CHAPTER 1

Introduction

The phenomenon of superconductivity was discovered in 1911 by Kammerlingh Onnes[1], who found that mercury became superconducting at about 4.2 K. After Onnes's discovery, superconductivity of many materials had been found, for example, the A-15 compounds were discovered in 1954 to be superconductors, with a T_c of 17.1[2]K in Y_3Si, Nb_3Sn and Nb_3Ge were found to be superconductors at 18.6[2]K and 23.2[3,4]K respectively. Until last year (1986) there is no material having T_c higher than 23.2K. Most of the researchers in this area had begun to have a mystical or cynical view that superconductivity above about 23.2 K was impossible.

In the year 1986 the great event happened. The predecessor of the exciting new results was the discovery of superconductivity in the mixed-valent perovskite structure oxide $BaPb_{1-x}Bi_xO_3$ with a T_c of 13K[5]. Then Bednorz and Müller[6] of IBM Zurich Research Laboratory found evidence of a much higher T_c in a multiphased sample of the Ba-La-Cu-O system. The work of Bednorz and Müller was confirmed and extended by the work of Uchida et.al.[7] at the University of Tokyo. Uchida et. al. made the important step of showing that the high-T_c phase in the multiphased material of Bednorz and Müller was $La_{2-x}Ba_xCuO_{4-y}$ with x Ø.1. which has the layerd perovskite K_2KiF_4 structure.(Fig.1), the structure which can be viewed as a stacking of LaO-CuO_2-LaO sandwiches.

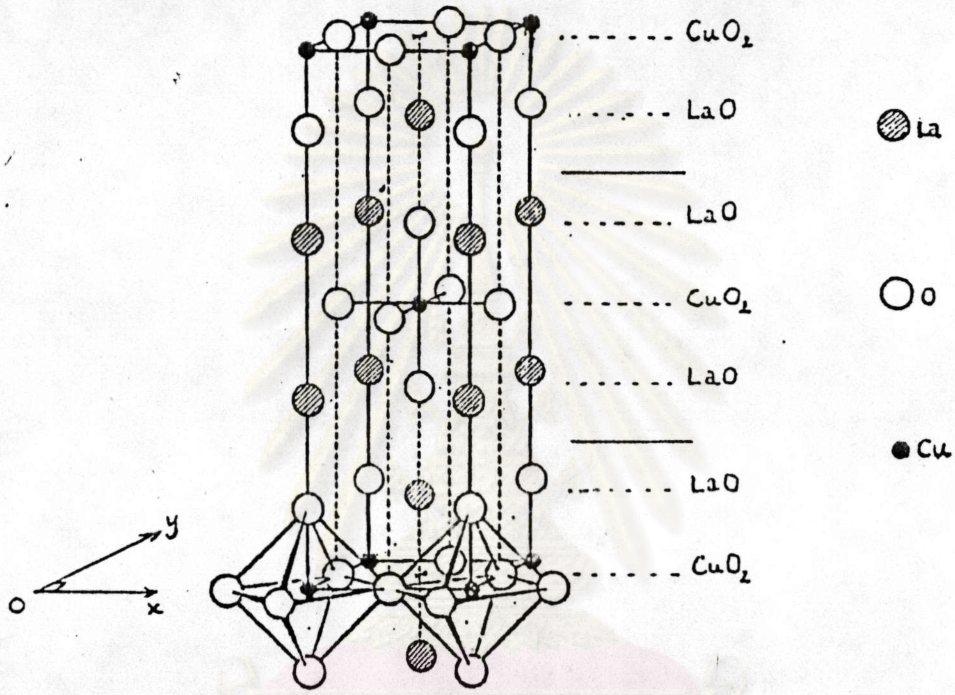

Fig. 1 The layered perovskite K_2NiF_4 structure

The role of the variable valence of copper (Cu^{3+},Cu^{2+}) on the properties of $La_{1.8}Sr_{0.2}CuO_4$ was pointed out[8] and the same role on $La_{2-x}Ba_xCuO_{4-y}$ is expected. The possibility of a two dimensional superconductivity has been discussed[9] and was found to be reasonable. These probably suggest that the states responsible for the superconductivity lie in the CuO_2 planes. Cava et.al.[8] also suggested that conventional phonon - mediated superconductivity can account for the high T_c in the class of materials. This indicates the applicability of the Bardeen, Cooper, and Schrieffer (BCS) theory[10] to the materials.

In this work we try to understand the fundamental mechanism for the superconductivity. What we do is to apply the BCS theory to the materials ($La_{2-x}Ba_xCuO_{4-y}$). Two parameters in the BCS thery are used. They are the density of electronic states at the Fermi level and the electron - phonon coupling strength. We begin, in chapter 2, with the energy band calculation of La_2CuO_4 in the tetragonal phase by using the tight - binding method [11]. The energy band containing the Fermi level is used, in chapter 3, to calculate the density of states. The result shows a logarithmic divergence in the density of states such that the change from the orthorhombic structure of the end - member La_2CuO_4 to the tetragonal structure of $La_{2-x}Ba_xCuO_{4-y}$, due to the increase in Cu^{3+}/Cu^{2+} ratio, can be explained. In chapter 4 the critical temperature is calculated by using the BCS theory. The electronic density of states from chapter 3 and a constant which is assumed to be the electron - phonon coupling strength are used in the calculation. The result explains the high critical temperature.