Pressure dependence of the superconducting critical temperature of the Tl_{0.5}Pb_{0.5}Sr_2Ca_{1-x}Y_xCu_2O_7 system

D. Tristan Jover, H. Wilhelm, and R. J. Wijngaarden
Department of Physics and Astronomy, Free University, De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands

R. S. Liu
Department of Chemistry, National Taiwan University, Roosevelt Road, Section 4, Taipei, Taiwan, Republic of China

(Received 22 October 1996; revised manuscript received 27 December 1996)

Using a cryogenic diamond anvil cell the pressure dependence of the superconducting transition temperature $T_c$ of Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ for $x=0.0$, 0.1, 0.2, and 0.35 has been measured resistively up to ~ 20 GPa. In high-$T_c$ superconductors there are two contributions to the pressure dependence of $T_c$: one related to pressure-induced charge transfer and one due to intrinsic effects. In the present experiment these contributions could be separated using a simple phenomenological model which incorporates the effect of changes in both the yttrium content $x$ and the applied pressure $p$ on $T_c$. In this system it is found that there hardly is any charge transfer by pressure so that the intrinsic pressure effect is the main contribution to $dT_c/dp$. The maximum $T_c$ which can be reached in this system is 112 K. [S0163-1829(97)07517-6]

I. INTRODUCTION

Since the discovery of superconductivity in the Tl-Sr-Ca-Cu-O system$^{1,2}$ it has taken some effort to improve the superconducting transition temperature $T_c$. The parent compound TlSr$_2$CaCu$_2$O$_7$ (Tl-1212 phase) is a metal, showing no signs of superconductivity at all down to liquid helium temperatures. At room temperature (300 K) TlSr$_2$CaCu$_2$O$_7$ has a resistivity of 7.2 mΩ cm which gradually decreases as temperature is lowered. Extrapolation of the resistivity curve to 0 K gives a residual resistance of 2.8 mΩ cm. Moreover, the nominal copper valency in this compound is +2.5. All of this indicates an excess of holes on the CuO$_2$ layers giving rise to a so-called overdoped state. The number of holes on these layers can effectively be reduced by either substituting Pb$^{4+}$ for Tl$^{3+}$ or Y$^{3+}$ for Ca$^{2+}$. As shown in Fig. 1, the structure of the resulting compound ideally is built up of alternating CuO$_2$ layers and (Tl,Pb)-O layers. The CuO$_2$ layers are essential for superconductivity to occur in these materials and are doped by the (Tl,Pb)-O layers which behave as charge reservoir as suggested by Hybertsen and Mattheiss$^3$ on the basis of band structure calculations. By now it seems well established that the superconducting and normal state properties of these and other related ceramic compounds depend strongly on the charge carrier density $n_h$ of the CuO$_2$ layers.$^{4,5}$ The charge carrier density is defined as the number of holes per CuO$_2$ layer and copper atom.

A systematic investigation of Tl$_{1-x}$Pb$_x$Sr$_2$Ca$_{1-y}$Y$_y$Cu$_2$O$_7$ was carried out by Liu et al.$^6,7$ By optimizing the oxygen content for a number of compounds with different $y$ and $x$, they were able to establish that at ambient pressure the highest $T_c$ of ~110 K is found for $y=0.5$ and $x=0.2$. Since many related compounds show an increase of $T_c$ with pressure$^{5,8-11}$ it is tempting to also try to further increase the $T_c$ of this system by applying pressure. Since the hole concentration is influenced both by the lead content $y$ and the yttrium content $x$, one of the two may be kept fixed and for the present study Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ was chosen.

This system with the Tl-1212 structure exhibits superconductivity over the entire range 0.0 ≤ $x$ ≤ 0.6. For $x=0.0$, $T_c$ has a value of 78 K. With increasing yttrium content $x$, $T_c$ increases to a maximum value of 108 K at $x=0.2$, and then decreases to 44 K at $x=0.5$. For $x≥0.6$, the system becomes semiconducting.

