Characteristics of Superconductivity in Superconductors

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Abstract: Superconductivity universally exists in a wide range of materials like free elements, alloy, oxide, metal salts, organics and so on, and superconductors itself consists of one or two, or even more elements chemical mixture. Therefore, studies on superconductivity characteristics in superconductors in search of its common features are crucial to the exploration of new superconductors and key to the establishment and description of superconductivity theory. Based on a thorough analysis of superconductivity characteristics in diversified superconductors, the paper concludes that the different superconductivity characteristics in superconductors result from different bond pattern in superconductor elements, but the general superconductivity mechanism of all superconductors remain the same.

Key words: superconductivity, superconductivity characteristics, superconductivity mechanism.

1. Introduction

In 1911, Kamerling Onnes discovered the loss of resistance in mercury at 4.2 K, or superconductivity [1]. Since then, researches into superconductivity in solid materials have been far and wide, including the studies in free elements, alloy, oxide, metal salts, organics and mixture [2]. The transition temperature of these superconductors may range from above 0.001 K to more than 134 K at high pressure [3]. This phenomena provides the researchers with varied possible projects and challenges on the way to the researches into new materials [4, 5]. Therefore, it is significant to conduct studies on analyzing the superconductivity characteristics in search of the general regularities in different superconductors. Based on a thorough analysis of superconductivity characteristics in diversified superconductors, the paper concludes that the different superconductivity

characteristics in superconductors result from different bond pattern in superconductor elements, but the general superconductivity mechanism of all superconductors remain the same.

2. Method

There are two basically different types of elements bonding in superconductors, namely metallic bonding and chemical bonding (covalent and ionic).

According to metallic bond features and chemical bond, the superconductors can fall into two categories:

(1) Metallic bond superconductors, in which elements carrying superconductivity are bonded together through metallic bonding;

(2) Chemical bond superconductors, in which elements carrying superconductivity are bonded together through chemical bonding (covalent and ionic).

The all superconductors' superconductivity are produced with electron media phonon mechanism. The different are the Cooper Pairs electrons originating from the different electrons of the elements in

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superconductors. The metallic bond superconductors' Cooper Pairs electrons originate valence electrons of the bearing superconductivity elements in superconductors while the chemical superconductors' Cooper Pairs electrons originate non-bonded electrons of the bearing superconductivity elements in superconductors.

3. Characteristics

3.1 Symmetry of Superconductors Electrons Pairs

Table 1 lists some superconductors, specifying their respective valence electrons orbits, bond pattern and superconductivity [6].

Table 1 shows that (1) the change of d electron numbers does not affect the symmetry of superconductors electrons pairs; (2) the change of valence electrons layers structures does not affect the symmetry of superconductors electrons pairs; (3) the change of valence electrons orbits follows the pattern of s-ds-fds, leading to the formation of metallic bonding, and the symmetry of superconductors electrons pairs still remains.

This is the case because of the bonding characteristics of metallic bond which is formed when the valence electrons energy is reduced to form conductive electrons in metals. But superconductors

electrons pairs start with the conductive electrons, that is, the valence electrons. It can be learned from Table 1 that the orbits characteristics of outmost layer in valence electrons are mainly to determine the symmetry of superconductors electrons pairs. Due to the valence electrons orbits structures of s-ds-fds, the symmetry of superconductors electrons pairs only is determined by the S orbit characteristics of valence electrons layers, for the outmost layer of sub-electrons is S orbit in valence electrons orbits structures.

Table 2 lists some superconductivity characteristics in A15 type superconductors [6].

Table 2 shows that (1) bonding pattern of the elements carrying conductivity determines the superconductivity characteristics of A15 type superconductors; (2) the d electrons numbers change in valence electron of the elements carrying conductivity does not affect the symmetry of superconductivity electrons pairs; (3) valence electrons orbits structural change does not affect symmetry of superconductivity electrons pairs; (4) bond pattern in non-bearing superconductivity elements is not related to electron pair symmetry, and the change in valence electrons layer, orbit or the number of valence electrons is unrelated to superconductivity electrons pairs symmetry; (5) similar the result in Table 1, metallic

Table 1 Characteristics of valence electrons orbits, bonding pattern and superconductivity of some superconductors.

