Pressure-Tuning the Pseudogap Critical Point in the Cuprate Nd-LSCO: a Thermopower Study

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Introduction

The properties of cuprate high-temperature superconductors are largely shaped by competing phases whose nature is often a mystery. Chiefly among them is the pseudogap phase, a defining universal property of cuprates that sets in at a doping p^*. Signatures of the pseudogap phase for $p < p^*$ take the form of large upturns at low temperature in the Hall coefficient [1,2] and the electrical resistivity [2,3], attributed to a drop in carrier density n from $n = 1 + p$ above p^* to $n = p$ below p^*. We recently showed that the actual value of p^*, which varies from one cuprate to another, is confined by the Lifshitz transition at p_{FS} from a large hole-like to an electron-like Fermi surface, such that $p^* \leq p_{FS}$. This work was based on electrical transport measurements under pressure at the NHMFL [4]. It is however still unknown how other probes, in particular the thermopower, which can be simpler to interpret at lower temperatures, behave in the close vicinity of p^*.

Experimental

In our earlier pressure study we showed, using resistivity and Hall effect measurements on the cuprate $La_{1.6-x}Nd_{0.4}Sr_xCuO_4$ (Nd-LSCO), that a pressure of 20 kbar shifts the pseudogap critical point p^* by some amount, and that this is driven by a shift of the Lifshitz transition. To further examine this effect, we performed thermopower measurements under pressure on Nd-LSCO on two samples with dopings p = 0.22 and 0.24, which are on either side of p^* = 0.23. To this end, we used a newly designed setup allowing us to obtain precise measurements of the Seebeck coefficient under hydrostatic pressure up to 20 kbar at low temperature. The measurements were performed at the NHMFL in the 31 T wide bore magnet in cell 7.

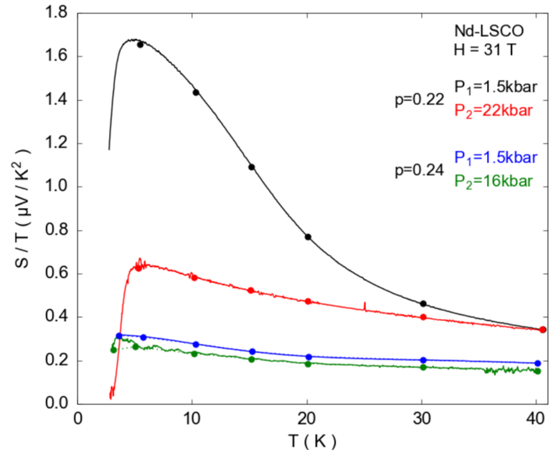

Fig.1 Seebeck coefficient normalized by temperature under pressure as a function of temperature, at 31 T, at p = 0.22, P = 1.5 kbar (black) and P = 22 kbar (red), and at p = 0.24, P = 1.5 kbar (blue) and P = 16 kbar (green).

Results and Discussion

At low temperatures, the amplitude of the Seebeck coefficient is inversely proportional to the carrier density and is independent of scattering (in a single-band model), which makes it ideally suited to probe the pseudogap. This is readily seen in our low pressure data at 1.5 kbar shown in the figure, where the Seebeck coefficient S, expressed as S/T, is nearly flat for p = 0.24, but shows a pronounced enhancement at low temperature at p = 0.22, a clear signature of the pseudogap phase. The enhancement between the p = 0.24 and p = 0.22 data is about 6-fold, which loosely corresponds to a drop in carrier density from $n = 1 + p$ to $n = p$. At high pressures, we see that the upturn in S/T for p = 0.22 has been fully suppressed, consistent with the suppression of the pseudogap phase with pressure inferred from our previous transport measurements [4]. The data for p = 0.24, in contrast, show only a weak rigid shift with pressure, as expected outside the pseudogap phase.

Conclusions

This thermoelectric study under pressure gives further proof that pressure is able to tune the pseudogap critical point p^*. This confirms the underlying mechanism where this effect is driven by a shift of the Lifshitz transition with pressure, and the associated constraint that the pseudogap can only exist on a hole-like Fermi surface. Our study also showed that we were able to perform precise thermoelectric measurements under high pressure, at low temperature and in high magnetic field, which opens up new opportunities for future measurements.

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