indicated in figure 7.

3.4. External hydrostatic pressure and chemical pressure

The discussion of chemical pressure effect will be based on the Rietveld analysis of the x-ray patterns obtained for our samples with $x = 0.05$ and 0.10. There is a clear reduction of volume (-0.43%) with increasing Re content. Our data are shown together with T_C values in table 4, where the most important information is that there is no variation of T_C. This behaviour as well as the volume reduction are in agreement with data already reported in the literature for the Hg, Re-1223 [32, 33] samples.

On the other hand, to discuss the effect of hydrostatic pressure we need to assume that the volume compressibility of our $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ sample is the same as determined for the Hg-1223 compound (close to 1% GPa^{-1} [36]). In this case a hydrostatic pressure around 0.9 GPa should lead to a cell volume reduction of -0.8%, which is the same order of magnitude as the one obtained by the variation induced by the chemical pressure. Despite this fact, the hydrostatic pressure causes a T_C increase of 3 K as can seen in figure 7.

For both cases, external hydrostatic and chemical pressure, there is a volume reduction of the cell, but only in the case of external hydrostatic pressure is there a variation of T_C. So it seems that the decrease of the unit cell under hydrostatic pressure leads to an increase of T_C, while the chemical pressure (mainly contraction along the c-axis) does not change T_C. Anisotropic pressure dependence of the superconducting transition temperature has been observed in a number of other high temperature superconductors

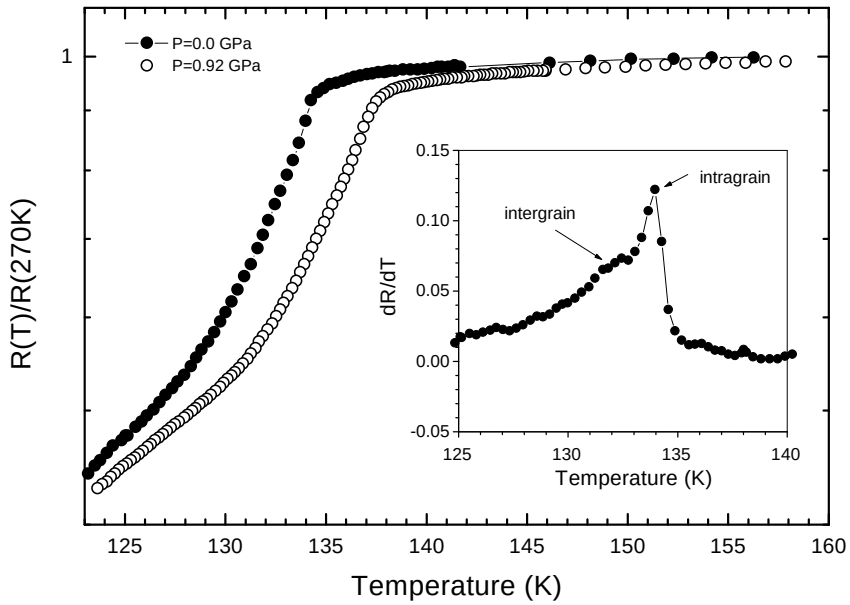

Figure 6. The pressure effect on the temperature dependence of the resistance (sample No IV). The inset with dR/dT shows the two peaks associated with intragrain superconductivity and percolation between the grains.

Table 4. The cell parameters as obtained from the Rietveld analysis and the parameters found in other works. The $T_{C\,onset}$ is related to ac susceptibility and the perceptual volume change takes into account the volume of $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ as V_0 and $\Delta V = (V - V_0)$.

Re (%)	$a = b$ (Å)	c (Å)	$S = R_{wp}/R_{exp}$	$\Delta V/V_0$ (%)	$T_{C_{on}}$ (K)	Ref.
0	3.8560(5)	15.853(2)	—	+ 0.45	134(1)	[32, 33]
5	3.8534(6)	15.742(4)	1.97	0	132.7(5)	This work
10	3.8513(7)	15.692(1)	2.79	−0.43	133.0(5)	[19]

[37–41]. It seems clear that the unit cell volume cannot be considered as the *unique* parameter affecting T_C in these complex materials.

