\documentclass[twocolumn, 11 pt]{article}

\usepackage[utf8]{inputenc}

\usepackage{mathptmx}

\usepackage[english]{babel}

\usepackage{siunitx}

\usepackage{geometry}

\usepackage{float}

\usepackage{graphicx}

\usepackage{mathtools}

\usepackage{verbatim}

\usepackage{tikz}

\usepackage{sidecap}

\usepackage{caption}

\usepackage{amsmath}

\usepackage{mathrsfs}

\usepackage{mathcomp}

\usepackage{textcomp}

\usepackage[backend=biber,style=apa]{biblatex}

\usepackage{hyperref}

\addbibresource{bibliography.bib}

\begin{comment}

\end{comment}

\geometry{a4paper, top=2cm, bottom=2cm, left=1.6cm, right=1.6cm}

\title{Resistance VS Temperature}

\author{Francesco Marcolini , Santiago Martinez }

\begin{document}

\maketitle

\begin{abstract}

\end{abstract}

\begin{section}{Introduction}

The present experience consists in the measurement of electronic properties of superconducting iron pnictide compounds, i.e. compounds in the Ba(Fe$\_{1-x}$Co$\_x$)$\_2$As$\_2$ family. The high value for the critical temperature in this family of materials (T=55K) and the magnetic nature of the matallic parent Fe makes this materials a matter of interest. Iron pnictides are compounds consisting of a stacking of Iron-Arsenic planes. The core structural feature for this family of materials is a square planar arrangement of Fe ions tetrahedrally coordinated by pnictogen or chalcogen atoms from the 15th and 16th groups. This arrangement gives rise to their special electronic and magnetic properties. Parent compounds are antiferromagnetic, with a coupled orthorhombic distortion, suppression of the long range magnetic order through doping leads to superconducting behaviour, see \ref{fig:pnictidesphase}.

\begin{figure}[H]

\centering

\includegraphics[width=0.7\linewidth]{pnictideTvsX.png}

\caption{Temperature-Nominal content $x$ for superconducting Iron pnictides Ba(Fe$\_{1-x}$Co$\_x$)$\_2$As$\_2$.}

\label{fig:pnictidesphase}

\end{figure}

Iron pnictides enter a superconducting phase through unconventional electron pairing mechanisms. Electrons are paired via antiferromagnetic fluctuations which enhance the electron couplings opposite to the BCS phonon-electron coupling seen in conventional superconducting materials(\cite{Matsuda}).

This superconducting state is described by an s$\pm$ pairing symmetry. For this particular state, superconducting gap exhibits opposite signs on different regions along the fermi surface, facilitated by repulsive interactions mediated by the spin antiferromagnetic fluctuations.

\end{section}

\begin{section}{Experimental set-up}

In order to reach temperatures below the critical value, of the order of tens of K, the sample needs to be cooled using a liquid helium cryostat. This consists of an inner "cold finger" enclosed by two outer shells that shield it from thermal radiation from the room. The intermediate stage reaches temperatures of about 60 K, a factor 5 smaller than room temperature, which results in a decrease of a factor $5^4$ of radiated power in the Stephan's law. One has to be careful of the fact that copper cables are also good thermal conductors, so they have to be wired around the copper part of the cold finger to be cooled to law temperatures before reaching the sample holder, placed on the "cold head". The connections between the sample holder and the samples are made of thin gold, which has optimal flexibility, useful at such small sizes, and holds to weldings better than copper. The sample holder, made of gold-plated copper, is protected from short-circuiting by a thin layer of paper glued to the surface, which insulates electrically but not thermally. Liquid helium extracts heat from the system, with a thermodynamic cycle, similarly to refrigerant gases contained in fridges, but at lower temperatures. Following the comparison with a fridge, the pump is substituted her by a piston to induce compression and decompression phases, and the contact with the thermal reservoir is realised using water. Conversely, it is also possible to speed up the spontaneous increase of temperature of the sample by making current pass through a resistance placed near the cold head\\

The measurement of temperature is obtained using a Scientific instrument M9700 temperature controller with a silicon p-n junction head glued near the sample, close enough to be able to ignore the temperature gradient between it and the sample, but far enough to avoid compromising it's integrity. The temperature controller also has a second probe, in contact with the cold finger. The difference in temperature measured by the two probes shows that there is a thermal inertia of the components, which results in the aforementioned thermal gradient. At the end the numerical values should reassure us on the validity of our approximations.\\

Resistivity is measured indirectly from voltage and current measurements, connected in a 4-point probe fashion as illustrated in figure \ref{fourpoints}. Two wires are connected to a current generator and the other two to a voltmeter. This allows to probe small resistances without having to worry about the influence of the parasite resistance of cables and contacts (see \cite{fourprobecit}). The four wires are connected to a Keithley source meter. This latter and the temperature controller are connected to the lab computer for data acquisition using the software Labview. Two metal surfaces put in contact create a difference of electric potential at the interface, which is big enough to disturb the measure taken by the voltmeter. To avoid this effect, the current source supplies a square wave centred at 0 and the voltmeter evaluates the difference between the maximum and minimum values, for which the interface contribution cancels out.

\begin{figure}

\centering

\includegraphics[scale=.25]{Capture d’écran 2024-12-19 134018.png}

\caption{Four point probe for resistivity measurements. \small{credits:\cite{fourprobecit}}}

\label{fourpoints}

\end{figure}

\end{section}

\begin{section}{Methods}

In this study we measure the temperature dependence of the resistivity of various samples of Ba(Fe$\_{1-x}$Co$\_x$)$\_2$As$\_2$ crystals with different cobalt $x$-doping values to be determined from the measurement of the dependence of the resistivity on temperature. The critical temperatures for the samples are of the order of 10K at most. Therefore, the measurement is prone to noise coming from thermal fluctuations and thermal transfer processes. To avoid these impurities in the measurements, the sample is set in vacuum using a primary pump, taking the sample and its surroundings to 10$^{-1}$Pa. In order to take the sample to low temperatures required for this study, the helium gas cryostat ARS is used. This also reduces the number of thermally interacting atoms with the sample, thus a secondary pump is no longer of use. The measurements will be done in two thermal channels, the cooling channel when the temperature for the sample is decreasing and the warming channel when the temperature of the sample is rising. Using a COM interphase and the software LABView the resistivity data from the Keithley current source-meter from and the temperature data from the temperature controller (M9700) is recorded in a data file for each sample and for each channel. Data is analized and fitted using python numpy

Critical temperatures show in the data as first order transitions, that means that the resistivity exhibits a discontinuous change in the first derivative as a function of the temperature. By extracting numerically the points where this gradient suffers an abrupt change in value we extract the values for these critical temperatures.

\end{section}

\begin{section}{Results and discussion}

\end{section}

\begin{section}{Conclusions}

\end{section}

\printbibliography

\appendix

\end{document}