Apart from searching for the highest $T_c$, studying this

FIG. 1. Schematic representation of the crystal structure of Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$. Ideally this structure is built up of alternating CuO$_2$ layers and (Tl,Pb)-O layers which act as charge reservoir (Ref. 3).
system may give important information on the pressure dependence of high-$T_c$ superconductors. As is well known, 12–19 the application of pressure not only changes the hole concentration on the CuO$_2$ layers, but also changes their maximum $T_{c,max}$ as a function of hole concentration. By studying the pressure dependence of samples with different hole concentrations (i.e., different yttrium content $x$) these two effects can be discerned experimentally. This was done previously at ambient pressure by, for instance, Neumeier and Zimmermann 14 and by García-Muñoz et al. 19.

In this paper, the pressure dependence of $T_c$ of various Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ samples is studied up to $\sim 20$ GPa. In Sec. II a phenomenological model is presented, which describes $T_c(x,p)$ in a single simple formula. After a description of the sample preparation and the experimental details in Secs. III and IV, it will be shown in Sec. V that the experimentally observed behavior of $T_c$ with pressure for the different samples can be used together with the model of Sec. II to find both the intrinsic pressure dependence of $T_c$ and the amount of pressure-induced charge transfer.

II. PHENOMENOLOGICAL MODEL

It is generally accepted that the superconducting critical temperature $T_c$ in high-$T_c$ superconductors varies approximately as an inverted parabola with the hole concentration $n_h$. 20–23 Below a certain minimum hole concentration the compounds are not superconducting and in this region they show nonmetallic behavior. As the hole concentration on the CuO$_2$ layers is increased, $T_c$ increases reaching a maximum value $T_{c,max}$ at an optimal hole concentration $n_{h,max}$. For still higher values of the hole concentration, $T_c$ starts to decrease and eventually goes to zero. In this region the compounds behave as normal metals. In most high-$T_c$ cuprates it appears that optimal doping occurs at $n_h \approx 0.16$. Compounds with a lower hole concentration are said to be underdoped while compounds with a higher hole concentration are said to be overdoped. This behavior can be expressed 24–26 by the following simple equation:

$$T_c(n_h) = T_{c,max}[1 - \beta(n_h - n_{h,max})^2].$$

(1)

Considerable effort has been devoted in recent years to elucidate the pressure dependence of the superconducting transition temperature of high-$T_c$ superconductors. High-pressure experiments on these compounds are done in the hope that they provide some answers as to why superconductivity occurs at such high temperatures. They may also provide important clues in order to synthesize other superconducting compounds with even higher $T_c$'s at ambient pressure. 27 The important information on the mechanism of superconductivity is contained in the pressure dependence of $T_{c,max}$ [see Eq. (1)]. Unfortunately, due to the strong pressure dependence of $n_x$, the pressure dependence of $T_{c,max}$ is generally very difficult to find. As will be shown below, the present study of a series of compounds with, at ambient pressure, different values of $n_x$, allows one to derive $T_{c,max}(p)$. This is possible even if the pressure dependence of $\beta$ and $n_{h,max}$ is taken into account.

The pressure dependence of $n_h$ is due to charge transfer from the (Tl,Pb)-O layers in Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ to the CuO$_2$ layers as a result of the contraction of the Cu-(apical) O bondlength 28 which favors removal of antibonding electrons. Thus, pressure raises the hole concentration on the CuO$_2$ layers which explains the similarity between pressure and doping experiments. The following relation, therefore, is able to describe the $T_c$ vs $p$ behavior observed in many high-$T_c$ compounds: 5,8,9

$$T_c(p) = T_{c,max}[1 - \alpha(p - p_{max})^2].$$

(2)

In Sec. V it will be shown that even in Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$, where there is hardly any charge transfer by pressure, the experimental data can be reasonably described by this parabola.

