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SCANNING TUNNELING MICROSPECTROSCOPY OF SOLIDS AND SURFACES

Final Report

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ABSTRACT

Experimental and theoretical research on the bulk and surface properties of conductive solid state materials has been performed based on the techniques of scanning tunneling microscopy and scanning tunneling spectroscopy, often at cryogenic temperatures. The research has focused on the electronic properties, particularly the superconductivity, of high temperature superconductors and other layered systems. The superconducting electronic density of states N(E)=dI/dV of the high T_c superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ was measured with spatial resolution of 5 A at 4.2K. An internal superconducting proximity effect was inferred to operate between Cu and Bi based layers of the crystal in those regions where the Bi layers are metallic in nature. This research project supported the thesis research of several young scientists, and led to a significant number of published papers, presentations and reports.

I. INTRODUCTION

This is the formal final report of a grant initiated in September 1987 with annual Progress Reports submitted on schedule through the year 1996. The scientific and personnel development accomplished during this period of support has been fully described in the nine Progress Reports. The present formal document is an overview of the work carried out, and of the students and postdoctoral fellows who were supported.

II. RESEARCH SUMMARY

The research has centered on the use of scanning tunneling microscopy particularly to look at the local density of states existing at the surface of high temperature superconductors. The work emphasized $Bi_2Sr_2CaCu_2O_{8+y}$ (BSCCO) High Temperature Superconductor single crystals. This was pioneering work initiated just as the HTS phenomenon was discovered. The first major accomplishment was in the Ph.D thesis work of Mr. Zhao Yan Rong who developed in-house a very effective computer program allowing the acquisition of the dI/dV (density of states) function at each pixel of a raster scan. This allowed simultaneous display of topography and local density of states, as side by side images. An interesting early result on single crystals of $Bi_2Sr_2CaCu_2O_{8+y}$ (BSCCO) indicated local fluctuations in the density of states function, tentatively attributed to local fluctuations in the oxygen doping of the samples. Such an effect is entirely reasonable in a material in which the coherence length is so short that significant random fluctuations can be expected in the numbers of dopant atoms in a coherence volume. This early using an elementary home-built STM work suffered however from a spatial resolution just short of that necessary to resolve individual atoms. The peak productivity of the work, which was aided considerably by the theoretical collaboration of Research Professor Yu. M. Ivanchenko, was achieved by about 1992, in which the PI presented a summary of the accomplishments in the overall review of DOE Basic Energy Sciences research, required by Dr. Wm. Happer, which was held in Arlington VA. This project was well ranked in this review. Shortly after this time the University decided to restructure and severely downsized the Physics group, leading to an absence of competent graduate students. (At present there are neither a Physics Department nor advanced degrees in Physics at this institution.) This decision, accompanied by a move of the remaining faculty research groups to smaller quarters and a much less supportive administrative atmosphere, led to the dissolution of the research group.

III. PERSONNEL

Ph.D graduates included Dr. Zhao Yan Rong, Dr. Alejandro Chang, Dr. Farun Lu, and Dr. Xiao-hui Wu. Postdoctorals included Dr. Sarath Meepagala and Dr. Lesley Cohen. Visiting students included Mr. Oded Millo and Mr. Jurgen Burger. Senior Visitors included Dr. Haran and Dr. Hong-jie Tao. An important contributor to the work was Research Professor Yu. M. Ivanchenko. Other students who were supported in part included Wongo Kim, Gordon Zhang and Fan Gao.

PUBLICATIONS

A substantial number of refereed publications, abstracts, and internal reports have been listed in the nine progress reports and will not be again fully enumerated. A few typical publications are: Z. Y. Rong, et al, "A Flexible Implementation of Scanning Tunneling Microspecroscopy on the Personal Computer Utilizing C-language", Rev. Scient. Instrum. 63, 3646 (1992); A. Chang, et al, "Observation of Large Conductance Variations in Direct Mapping of the Energy Gap of Single Crystal $Bi_2Sr_2CaCu_2O_{8+y}$ ", Phys. Rev. B45 7945 (1992); Z. Y. Rong, et al ,"STM Control of Non-integer Charge Q_o on the Central Electrode of a Double Tunnel Junction", IEEE Trans. MAG 28 67 (1992); and Z. Y. Rong, "C Programs for Scanning Tunneling Spectroscopy Data Acquisition", Polytechnic University Department of Physics Technical Report, unpublished.

PRESENTATIONS

This research was regularly reported, principally at the American Physical Society March Meetings in contributed papers. The P. I. also gave, eg, invited papers at MRS Meeting in Boston, MA 12/3/92 (at which Mr. Alejandro Chang, a Ph. D. candidate was competing for a student research prize), at the Molecular & Oxide Superconductors Conference in Eugene, OR in 8/93, at a Superlattice Conference in Cincinnati OH, at a Scanning Tunneling Microscopy Conference in Switzerland, and at a UNESCO summer school in Beijing. These and other presentations have been recorded in previous reports.

PATENTS

This research did not lead to any patent applications.