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“中外物理学精品书系”
编委会

序　　言

物理学是研究物质、能量以及它们之间相互作用的科学。她不仅是化学、生命、材料、信息、能源和环境等相关学科的基础,同时还是许多新兴学科和交叉学科的前沿。在科技发展日新月异和国际竞争日趋激烈的今天,物理学不仅囿于基础科学和技术应用研究的范畴,而且在社会发展与人类进步的历史进程中发挥着越来越关键的作用。

我们欣喜地看到,改革开放三十多年来,随着中国政治、经济、教育、文化等领域各项事业的持续稳定发展,我国物理学取得了跨越式的进步,做出了很多为世界瞩目的研究成果。今日的中国物理正在经历一个历史上少有的黄金时代。

在我国物理学科快速发展的背景下,近年来物理学相关书籍也呈现百花齐放的良好态势,在知识传承、学术交流、人才培养等方面发挥着无可替代的作用。从另一方面看,尽管国内各出版社相继推出了一些质量很高的物理教材和图书,但系统总结物理学各门类知识和发展,深入浅出地介绍其与现代科学技术之间的渊源,并针对不同层次的读者提供有价值的教材和研究参考,仍是我国科学传播与出版界面临的一个极富挑战性的课题。

为有力推动我国物理学研究、加快相关学科的建设与发展,特别是展现近年来中国物理学者的研究水平和成果,北京大学出版社在国家出版基金的支持下推出了"中外物理学精品书系",试图对以上难题进行大胆的尝试和探索。该书系编委会集结了数十位来自内地和香港顶尖高校及科研院所的知名专家学者。他们都是目前该领域十分活跃的专家,确保了整套丛书的权威性和前瞻性。

这套书系内容丰富,涵盖面广,可读性强,其中既有对我国传统物理学发展的梳理和总结,也有对正在蓬勃发展的物理学前沿的全面展示;既引进和介绍了世界物理学研究的发展动态,也面向国际主流领域传播中国物理的优秀专著。可以说,"中外物理学精品书系"力图完整呈现近现代世界和中国物理科学发展的全貌,是一部目前国内为数不多的兼具学术价值和阅读乐趣的经典物理丛书。

“中外物理学精品书系”另一个突出特点是，在把西方物理的精华要义“请进来”的同时，也将我国近现代物理的优秀成果“送出去”。物理学科在世界范围内的重要性不言而喻，引进和翻译世界物理的经典著作和前沿动态，可以满足当前国内物理教学和科研工作的迫切需求。另一方面，改革开放几十年来，我国的物理学研究取得了长足发展，一大批具有较高学术价值的著作相继问世。这套丛书首次将一些中国物理学者的优秀论著以英文版的形式直接推向国际相关研究的主流领域，使世界对中国物理学的过去和现状有更多的深入了解，不仅充分展示出中国物理学研究和积累的“硬实力”，也向世界主动传播我国科技文化领域不断创新的“软实力”，对全面提升中国科学、教育和文化领域的国际形象起到重要的促进作用。

值得一提的是，“中外物理学精品书系”还对中国近现代物理学科的经典著作进行了全面收录。20世纪以来，中国物理界诞生了很多经典作品，但当时大都分散出版，如今很多代表性的作品已经淹没在浩瀚的图书海洋中，读者们对这些论著也都是“只闻其声，未见其真”。该书系的编者们在这方面下了很大工夫，对中国物理学科不同时期、不同分支的经典著作进行了系统的整理和收录。这项工作具有非常重要的学术意义和社会价值，不仅可以很好地保护和传承我国物理学的经典文献，充分发挥其应有的传世育人的作用，更能使广大物理学人和青年学子切身体会我国物理学研究的发展脉络和优良传统，真正领悟到老一辈科学家严谨求实、追求卓越、博大精深的治学之美。

温家宝总理在2006年中国科学技术大会上指出，“加强基础研究是提升国家创新能力、积累智力资本的重要途径，是我国跻身世界科技强国的必要条件”。中国的发展在于创新，而基础研究正是一切创新的根本和源泉。我相信，这套“中外物理学精品书系”的出版，不仅可以使所有热爱和研究物理学的人们从中获取思维的启迪、智力的挑战和阅读的乐趣，也将进一步推动其他相关基础科学更好更快地发展，为我国今后的科技创新和社会进步做出应有的贡献。

“中外物理学精品书系”编委会　主任
中国科学院院士，北京大学教授
王恩哥
2010年5月于燕园

内　容　简　介

高温超导电性从被发现至今已经27年了，但是在高温超导电性的微观机理方面目前还没有被普遍承认的理论。最近的一些实验表明在铜氧化物高温超导体中存在着明显的电声子相互作用，这种相互作用对高温超导电性的贡献值得深入系统地研究。