III. SAMPLE PREPARATION AND CHARACTERIZATION

Samples with nominal composition Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ (0 $\leq$ x $\leq$ 1) were prepared by a solid state reaction as described in detail by Liu et al. 5,7 and Liang et al. 29 High purity CaCO$_3$, Y$_2$O$_3$, SrCO$_3$, and CuO powders from Aldrich Chemical Co. are thoroughly mixed in the appropriate stoichiometric amounts using a mortar and a pestle and subsequently calcined at 970 °C for 12 h in air to form a precursor. This precursor is then mixed with Tl$_2$O$_3$ and PbO, ground, and finally pressed into a pellet (10 mm in diameter and 2 mm in thickness) under a pressure of 0.2 GPa. In order to prevent loss of thallium and lead during sintering in a furnace at 950 °C for 3 h in flowing oxygen, the pellets are wrapped in gold foil. After sintering, the furnace is cooled down to room temperature at a rate of 5 °C/min. As determined by powder x-ray diffraction measurements 30 all the members of the solid solution Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ (Tl-1212) belonging to the tetragonal P4/mmm space group (see Fig. 1). More importantly, these measurements confirmed that the sintered samples are homogeneous both in structure and composition. 7

By now it has been established that substitution of Pb in the Tl sites 31–33 or Y in the Ca sites 34,35 not only stabilizes the crystal structure of the phase responsible for high temperature superconductivity but in addition also increases the volume fraction of superconducting material in the Tl-1212 phase. As mentioned in the Introduction and as previously proposed, 6 substitution of Y$^{3+}$ for Ca$^{2+}$ in the system Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ effectively reduces the hole concentration on the CuO$_2$ layers. Several experimental findings seem to corroborate this. With increasing concentration of Y$^{3+}$ in the Ca$^{2+}$ sites, the following effects have been observed: 6,7 (1) an increase in the $a$ lattice parameter as determined from Rietveld refinement of neutron powder diffraction data, which generally is attributed to a decrease in the average copper oxidation state, leading to longer Cu-O distances within the CuO$_2$ layers, (2) an increase in the room temperature resistivity, (3) a decrease in the effective number of holes determined from Hall coefficient measurements, and (4) an increase in the absolute value of the thermoelectric power. Contrary to the increase in the $a$ lattice parameter, the $c$ lattice parameter decreases. This is probably due to the fact that in an eightfold coordination the radius of the Y$^{3+}$ (1.019 Å) is slightly smaller than that of the Ca$^{2+}$ ion (1.12 Å). 36
Several Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{0.8}$Y$_{0.2}$Cu$_2$O$_7$ samples were subjected to annealing treatments which included slow cooling to 350 °C in oxygen and annealing at 500 °C and 600 °C in 2, 0.2, 0.009, and 0.0 % of oxygen in nitrogen at 1 bar. Following each of these annealings no significant shift in the diamagnetic onset temperature of 108 K was observed. Liu et al.\textsuperscript{17} hence conclude that this compound with the highest $T_c$ is very stable and does not exhibit any deviation of the oxygen stoichiometry. In all compositions the oxygen stoichiometry determined from neutron diffraction experiments was found to be very close to 7 and independent of the yttrium content $x$. As at ambient pressure, the sample with nominal composition $x=0.4$ showed a higher $T_c$ value (extrapolated from the $T_c$ vs $p$ curve) compared to the one reported by Liu et al.\textsuperscript{17} it is not inconceivable that the small piece used in the high-pressure experiment had a slightly lower yttrium content with as result a higher hole concentration and hence a higher $T_c$ value. Using $T_c$ as a calibration, $x$ should have a value of $\sim 0.35$ (see Ref. 7) instead of 0.4. Throughout the rest of this paper this value will be used in the calculations and the sample is consequently labeled $x=0.35$.

IV. EXPERIMENTAL DETAILS

Pressure is generated and applied to the samples using a cryogenic diamond anvil cell\textsuperscript{37} (DAC). Its principle of operation is described in detail by Scholtz et al.\textsuperscript{37} and by Tristan Jover et al.\textsuperscript{10,38} The applied pressure is determined in situ, close to the superconducting transition of the samples, with the ruby fluorescence method. After correction for the temperature-induced shift of the ruby $R_1$ fluorescence line,\textsuperscript{39} the calibration of Mao et al.\textsuperscript{40} is used. All experiments are made with the same pressure cell. The pressure is always changed at $\sim 185$ K and the data points are taken with increasing pressure only.

The temperature of the sample is measured using a standard platinum resistor placed in a copper block in which one of the diamonds is mounted. Since at low temperatures diamond has an even higher thermal conductivity than copper, there is good thermal contact between sample and thermometer. To check for possible thermal gradients in the body of the high-pressure cell, two other platinum resistors are mounted approximately 1 cm above and below the diamond anvils. The temperature difference is found to be 0.6 K. Interpolated linearly, this corresponds to a temperature difference across the sample of 3 mK.

