In-plane and out-of-plane temperature dependencies of the resistivity in single crystals and films of Nd_2CuO_4

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Abstract

The temperature dependencies of the in-plane ρ_{ab}(T) and out-of-plane ρ_c(T) resistivities of two groups of Nd_2CuO_4 single crystals (films and bulk single crystals) was investigated in a temperature range 20-300 K. The effect of modified heated treatment and annealing conditions on transport properties of the pra-crystals Nd_2CuO_4 was studied. It was found that nonstoichionometric disorder leads to different dependencies of the resistivity both ρ_{ab}(T) and ρ_c(T).

Key words: transport properties; anisotropy; single crystals; films

1. Introduction

Superconducting compounds based upon the T' phase of Nd_2CuO_4 system were discovered in 1989 [1]. Pure Nd_2CuO_4 forms a body-centered tetragonal structure with square planar coordination of the oxygen ions. Superconductivity in Nd_2CuO_4 system appears for example with Ce-doping in $Nd_{2-x}Ce_xCuO_4$ and after annealing in the reduced atmosphere. Moreover T_c value is very sensitive to the reduction process [2]. The varying of the one can result in enhancement of doping region where superconductivity is appear [3], [4]. The Nd-compounds with the perovskite-like structure are characterized by the property of reversible absorption and desorption of the oxygen. But as we know nobody investigated the treatment influence on this material without doping. The aim of the present work is to study the effect of modified heated treatment and annealing conditions on transport properties of the pra-crystals Nd_2CuO_4.

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2. Experiment

Flux separation techniques were used for growing of the first group of the samples - single crystal films Nd_2CuO_4 [5] :three films (001) – "as grown", "after annealing in O_2" (60 min, 500^0C, 1.01 bar) and "after annealing in vacuum" (60 min, 780^0C, $1.33{\cdot}10^{-5}$bar) had a good quality according X-ray diffraction data.

The second group of the samples: four Nd_2CuO_4 bulk single crystals were grown by the flux technique in aluminia crucible [3], three of them were encapsulated in polycrystalline material $Nd_{1.85}Ce_{0.15}CuO_4$ and then heated during 72 hours in argonium at temperatures 1000^0C, 1025^0C and 1050^0C (Nd1000, Nd1025, Nd1050).

3. Results and discussion

C-axis lattice constant for three different films and four single crystals (Table 1) were estimated from X-ray diffraction data (Co-K_α radiation). They are a little difference in two groups of our samples, but in both

cases we have found the change of the lattice constants. In bulk single crystals c decreases with increase of the annealing temperature.

Table 1

Sample	Treatment	c (Å)	ΔT (K)	ΔE (meV)
$Nd_2CuO_4/SrTiO_3$	as grown	12.177	80-150	34
	annealing in vacuum	12.1854	70-180	25
	annealing in O_2	12.1596	80-150	45
Nd_2CuO_4	as grown	-	80-290	60
			30-45	10.5
	Nd1000	12.143		-
	Nd1025	12.138	80-170	50
	Nd1050	12.134		-

It was found that all single crystal films and as grown bulk single crystal have an activating dependencies of the resistivity ρ_{ab}(T) in some temperature ranges (see Fig.1 and Table 1). An increase of the annealing temperature changes the temperature dependencies of the resistivity in bulk single crystals. So, for the sample Nd1025 we observed a dependence with $\Delta E \cong 50$ meV, but the ρ_{ab}(T) of Nd1000 is more weak and obey to the law $\sim T^{-1}$. For the sample Nd1050 we observed variable range hopping conduction in the range 40-240 K.

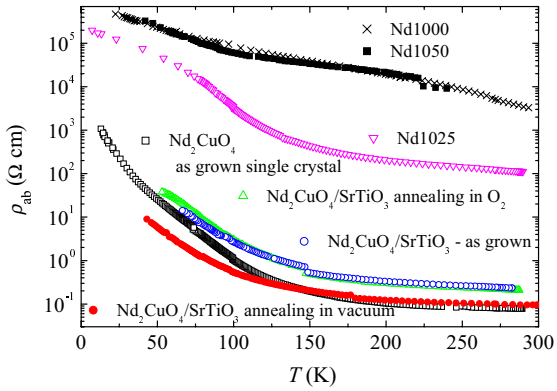

Fig. 1. Temperature dependencies of ρ_{ab} for single crystals and films.

Fig.2 shows the out-of-plane temperature dependencies of the resistivity for bulk single crystals. As grown single crystal have an activating dependencies in two temperature range with different activation energies: 100-300K $\Delta E \cong 17$meV and in the range 50-100K $\Delta E \cong 32$meV. And any change of the annealing regime leads to the change of the temperature behavior of the resistivity: it can see that the sample Nd1025 and Nd1050 have not activating dependencies of the resistivity except Nd1000, where was found

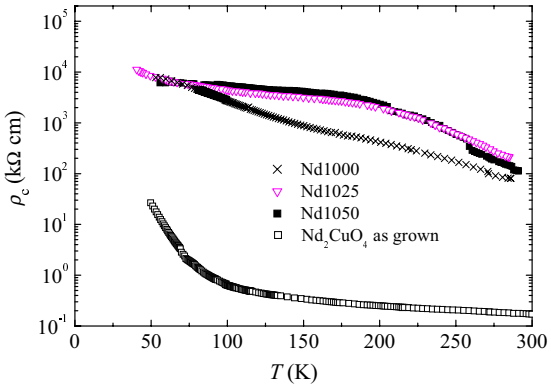

Fig. 2. Temperature dependencies of ρ_c for single crystals.

a variable range hopping conductivity in the range 80-240K. And values of the ρ_c after any annealing reach $\sim 100\,k\Omega\times$cm at 300 K (for as grown bulk single crystal $\rho_c \cong 200\,\Omega\times$cm).

We have found that the temperature dependencies of the anisotropy coefficient of the resistivity have the nonmonotonous behavior. Two samples (Nd1025 and Nd1050) have a maximum of the anisotropy coefficient around T=150-200K. $\rho_c/\rho_{ab} \cong 10^3$ for as grown single crystal and increase after annealing up to $\rho_c/\rho_{ab} \cong 10^4$ for Nd1025. So, additional annealing of pra-crystals Nd_2CuO_4 leads to essential increase of the resistivity along c-axis due to removing of the nonstoichiometric oxygen [4],[6]. And interplay between growth conditions and annealing temperature will permit to expand the superconducting region for underdoped compound of $Nd_{2-x}Ce_xCuO_4$.

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