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Investigation of Magnetic Anisotropy of the Nd_2CuO_4 Single Crystals

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Abstract. Investigations of the arising and disappearing of the 90° anisotropy of the magnetic properties of Nd_2CuO_4 , when magnetic field, with orientations in the (001) plane, is increased at $T \sim 4.2\text{K}$ are described. Experiments are made with v.s.magnetometer, which can measure three components of the magnetic moments.

1. INTRODUCTION

Investigations of the magnetic properties of Nd_2CuO_4 single crystals of $I4/mmm$ structure are in the current interest as this material with two kind of magnetic ions is used for HTS. In this material Cu magnetic ions are antiferromagnetically ordered from $T_N = 255\text{K}$, Nd magnetic moments are in paramagnetic state above $1.5\text{-}2\text{K}$ with strong polarization of Nd along Cu magnetic moments at $T \sim 4.2\text{K}$, [1,2]. Dependencies of the components of the sample magnetic moments, along magnetic field and perpendicular to it, from magnetic field and it's orientations in the (001) plane of Nd_2CuO_4 at $T \sim 4.2\text{K}$ are investigated in this work.

2. EXPERIMENTAL EQUIPMENT

Dependencies of the three perpendicular components of the sample magnetic moments from the magnetic field - $M_{x,y,z}(H)$ and from the magnetic field orientations with respect to crystallographic axis of the samples - $M_{x,y,z}(H, \varphi)$ with accuracy of the separate investigations of $\vec{M}$ components $\sim 10^{-2} - 3 \cdot 10^{-3}$ and sensitivity $\sim 10^{-6}$ can be investigated with the v.s.magnetometer, [3]. In the Fig.1 the arrangement of the M1, M2, M3 measuring and control M4 coils with respect to the X, Y, Z coordinates of the v.s.magnetometer and it's scheme are presented. Samples vibrate along vertical OZ direction, perpendicular to the orientation of the applied magnetic field - OX direction. Axis of the measuring coils are oriented along OZ direction. Using of the control M4 coils allows a deviation of the measuring and control signals. Divided signals from the M1, M2, M3, measuring coils, which are determined by the values of the components of the sample magnetic moments on the OX, OY, OZ directions are amplified and sent to the "Y" coordinate of the R.C. "Vectra". Signals, which are determined by the values of the applied magnetic fields, or angles of the sample rotation around OZ direction are sent to the "X" coordinate of P.C. Ranges of the magnetic fields $0 - 85\text{kOe}$. and temperatures $1.5 - 300\text{K}$ are used in the device, [3]. The calibration of the magnetometer and control of the separate measuring of the components of the sample magnetic moments are made with antiferromagnetic MnF_2 single crystals, [3], at liquid helium temperatures.

Fig.1. Arrangement of the M1, M2, M3 measuring, M4 control coils and the scheme of the v.s.magnetometer

3. RESULTS AND DISCUSSIONS

The arising and disappearing of the 90° anisotropic $M_{x,y}(H)$ and $M_{x,y}(H_0, \varphi)$ dependencies from magnetic field and its orientations in the (001) plane of the Nd_2CuO_4 , when the magnetic field, with orientations in this plane, is increased, are observed at liquid helium temperatures. The ratio of the observed magnetic moments $M_y(H)/M_x(H) \sim 10^{-2}$. At $T=4.2\text{K}$ and magnetic field orientation along [100] axis magnetic susceptibility of the sample $\chi = (1.83 \pm 0.06)10^{-1}\text{CGSM/mol}$. The $M_{x,y}(H_0, \varphi)$ dependencies of Nd_2CuO_4 single crystal at different values and orientations of the magnetic fields in the (001) plane of the sample at $T=1.8\text{K}$ are presented in Fig.2a,b,c. Orientations of the [100] and [110] axis, when applied magnetic field is oriented along these axis are presented in Fig.2 also. Values of the observed $M_{x,y}(H_0, \varphi)$ components of the magnetic moments and their dependence from the temperature are determined by Nd magnetic moments, as the ratio of the magnetic susceptibilities of the ordered Cu and paramagnetic Nd magnetic moments at $T \sim 4.2\text{K}$, $\chi(\text{Cu})/\chi(\text{Nd}) \sim 10^{-3}$. The arising of the anisotropy of the $M_x(H)$ and $M_x(H_0, \varphi)$ dependencies and appearing of the $M_y(H_0, \varphi)$ dependencies are observed from the magnetic fields $H_0 \sim 8.4\text{kOe}$. On the $M_y(H_0, \varphi)$ dependencies, when the applied magnetic field is increased, from $H \sim 20\text{kOe}$ (at $T=1.8\text{K}$) there is observed the arising of the quick change of the $M_y(H_0, \varphi)$ at the magnetic field orientations along [100] and [010] axis. At the magnetic fields higher then $H_0 \sim 60\text{kOe}$. and at the saturation of the Nd magnetic moments along applied magnetic field anisotropy of $M_x(H)$ and $M_{x,y}(H_0, \varphi)$ and values of $M_y(H)$ and $M_y(H_0, \varphi)$ dependencies decrease, Fig.2 a,b,c.

Fig.2a,b,c. $M_{x,y}(H_0, \varphi)$ dependencies of Nd_2CuO_4 from $\vec{H}$ orientations in (001) plane. $M_x(H_0, \varphi)$ at $H_0=5.4, 33.8\text{kOe}$. curves 1, 2, $T=1.8\text{K}$; $H_0=62\text{kOe}$. curve 3, $T=1.9\text{K}$. $M_y(H_0, \varphi)$ at $H_0=5.4, 26.4, 84.4\text{kOe}$. curves 4, 5, 6. $T=1.8\text{K}$

Dependencies of the $M_{x,y}(H)$ and $M_{x,y}(H_0, \varphi)$ magnetic moments from values of the magnetic field and its orientations in the (001) plane of the sample can be explained by polarization of Nd along Cu magnetic moments with assumption about non collinear structure of magnetic ordering of Cu magnetic moments, when Cu magnetic moments are oriented along [100] and [010] axis, [2]. Appearance of anisotropic $M_{x,y}(H_0, \varphi)$ dependencies at temperatures $T \sim 4.2\text{K}$ are explained by existence of two magnetic phase transitions, connected with rotations of Nd(Cu) magnetic moments to perpendicular to $\vec{H}$ directions, when applied magnetic field is oriented along [110] axis and [100] axis, $H_{c1}(T)$ and $H_{c2}(T)$, and by saturation of Nd magnetic moments along $\vec{H}$ in high magnetic field. At $T=1.8\text{K}$, magnetic fields $H_{c1} \sim 8.4\text{kOe}$. and $H_{c2} \sim 46\text{kOe}$. The Nd and Cu magnetic systems can be investigated separately with the $M_{x,y}(H)$, $M_{x,y}(H_0, \varphi)$ experiments in the magnetic fields $H \geq 120\text{kOe}$. at the saturation of the Nd magnetic moments along applied magnetic fields.

4. CONCLUSIONS

Arising and disappearing of the anisotropy of the magnetic properties of the Nd_2CuO_4 single crystals in (001) plane of the sample, which are connected with rotation of the Nd(Cu) magnetic moments to the perpendicular to the applied magnetic field direction at the increasing of the applied magnetic field at liquid helium temperatures are investigated with v.s.magnetometer, which can measure three perpendicular components of the sample magnetic moments.

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