The superconducting transition temperature $T_c$ of the sample is determined resistively using the standard four-probe technique. The electrical leads are placed on top of one of the diamonds. These leads consist of flattened gold wires with a diameter of 25 µm which are pressed onto the sample for electrical contact. The four-point resistance $R(T)$ of the sample as a function of temperature is then measured with a Keithley 2001 multimeter using a current of 1 mA.

V. EXPERIMENTAL RESULTS AND DISCUSSION

In Fig. 2 the $T_c$ values at ambient pressure (extrapolated values from the $T_c$ vs $p$ curves) of the investigated samples are plotted as a function of the yttrium content $x$. While the
The $T_c$ values obtained for all four samples are plotted as a function of pressure in Fig. 4. A parabolic pressure dependence of $T_c$ is found for all samples except for the one with $x = 0.0$. This sample shows an approximate linear $T_c$ vs $p$ dependence. For the nearly optimal doped sample ($x = 0.2$) $T_c$ reaches a maximum value of 112 K at ~8 GPa. A further increase in pressure only leads to a decrease in $T_c$. A similar behavior is also seen in the $x = 0.1$ and $x = 0.35$ samples.

In agreement with Eq. (2), the quadratic function

$$T_c(p) = b_0 + b_1 p + b_2 p^2$$

was used to fit the experimental data for each compound with different yttrium content $x$ in Fig. 4 where $T_c$ is expressed in K and $p$ in GPa. The fit parameters $b_i$ are given in Table I, the corresponding curves are the solid lines shown in Fig. 4. These fits will now be used to construct a single function $T_c(x,p)$ which describes all the data of Fig. 4. As a first step parabolas such as the one shown in Fig. 2, which holds for ambient pressure, are constructed at various pressures; i.e., the relation

$$T_c(x) = a_0 + a_1 x + a_2 x^2$$

is constructed for $p = 0.2, \ldots, 20$ GPa. Since in general the increment in pressure in the experiment is not constant, at each given pressure for all four $x$ values the corresponding $T_c$ values are obtained by the interpolation of Eq. (3) of which the appropriate coefficients are given in Table I.

As a result the fit parameters $a_i$ are obtained at all pressure values considered. To obtain a single function $T_c(x,p)$, a smooth function can be fitted to the parameters $T_c(x=0.0)$, $T_c(x=0.1)$, $T_c(x=0.2)$, and $T_c(x=0.35)$ as a function of pressure after rewriting Eq. (4) as follows:

$$T_c(x,p) = \left( a_0 - \frac{a_1^2}{4 a_2} \right) \left[ 1 - \frac{a_2}{a_0 - (a_1^2/4 a_2)} \right] \left( x + \frac{a_1}{2 a_2} \right)^2$$

$$= T_c^{\text{max}}(p) \left[ 1 - \beta^*(p) (x - x_{\text{max}}(p))^2 \right].$$

(5)

The pressure dependence of $T_c^{\text{max}}$, $\beta^*$, and $x_{\text{max}}$ is shown in Fig. 5. It turns out that in order to describe all these dependencies separately a simple quadratic function similar to Eq. (3) suffices. The fit parameters $c_i$ so obtained for each function are given in Table II. Equation (5) together with these parameters now completely defines $T_c(x,p)$. As an example $T_c(x,p)$ may be calculated for $x = 0.0$, 0.1, 0.2, and 0.35. The result of this calculation is shown as the dashed lines in Fig. 4. Clearly $T_c(x,p)$ very closely fits the experimental data, which shows that the procedure used here is justified. Of course not only the fit to the experimental data can be calculated, but indeed the whole $T_c(x,p)$ landscape can be investigated. The result is shown as a contour plot in Fig. 6: the maximum $T_c$ which can be reached in this particular system is 112 K. This value can be reached only under pressure at optimal yttrium content ($x = 0.21$). As stated above, this analysis is done with a corrected concentration value of $x = 0.35$ for one sample. If for this sample the nominal value $x = 0.4$ (which applies for the bulk from which it was taken) is used, the quantitative analysis is slightly modified. For example, the maximum $T_c$ would then occur for $x = 0.23$.