本书收集了高温超导电性研究中关于电声子相互作用的部分重要理论和实验结果，有很高的科学水平和创见，内容新颖，对于从事高温超导电性研究的科技工作者有重要的参考价值。

Preface

In early studies of high-T_c superconductivity (HTSC), the role of electron-phonon interaction (EPI) in cuprates was questioned by researchers because some important properties of the cuprates could not be explained by conventional BCS theory [1]. For instance, the isotope effect in the cuprates is not evident as in conventional superconductors. Many theories were proposed to account for the mechanism of HTSC, such as resonating valence bond (RVB) theory [2], strong coupling theory [3], spin exciton model [4], $t-J$ model [5] and so on. But it was soon realized that these new theories were inadequate to explain the mechanism of HTSC. At the same time, substantial electron-phonon interaction became visible in the cuprates. In 2001, Lanzara et al., using angle-resolved photoemission spectroscopy (ARPES), observed for the first time that there was an abrupt change of the electron velocity at 50-80 meV in the different families of the cuprates which was referred to as the "kink" in the electronic dispersion [6]. Interestingly, however, the most likely candidate responsible for this "kink" was really the strong interaction between electrons and phonons. Meevasana interpreted this "kink" as the result of the coupling between electrons and special phonons with some collective behavior [7]. Subsequently, it was found that the isotope effect in high-T_c superconductors was not negligible, as previously thought, but instead it was nontrivial. For example, Khasanov directly observed evident oxygen isotope ($^{16}O/^{18}O$) effect on the in-plane penetration depth of YBCO film [8]. And Iwasava found a distinct oxygen isotope shift near the electron-phonon coupling "kink" in the electronic dispersion of BSCCO system, which demonstrated the dominant role of the EPI in the cuprates [9].

Of course, a lot of researchers did not agree with the EPI scenario. For instance, Allen thought the EPI in the cuprates could not induce their d-wave symmetry [10]. This was just the difference between the high T_c superconductors and conventional superconductors, whose wave function was of s-wave symmetry.

Another important fact was that the pseudogap existed universally in the high T_c cuprate superconductors [11]. Further, it was shown that there are two distinct energy scales and quasiparticles in the cuprates, one with larger energy corresponding to the pseudogap and the other one with smaller energy corresponding to the superconducting gap [12, 13]. This has raised an important question whether the pseudogap and the *d*-wave symmetry are induced by the EPI? Although the experiments mentioned above indicated the important significance of the EPI, the relationship between the pseudogap and the EPI and that between the *d*-wave symmetry and the EPI were not clearly clarified. In order to explain the mechanism of HTSC, one must answer these two questions inevitably.

Polarionic or bipolaronic models have been proposed to explain how the EPI or lattice dynamics in the cuprates determines the HTSC [14-16]. In conventional superconductors, the energy of phonons is just considered, and the symmetry of wave function is s-type. With the strong anisotropy of HTSC, the anisotropy of phonons should be taken into account which may induce *d*-wave symmetry. It was suggested that quasi-two-dimensional charge carriers weakly coupled with the anisotropic phonons undergo a quantum phase transition from conventional *s*-wave symmetry to unconventional *d*-wave symmetry. Therefore, the anisotropic phonons and thereby the anisotropic EPI are responsible for the *d*-wave pairing in the cuprates.

In spite of this, the strong anisotropy of phonons must arise from the anisotropy of the crystalline structure. It may be from some special local structure in the cuprates [17]. What is the particularity of the phonons in the cuprates? One must find the answers from the crystalline structure.

As more and more important results on the EPI and lattice dynamics have been discovered, it is felt most timely to edit a book that includes these issues. Because the field has grown indeed so vastly there is always the risk that I may be missing a number of important publications for which, I hope, the reader will generously excuse me.

The book contains the experimental and theoretical studies about the EPI. The experimental part covers the results of ARPES, isotopic effect, elastic neutron scattering study of electron-phonon and lattice role and so on. The theoretical part covers the electron-phonon, polaron and bipolaron aspects, also includes a number of other related papers supporting lattice role.

I would like to thank all the contributors for their support and encouragement to create this book. They are (in alphabetical order): Prof. Alexandrov at Loughborough University UK, Dr. Aiura at Tokyo University of Science, Prof. Kresin at Lawrence Berkeley, Dr. Koikegami at Japan and Nanoelectronics Research Institute, Prof. Lanzara at University of California, Berkeley, Prof. Pintschovius at Forschungszentrum Karlsruhe, Germany, Prof. Reznik at University of Colorado Boulder, Prof. Wolf at University of Virginia, Dr. Weyeneth and Prof. Mueller at Universität Zürich, and Prof. Zhao at UCLA.

Han Zhang
Peking University, China
Sept 26, 2012

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Part I

Reviews

Colloquium: Electron-Lattice Interaction and Its Impact on High T_c Superconductivity*

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Abstrct In this Colloquium, the main features of the electron-lattice interaction are discussed and high values of the critical temperature up to room temperature could be provided. While the issue of the mechanism of superconductivity in the high T_c cuprates continues to be controversial, one can state that there have been many experimental results demonstrating that the lattice makes a strong impact on the pairing of electrons. The polaronic nature of the carriers is also a manifestation of strong electron-lattice interaction. One can propose an experiment that allows an unambiguous determination of the intermediate boson (phonon, magnon, exciton, etc.) which provides the pairing. The electron-lattice interaction increases for nanosystems, and this is due to an effective increase in the density of states.

I. Introduction

This Colloquium addresses the current experimental and theoretical situation concerning the importance of the interaction between electrons and the crystal lattice in novel superconducting systems, especially in high T_c cuprates. It will be demon-

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