The different T_C dependence, concerning external hydrostatic and chemical pressure, may be discussed on the basis of the pressure-induced charge transfer model (PICTM) modified by Almasan *et al* [42]. The variation of T_C can be given by the Neumeier and Zimmermann [43] equation:

$$dT_C/dP = dT_C^i/dP + [\partial T_C/\partial n][\partial n/\partial P] \qquad (1)$$

where the first term is an intrinsic variation of T_C with pressure, while the change in T_C due to the hole concentration, modified by the pressure, is given in the second term.

In the case of chemical pressure, there is an anisotropic volume reduction and $\partial T_C/\partial c \approx 0$, as shown in table 4. This is an indication that we are close to the optimal oxygen doping for both samples ($x = 0.05$ and $x = 0.10$), as suggested by other authors [37, 44]. This is also a condition for the vanishing of the second term, $[\partial T_C/\partial n][\partial n/\partial P] \approx 0$.

The intrinsic term in equation (1) seems to depend on the a, b lattice parameters [44]. Since in our samples they remain almost constant, this term will also vanish, $dT_C^i/dP \approx 0$. Therefore, $dT_C/dP = 0$ for chemical pressure.

In the case of external hydrostatic pressure, it is assumed that the sample $Hg_{0.95}Re_{0.05}Ba_2Ca_2Cu_3O_{8+\delta}$ has an optimal doping and the second term in equation (1) is expected to be zero. The T_C variation will be determined only by the intrinsic term, which can be evaluated as $dT_C^i/dP \approx 3.5$ K GPa^{-1}, if a linear fit is considered for the experimental data as shown in figure 6. It would be interesting to investigate how this fact depends on the Re concentration.

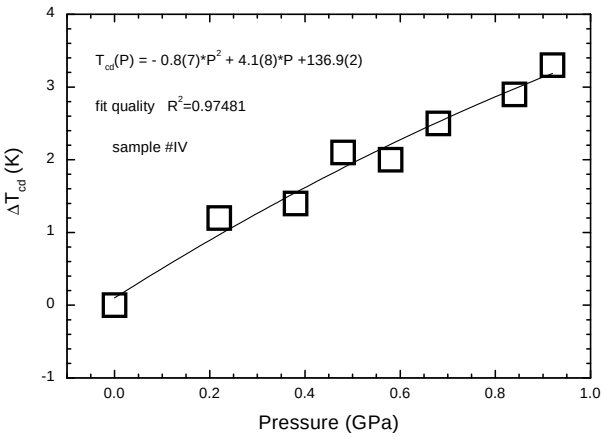

Figure 7. Pressure dependence of the transition temperature T_{cd} (T_{cd} as defined by D Tristan Jover *et al* [31]) obtained by the temperature variation of resistance under hydrostatic pressure in sample No IV.

The different effect induced by external hydrostatic pressure and chemical pressure seems to be related to the intrinsic term dT_C^i/dP. Such a kind of non-equivalence between external hydrostatic and chemical pressure has

already been found in other systems [28, 45] and some theoretical models have been proposed to investigate the intrinsic term as the important factor in T_C changes under pressure [44, 46, 47].

4. Conclusion

This work suggests a method to obtain single phase Hg, Re-1223 superconductor, with low Re content, without high pressure synthesis. Such result was achieved with the analysis of the variation of the pressure, and sintering temperature, as given by the TBA. The Hg filling factor was an important parameter to control ($\mathrm{ff}_{Hg} \geqslant 0.01$ g cm^{-3}) as well as the oxygen partial pressure (low) during the precursor preparation.

The variation of T_C with hydrostatic pressure, determined from resistance measurements, can be reproduced by a parabolic curve. This behaviour is similar to the one already determined for the Hg family of superconductors without Re doping. The maximum $T_C(P)$ for our sample is expected for pressures between 2.5 GPa and 41 GPa, which is above the limit of our present experimental conditions; however high pressure resistance measurements up to 30 GPa are under way in the University von Köln.

The pressure experiments have shown that there is a clear non-equivalence between chemical and external hydrostatic pressure for $Hg_{1-x}Re_xBa_2Ca_2Cu_3O_{8+\delta}$ in the $0.00 < x < 0.10$ range, and this different T_C dependence can be discussed in the framework of a modified PICTM. More detailed studies on samples with different Re content are being performed. They will allow us to obtain better understanding of the influence of the intrinsic term on the chemical and external hydrostatic pressure [48].

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