CHAPTER I

INTRODUCTION

Preliminary

The experimentally determined fact that the critical temperature T_c of a superconductor is proportional to $M^{-1/2}$ where M is the atomic mass, the so-called isotope effect [1], is one of the phenomena that must be explained by the successful theory of superconductivity. A deviation from this proportion in a large number of materials is explained by the inclusion of the Coulomb repulsion term. After the discovery of the high transition temperatures in the oxide superconductors [2-7], the experimental findings, replacing O^{16} by O^{18} the oxygen isotope effect exponent was found to be about 0.2 for La-Sr-Cu-O systems [8-11] and almost zero for Y-Ba-Cu-O and Bi-Sr-Ca-Cu-O systems [12-25]. This independence on the isotopic mass is apparently inconsistent with the theory of the pure phonon mechanism for the oxide superconductors. It is not clear at the present time if the partial isotope effect in 30 K, La-Sr-Cu-O superconductors and almost complete absence of the isotope effect in 90 K, Y-Ba-Cu-O and 110 K, Bi-based superconductor ones can be understood in a similar way to that for the low-T_c compounds. Many theoretical models have in consequence been proposed to account for the observation[26-28]. Recently, Daemen and Overhauser [29] found that the existence of a short range interaction suppresses the isotope effect significantly at higher critical temperature. Müller [22] indicated that the anharmonicity of paramidal apex oxygen related with the isotope effect and C.C. Tsuei [30] uses the two-dimensional density of states (van Hove singularity) to explain the anomalous isotope effect in La-Sr-Cu-O systems [23].

Outline of Thesis

The purpose of this thesis is to evaluate the formula of the isotope effect exponent by using the van Hove singularity in the density of states N (ξ) in the Fermi level and the double square-well model of the pair interaction along with a conventional BCS theory which is also responsible for high temperature superconductors. The classification of superconductors are separated in the consideration of their coupling strength parameter. It will be pointed out that nonelectron-phonon mechanism may be dominant in the oxide superconductors.

In the next chapter, we review the history of superconductors, the classical and the new high temperature superconductors. The theoretical survey of the old superconducting materials are also present, this review only gives the basic ideas but not the particulars. A discussion of the crystal structure of the copper oxide superconductors and some of their properties are given in chapter III. Chapter IV is devoted to review the investigation on the isotope effect, the definition and prior calculation of the isotope exponent are pointed out. In chapter V, we generalize the formula for the isotope effect exponent by using the double square-well interaction as the pair interaction and van Hove singularity in the density of states. By making use of our theoretical formula for the exponent and experimental data, we could determine the empirical value for the electron-phonon couplings as compared with the electronic interaction and show their correlation with the temperature. Discussion and conclusion, including suggestion, will be given in the chapter VI.