

**Zeitschrift:** Helvetica Physica Acta  
**Band:** 62 (1989)  
**Heft:** 6-7

**Artikel:** Physical properties of Nd<sub>1.85</sub>Ce<sub>0.15</sub>CuO<sub>4-y</sub> at high pressure and with different oxygen contents  
**Autor:** Bucher, B. / Rusiecki, S. / Wachter, P.  
**DOI:** <https://doi.org/10.5169/seals-116144>

### **Nutzungsbedingungen**

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. [Mehr erfahren](#)

### **Conditions d'utilisation**

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. [En savoir plus](#)

### **Terms of use**

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. [Find out more](#)

**Download PDF:** 14.12.2025

**ETH-Bibliothek Zürich, E-Periodica, <https://www.e-periodica.ch>**

## PHYSICAL PROPERTIES OF $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{4-y}$ AT HIGH PRESSURE AND WITH DIFFERENT OXYGEN CONTENTS

B.BUCHER, S.RUSIECKI and P.WACHTER,  
Laboratorium für Festkörperphysik, ETH-Hönggerberg, CH-8093 Zürich

We have measured initial susceptibility on  $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{4-y}$  with  $y$  varying from 0.02 to 0.32.  $T_c$  was quite insensitive to the different oxygen contents. The pressure dependence  $dT_c/dp$  for a compound with  $y = 0.03$  was determined to be  $-0.04$  K/kbar.

### Introduction

Since the discovery of electron-doped superconductivity in high- $T_c$  cuprates [1], each model on high- $T_c$  superconductivity has had to suffer a checking whether it is symmetric upon doping of either holes or electrons. A single-band model can be thought of to accomplish this symmetry. The theories based on holes with spin  $S = 1/2$  fail to explain superconductivity with spin-holes on the  $\text{Cu}^{1+}$  ions. However, from the beginning Wachter and Degiorgi [2] and de Jongh [3] have proposed a polaronic model in which they postulated a singlet state of the  $\text{Cu}^{3+}$  ion. The  $S = 0$  state of  $\text{Cu}^{3+}$  had been an issue but now from the  $\text{NdCeCuO}$ -compounds it turns out unambiguously that it is a spin-hole responsible for superconductivity.

### Experiment, Results

We have prepared the  $\text{NdCeCuO}$  compound by mixing appropriate amounts of  $\text{CeO}_2$ ,  $\text{Nd}_2\text{O}_3$  and  $\text{CuO}$  to achieve a composition of  $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_4$ . The mixed oxides were calcined in air at  $950^\circ\text{C}$  for 10 hours, pressed into pellets and sintered in air at  $1150^\circ\text{C}$  for 12 hours. The samples were quenched in air to room temperature. The as prepared material was not superconducting. Then the samples were placed into a Perkin-Elmer thermo-analyzer and quantitative amounts of oxygen were removed by heating up to  $1140^\circ\text{C}$  in an atmosphere of pure argon gas for different times. When the samples had reached the desired oxygen content they were quenched with a cooling rate of  $10^\circ\text{C}/\text{min}$ . Beginning from an oxygen deficiency of  $y = 0.02$  per formula unit superconductivity was observed with  $T_c$  near 23 K. Up to  $y = 0.22$  the samples were single phase with a  $T_c$  not changing appreciably. Typical curves of the ac-susceptibility are shown in Fig. 1. The sample with  $y = 0.32$  was investigated by X-ray diffraction to have two phases. Probably one of them (nonsuperconducting) is responsible for the magnetic response at 8 K. The lattice parameters of a specific superconducting compound with  $y = 0.04$  were  $a = 3.947(\pm 0.001)\text{\AA}$  and  $c = 12.08(\pm 0.002)\text{\AA}$ .