### Table I

<table>
<thead>
<tr>
<th>$x$</th>
<th>$b_0$</th>
<th>$b_1$</th>
<th>$b_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>78.4</td>
<td>-0.40</td>
<td>0</td>
</tr>
<tr>
<td>0.1</td>
<td>99.3</td>
<td>0.77</td>
<td>-0.057</td>
</tr>
<tr>
<td>0.2</td>
<td>105.2</td>
<td>1.5</td>
<td>-0.094</td>
</tr>
<tr>
<td>0.35</td>
<td>92.0</td>
<td>1.1</td>
<td>-0.098</td>
</tr>
</tbody>
</table>

FIG. 3. Typical resistance curves of Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{0.8}$Y$_{0.2}$Cu$_2$O$_7$ at two different pressures. The curves are normalized with respect to the resistance values measured at $T=80$ K. The superconducting transition temperature $T_c$ is defined as the intersection of the tangent through the inflection point of the resistive transition with a straight line fit of the normal state just above the transition as shown by the dashed lines. A clear shift of $T_c$ towards higher values is observed in going from 2.5 GPa to 10.8 GPa.

FIG. 4. Pressure dependence of $T_c$ of four differently doped Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$ samples. The solid lines are fits to the experimental data using a parabolic $T_c$ vs $p$ dependence, while the dashed lines result from a full $T_c(x,p)$ fit (see text).
FIG. 5. The values of $T_{c\text{max}}$, $\beta^*$, and $x_{\text{max}}$ at $p = 0.2, \ldots, 20$ GPa. The solid lines show the parabolic fits of which the parameters are given in Table II.

while the sharp dropoff at the upper right corner in Fig. 6 is reduced: the position of the 75 K isotherm as shown would then represent a 90 K isotherm.

Now Fig. 5 will be discussed in more detail. The pressure dependence of $T_{c\text{max}}$, which represents the intrinsic pressure dependence of $T_c$, shows a maximum around 8 GPa, consistent with Fig. 4. In general, a maximum for $T_{c\text{max}}$ as a function of pressure would be expected: due to the stronger coupling between CuO$_2$ layers $T_c$ increases until the layers are too close and deformation or other detrimental effects take over. The parameter $\beta^*$ defines the width of the parabola shown in Fig. 2, and corresponding ones at higher pressures. The increase of $\beta^*$ with pressure implies a slight narrowing of the parabola, which means that $T_c$ is more sensitively dependent upon doping, but also that the compound is superconducting in a narrower range of doping. In principle the parameter $x_{\text{max}}$ contains two contributions due to (i) the effect of doping by Y$^{3+}$, Pb$^{4+}$ and oxygen deficiency and (ii) the fact that the ambient pressure maximum of $T_c$ vs $n_h$ is not at $n_h = 0$ but at $n_h = n_{h\text{max}} \approx 0.16$. Incidentally, as explained above there is practically no oxygen deficiency in these compounds and doping due to it can be ignored. The pressure dependence of $x_{\text{max}}$ also contains these two contributions: the pressure-induced shift in $n_{h\text{max}}$ and in doping by Y$^{3+}$ and Pb$^{4+}$. Regrettably these two contributions cannot be separated in the present experiment.

It is of course interesting to try and relate $x$ to $n_h$; first the zero-pressure case is considered. As the high-$T_c$ superconductors are usually considered to be ionic, the charges can be assigned to each of the constituent cations (metal ions) and anions (oxygen ions) which are represented as point charges. Assigning the nominal valencies to the ionic constituents of Tl$_{0.5}$Pb$_{0.5}$Sr$_2$Ca$_{1-x}$Y$_x$Cu$_2$O$_7$, i.e., Tl$^{3+}$, Pb$^{4+}$, Sr$^{2+}$, Ca$^{2+}$, Y$^{3+}$, Cu$^{2+}$, and O$^{2-}$, the number of holes per CuO$_2$ layer per copper atom would be given by

$$n_h = 0.25 - \frac{x}{2}.$$  

(6)

