ELECTRON TUNNELLING STUDY OF HIGH-TEMPERATURE SUPERCONDUCTORS

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TO MY FAMILY

PREFACE

I would like to thank my supervisor, Dr C.J. Adkins, and my fellow students at the Cavendish laboratory, especially Anthony Holden, Alison Speakman and Simon Dunkley, for their friendship and help over the past six years. I would also like to thank the workshop and electronics department technicians for their assistance and patient guidance, and Ken Gadsby and Pete Flaxman for supplying the cold stuff. Special thanks to Dave Swainston and Paul Booth of the LTP workshop, and Dave Powell of the student workshop for (hopefully) imparting to me some of their considerable skill and knowledge. Thanks also to my eagle-eyed copy editor, Sarah Hamilton, and to my colleagues at Hewlett-Packard (CPB) for help with the computing and DTP facilities.

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This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where reference or acknowledgement is made in the text. The dissertation is not substantially the same as any that I have submitted for a degree, diploma or other qualification at any other University. I further state that no part of my dissertation has already been or is being concurrently submitted for any such degree, diploma or qualification.

Simon Chandler
August 14, 1993

ABSTRACT

This dissertation describes work carried out between June 1987 and October 1991, in the Low Temperature Physics Group at the Cavendish Laboratory, Cambridge.

The aim of this work was to use electron tunnelling spectroscopy to measure the density of excitation states of the recently discovered high-temperature superconductors. Tunnelling is the most sensitive method for measuring a superconductor's energy gap, and historically has provided important evidence for the microscopic mechanism of superconductivity in conventional metals. It was hoped that electron tunnelling would prove equally successful in revealing the mechanism of superconductivity in these new materials.

Preliminary experiments showed that a thick, degraded surface layer prevented preparation of high-quality tunnel junctions by conventional evaporation techniques. For this reason, apparatus for the formation and fine control of low-temperature point-contact junctions was constructed, together with new measurement electronics and a computer-controlled data-acquisition system.

To test this apparatus, point-contact junctions were formed on conventional superconductors. By increasing pressure of the tip on the sample the junction could be moved from the tunnelling to the metallic regime.

Point-contact measurements were then made on a number of ceramic, single-crystal and thin-film high-temperature superconducting materials; some not previously investigated by tunnelling. Although 'gap-like' structure was occasionally observed, anomalous features (e.g., voltage-dependent background, broadening, large zero-bias conductance) were always present and usually dominated the tunnelling characteristics. These complicate estimation of the energy gap and preclude measurement of more subtle properties such as gap anisotropy or the effective phonon spectrum, α^2F. The origins of these non-ideal features have been much debated in the literature and are reviewed in this dissertation.

In the case of thin films deposited by laser ablation the tunnelling characteristics were dominated by single-electron tunnelling effects (Coulomb gap and staircase structure). The results suggest that the surface region consists of numerous, isolated normal metal particles.

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