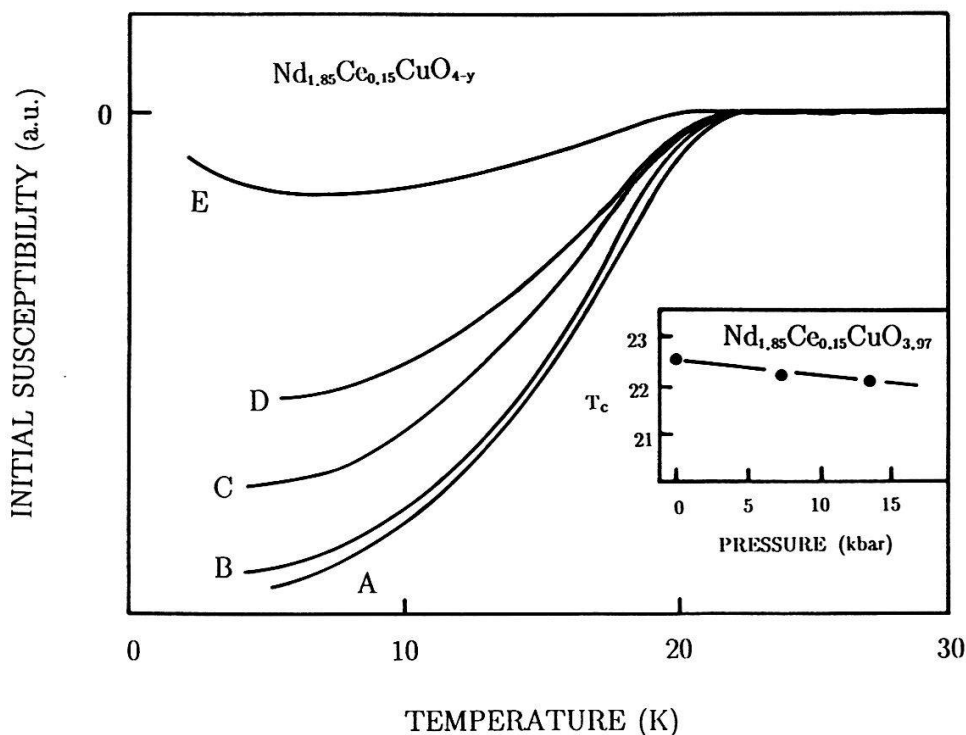
Further we have measured the pressure dependence of  $T_c$  up to 15 kbar as described in a previous paper [4]. There was only a weak pressure dependence of  $dT_c/dp = -0.04$  K/kbar (see inset of Fig.1).

### Discussion

It is amazing that the variation of the oxygen content does not influence the transition temperature. A too large loss of oxygen ( $y > 0.22$ ) results in a transformation to a red-brown phase. We believe that the outgoing oxygen comes from the  $(\text{Nd,Ce})\text{O}$ -planes between the superconducting  $\text{CuO}_2$  sheets. As Ce can exist in two valence states the charge balance can be achieved by the transition  $\text{Ce}^{4+} \rightarrow \text{Ce}^{3+}$ . Thus, the  $\text{CuO}_2$  plane is stable and even more two-dimensional than in other superconducting cuprates.

Let us look at the pressure dependence. Assuming a band model, pressure causes a broadening of the bandwidth. However, all cuprates have more or less the same superconducting  $\text{CuO}_2$ -planes and thus a similar band structure. Therefore, upon applying pressure, they should behave in a similar way. But the pressure dependence  $dT_c/dp$  of the superconducting cuprates differs within the large range of  $-0.05$  to  $0.6$  K/kbar which is not very consistent with the band-picture.

We suggest a model of exchange coupled bipolarons as described by Wachter and Degiorgi [2]. In this model the concentration of polarons ( i.e. the concentration of  $\text{Cu}^{3+}$  resp.  $\text{Cu}^{1+}$  ) is crucial. At high pressure the apical oxygen ion is shifted towards the  $\text{CuO}_2$ -plane and can serve as a doping reservoir. The more apical O-ions available the more effective will be an applied pressure to adjust the optimal concentration. From this point of view it seems reasonable that the  $(\text{La,Ba})_2\text{CuO}_4$  family with two apical O-atoms and the  $\text{YBa}_2\text{Cu}_4\text{O}_8$  and  $\text{YBa}_2\text{Cu}_{3.5}\text{O}_7$  [5] compounds with two chains resp. alternatively two and one chain as intercalation exhibit a strong pressure dependence. The  $\text{YBa}_2\text{Cu}_3\text{O}_7$  composition with only one apical oxygen is to show a lower  $dT_c/dp$  as is really the fact. For the  $\text{NdCeCuO}$ -compound with no apical oxygen above  $\text{Cu}(2)$ , it is not surprising that we even have detected a negativ  $dT_c/dp$ .



**FIG. 1** Initial susceptibility of  $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{4-y}$  with the different oxygen contents  $y$  : A: 0.03, B: 0.07, C: 0.02, D: 0.21, E: 0.32. The inset shows the pressure dependence of  $T_c$  of  $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{3.97}$ .

- [1] Y. Tokura, H. Takagi and S. Uchida, *Nature* **337**, 3345 (1989)
- [2] P. Wachter and L. Degiorgi, *Solid State Commun.* **66**, 211 (1988)
- [3] L. T. de Jongh, *Solid State Commun.* **65**, 963 (1988)
- [4] B. Bucher, J. Karpinski, E. Kaldis and P. Wachter, *Physica C* **157**, 478 (1989)
- [5] The pressure dependence of  $\text{YBa}_2\text{Cu}_{3.5}\text{O}_7$  was determined to be  $dT_c/dp = 0.45$  K/kbar (to be published elsewhere)