Freezing of stripes in lightly-doped \( \text{La}_{2-x}\text{Sr}_x\text{CuO}_4 \) as manifested in magnetic and transport properties of untwinned single crystals

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**Abstract**

Resistivity and magnetization measurements are used for studying the transverse sliding of AF domain boundaries in lightly doped \( \text{La}_{2-x}\text{Sr}_x\text{CuO}_4 \). We discuss that it is the freezing of the transverse boundary motion that is responsible for the appearance of “spin-glass” features at low temperatures.

**Key words:** stripes; antiferromagnetic state; high-\( T_c \) cuprates

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In high-\( T_c \) cuprates, charges and spins in the \( \text{CuO}_2 \) planes tend to self-organize in a peculiar striped manner, where the doped holes form quasi-1D “charged stripes” separating antiferromagnetic (AF) domains [1–5]. Manifestations of the unidirectional AF domain (stripe) structure in lightly doped \( \text{La}_{2-x}\text{Sr}_x\text{CuO}_4 \) (LSCO) have been found in neutron scattering [1] and in such macroscopic properties as magnetic susceptibility [3] and resistivity [4,5]; in particular, remarkable in-plane resistivity anisotropy [5] has shown that the charge motion is actually facilitated along the stripe direction. Here we report that the resistivity and magnetization can also be used for studying the transverse sliding of the AF domain boundaries, and show that the stripe freezing in lightly doped LSCO coincides with the transition into the “spin-glass” state.

The details of LSCO crystal growth and detwinning (the crystals were detwinned to avoid the stripe pinning by crystallographic twin boundaries) along with details of measurements are described in Refs. [3–5].

Owing to the spin canting induced by the Dzyaloshinskii-Moriya interaction, the AF order in LSCO is always accompanied with a weak ferromagnetic component [6]. At zero magnetic field, the weak ferromagnetism is hidden: the direction of canted moments depends on the local phase of the AF order, and is

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![Fig. 1. (a-d) Motion of AF domain boundaries in LSCO upon the weak-ferromagnetic transition; gray arrows indicate the direction of canted moments, which is uniquely linked with the phase of the AF order. (e) Magnetization behavior (\( H \parallel c \)) of \( \text{La}_2\text{CuO}_4 \) illustrating the transition into the WF state.](image-url)
opposite in neighboring \( \text{CuO}_2 \) planes (Fig. 1a). Apparently, if \( \text{CuO}_2 \) planes themselves contain AF domains with opposite phases, the canted moments form a similar pattern in the in-plane direction, changing their sign upon crossing the antiphase AF-domain boundaries (Fig. 1b). A magnetic field applied along the \( c \)-axis couples with the canted moments and eventually causes a transition into the weak-ferromagnetic (WF) state \([6]\), where the phase of the AF order is unified and all the canted moments are aligned along the field direction (Fig. 1d); the corresponding step-like increase in the magnetization is illustrated in Fig. 1e. Whatever the initial magnetic state is – a homogeneous AF order (Fig. 1a) or a striped domain structure (Fig. 1b) – the transition into the WF state should involve the transverse motion of the antiphase domain boundaries as shown in Fig. 1c. This opens an intriguing possibility of studying the kinetics of the transverse domain-boundary (stripe) sliding.

A large change in the resistivity at the WF transition \([6]\) points to the magnetoresistance (MR) as the most convenient probe to watch the transition kinetics. Figure 2 illustrates the MR behavior in a \( \text{La}_{0.99}\text{Sr}_{0.01}\text{CuO}_4 \) crystal upon increasing \((\circ)\) and decreasing \((\bullet)\) magnetic field at a rate of 0.4 T/min.

![Fig. 2.](image)

**Fig. 2.** The \( c \)-axis MR measured in a \( \text{La}_{0.99}\text{Sr}_{0.01}\text{CuO}_4 \) crystal upon increasing \((\circ)\) and decreasing \((\bullet)\) magnetic field at a rate of 0.4 T/min.

The following physical picture can be drawn from the obtained results: At high temperatures, the AF domain boundaries are mobile and fluctuating in the transverse direction; however, at low temperatures their pinning quickly gains strength, bringing about the freezing of the AF domain structure, and corresponding memory features in transport and magnetic properties.

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References


