Incommensurate properties of high-T_c superconductor $YBa_2Cu_3O_{6.93}$

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Abstract

The resonance and incommensurate peaks in optimally doped high- T_c superconductor $YBa_2Cu_3O_{6.93}$ are observed by means of TOF neutron scattering technique in a wide q-E space. Overall dynamical properties around (π, π) suggest the incommensurability of $\delta \cong 0.1$ (at E=36 meV) corresponds to the previous triple-axis measurement. Obtained δ=0.1 is smaller than that expected from stripe model. In the high frequency region it is also found the same type of resonance and incommensurate peaks at E=53 meV.

Key words: superconductivity; incommensurate; $YBa_2Cu_3O_{6.93}$; neutron scattering

1. Introduction

Despite much work on high-T_c cuprates there still remains obscurities on the contributions of magnetism and phonons. The discovery of incommensurate (IC) properties in $La_{2-x}Sr_xCuO_4$ has been expected to solve the role of magnetism to the high-T_c superconducting mechanism [1]. It is crucial to investigate if this 2-dimensional spin correjBmeBKrVdnklations (stripes) are related to a realization of high-T_c superconductivity. In particular the dynamical properties of these correlations segregated by charge stripes could provide us much information. Here we report the dynamical properties of IC peak of optimally doped high-T_c superconductor $YBa_2Cu_3O_{6.93}$ in a wide q-E space.

In $YBa_2Cu_3O_y$ (YBCO) system numerous neutron experimental work have been done so far [2], however, much of these experiments were on "under-doped" YBCO system. It is known that strong IC spin fluctuation and weak resonance peak intensity are observed in low doping region, on the contrary near the optimally doping concentration, resonance peak is luminous and IC peak intensity fade away. We concentrate on the optimally doped sample with T_c=92.5 K in order to obtain the whole dynamical structure in the vicinity of antiferromagnetic zone center (π, π).

Inelastic neutron scattering experiment was performed at the ISIS neutron facility in Rutherford-Appleton Laboratory using MAPS spectrometer which is optimized to measure high energy magnetic excitations with pulsed neutron source. Several single crystals are oriented on Al plate with $c//k_i$ and sample weight are 30 grams in total. Incident neutron energy of E_i=64 and 80 meV were adopted to maximize the intensity around excitation energy in the range of 40< E <50 meV. In order to monochromize the incident neutron beam and optimize the neuron flux and resolution, suitable choppers and frequency of chopper rotation were selected, which yields the

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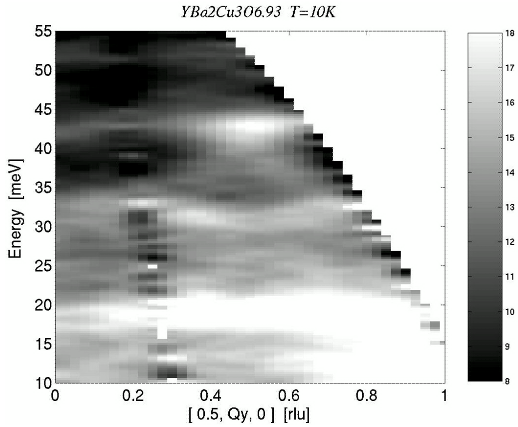

Fig. 1. Phonon and magnon excitation contour map sliced (0.5, Qy, 0) via magnetic zone center (π, π) (Qy=0.5).

energy resolution 2.2 meV for E_i=64 meV.

2. Results

The obtained overall $S(q,\omega)$ in the vicinity of (π, π) after correction of detector efficiency and Bose population factor is depicted in Fig. 1 as a contour plot. Below distinctive resonance peak at 41 meV, IC peak is lying in the range of 35< E <40 meV as arch shape reaching the intense phonon branch at 33 meV. Also much weight at (π, π) and E=26 meV are observed. Fig. 2 shows 1D-cut at (π, π) both T=10 and 110 K (> T_c). Due to the phonon branch there observe some intensities at E=43 meV even above T_c. To avoid the phonon contribution a subtracted data from 10 K to 110 K is plotted at lower panel on Fig. 2. Decreasing temperature spectral weight around 25 meV which corresponds to spin excitation shifts to resonance peak intensity.

The series of constant-E cut at various energy tells us that an incommensurability is δ ≅0.1 (rlu) at E=36 meV. Below 36 meV the IC peak intensity diminishes rapidly. Hence, it is not trivial to give a correct incommensurability at this energy. In Fig. 1 one can see IC peak close to phonon dispersion and it seems that the phonon intensity are enhanced at closing point. This implies a possible phonon-magnon coupling, and the idea based on stripe model prefer this type of spin-lattice correlation due to the spin and charge segragation. As highly underdoped $YBa_2Cu_3O_{6.35}$ charge ordering and magnetic IC peak has been found in recent year [4]. These results indicate the role of stripe-phase in YBCO. However, in the optimally doped system, situation is not the same. Especially obtained incommensurability δ is not expected from stripe model.

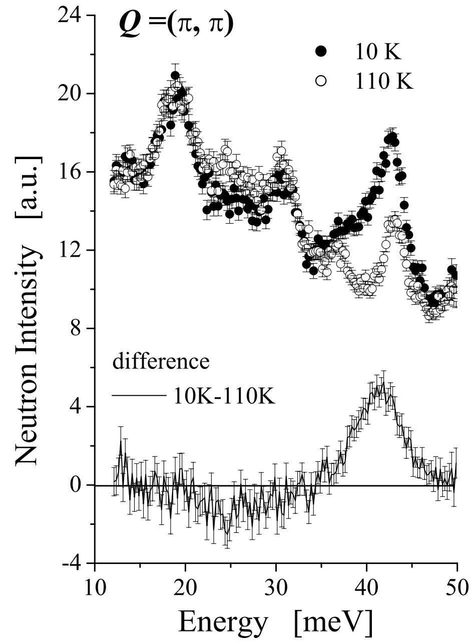

Fig. 2. Excitation spectrum at (π, π) T=10 and 110 K (well below and above T_c). The lower represents the difference between these temperature.

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