The validity of this relation can be easily checked. The parabola given by Eq. (1) yields precisely $T_c = 0$ for $n_h = n_{h\text{max}} = \sqrt{1/\beta}$. The width of the parabola at its base is thus given by $\Delta n_h = 2 \sqrt{1/\beta}$; it is well known that $\Delta n_h \approx 0.22$. Using the fit to the experimental data in Fig. 2 it is found that $\Delta x \approx 0.8$, where $\Delta x$ is defined analogously to $\Delta n_h$. As a first approximation $n_h = \text{const} + (\Delta n_h / \Delta x)x$ or after substituting the values for $\Delta n_h$ and $\Delta x$ given above:

$$n_h = \text{const} - \frac{x}{3.6}.$$  

(7)

Comparing this relation to Eq. (6), it becomes clear that the CuO$_2$ layers in this particular system benefit only from about half of the chemical doping. Possibly some charge is trapped elsewhere, or not all Y$^{3+}$ replaces Ca$^{2+}$.

Now the magnitude of $\partial n_h / \partial p$ close to zero pressure is discussed. If the initial slope $\partial x_{\text{max}} / \partial p$ is entirely attributed to a change in the hole concentration $n_h$ (to obtain an upper bound) then it is found that $\partial n_h / \partial p \approx 3.9 \times 10^{-4}$ GPa$^{-1}$, close to the value of $5 \times 10^{-4}$ GPa$^{-1}$ found for CaLaBaCu$_2$O$_7$. Both CaLaBaCu$_2$O$_7$ and

FIG. 6. Contour plot of $T_c(x,p)$. The maximum $T_c$ which can be reached in this particular system is 112 K. This value can be reached only under pressure and at optimal yttrium content ($x = 0.21$).
\[ T_{\text{c}} = \frac{\text{pressure dependence of the superconducting critical temperature}}{\text{of several}} \]

One of the authors (D.T.J.) would like to thank M. Tristan Jover. H.W. acknowledges the Human Capital and Mobility Program of the European Community under Contract No. ERBCHBIICT 940952 for its financial support and the hospitality of the Free University in Amsterdam.

**ACKNOWLEDGMENTS**

Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several \( T_{\text{c}} = \frac{\text{pressure dependence of the superconducting critical temperature}}{\text{of several}} \) samples has been measured resistively under quasi-hydrostatic conditions. The \( T_{\text{c}} \) behavior for the different samples investigated can be explained in terms of a phenomenological model which basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.

\[ \text{VI. CONCLUSION} \]

\[ \text{Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several} \]

\[ \text{samples has been measured resistively under quasi-hydrostatic conditions. The} \]

\[ T_{\text{c}} \text{ behavior for the different samples investigated can be explained in terms of a phenomenological model which} \]

\[ \text{basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.} \]

\[ \text{Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several} \]

\[ \text{samples has been measured resistively under quasi-hydrostatic conditions. The} \]

\[ T_{\text{c}} \text{ behavior for the different samples investigated can be explained in terms of a phenomenological model which} \]

\[ \text{basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.} \]

\[ \text{Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several} \]

\[ \text{samples has been measured resistively under quasi-hydrostatic conditions. The} \]

\[ T_{\text{c}} \text{ behavior for the different samples investigated can be explained in terms of a phenomenological model which} \]

\[ \text{basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.} \]

\[ \text{Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several} \]

\[ \text{samples has been measured resistively under quasi-hydrostatic conditions. The} \]

\[ T_{\text{c}} \text{ behavior for the different samples investigated can be explained in terms of a phenomenological model which} \]

\[ \text{basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.} \]

\[ \text{Using a cryogenic diamond anvil cell the pressure dependence of the superconducting critical temperature of several} \]

\[ \text{samples has been measured resistively under quasi-hydrostatic conditions. The} \]

\[ T_{\text{c}} \text{ behavior for the different samples investigated can be explained in terms of a phenomenological model which} \]

\[ \text{basically involves two terms: one directly related to pressure-induced charge transfer and another more dominant one related to intrinsic effects.} \]
40 H. K. Mao, J. Xu, and P. M. Bell, J. Geophys. Res. 91, 4673 (1986).