Superconducting material	Valence electrons orbits structure	Bonding pattern	Symmetry of superconductivity electrons pairs	T _c value (K)	Superconductivity mechanism	Superconduction theory
Cs (under pressure)	6s ¹	M	S	1.6	e-h	BCS
Ba (under pressure)	6s ²	M	S	1.3	e-h	BCS
La	5d ¹ 6s ²	M	S	5.98	e-h	BCS
Hf	4f ¹⁴ 5d ² 5s ²	M	S	0.165	e-h	BCS
Ta	4f ¹⁴ 5d ² 5s ²	M	S	4.48	e-h	BCS
W	4f ¹⁴ 5d ³ 5s ²	M	S	0.12	e-h	BCS
Re	4f ¹⁴ 5d ⁴ 5s ²	M	S	1.7	e-h	BCS
Os	4f ¹⁴ 5d ⁵ 6s ²	M	S	0.65	e-h	BCS
Ir	4f ¹⁴ 5d ⁶ 6s ²	M	S	0.14	e-h	BCS
Hg	4f ¹⁴ 5d ¹⁰ 6s ²	M	S	4.15	e-h	BCS
V	3d ³ 4s ²	M	S	5.3	e-h	BCS
Nb	4d ⁴ 5s ¹	M	S	9.26	e-h	BCS
Pa	6d ⁴ 7s ¹	M	S	1.4	e-h	BCS

Note: M stands for metallic bond, and e-h for electron-phonon mechanism.

Table 2 characteristics of some A15 superconductors.

Superconductors	V ₃ Si	V ₃ Ga	Nb ₃ Al	Nb ₃ Sn	Nb ₃ (Al _{0.15} Ge _{0.25})	Nb ₃ Ge
valence electrons structure of the bearing superconductivity elements	3d ³ 4s ²	3d ³ 4s ²	4d ⁴ 5s ¹	4d ⁴ 5s ¹	4d ⁴ 5s ¹	4d ⁴ 5s ¹
valence electrons structure of the non-bearing superconductivity elements	2s ² 3p ²	4p ¹	3s ² 3p ¹	5p ²	3s ² 3p ¹ ,4p ²	4p ²
Element bonding bearing superconductivity elements	M	M	M	M	M	M
Element bonding in non- bearing superconductivity elements	C	C	M	M	M, C	C
Symmetry of superconductor electrons pairs	S	S	S	S	S	S
T _c (K) value	17.0	16.8	18.8	18.1	21.0	23.2
Superconductivity mechanism	e-h	e-h	e-h	e-h	e-h	e-h
Superconduction theory	BCS	BCS	BCS	BCS	BCS	BCS

Notes: M stands for metallic bond, e-h for electron-phonon mechanism, and C for Covalent bond.

Table 3 supeconductivity characteristics of some superconductors.

superconductors	copper oxide superconductors [3]	Element Alloy superconductors [6]	Alloy CeRhTn ₅ [7]	Sr ₂ RnO ₄ [8]
T _c (K)	30-134	0.001-23.5	1.2	0.93
Bonding features	Ionic bond	Metallic bond	Metallic bond	Ionic bond
Wave of superconductors electrons pairs	d	s	p	p
Orbits of outmost layer in bearing superconductivity elements	d	s	p	p

Table 4 Energy gap characteristics of some superconductors.

superconductors	Copper oxide superconductors [3]	Element, metal superconductors [6]	Iron superconductors [9, 10]
T _c (K)	30-134	0.001-23.5	17-55
Element Bonding characteristics	Ionic bond	Metallic bond	Ionic bond
energy gap symmetry	asymmetrical distribution	symmetrical distribution	asymmetrical distribution

bond is formed between the elements carrying conductivity and the electrons pairs symmetry is determined only by the orbits features in S orbits of the valence electron layer in elements carrying superconductivity. This is the case because the outmost layer of sublayer in valence electron carrying superconductivity turns out to be S orbits.

Table 3 lists some superconductivity characteristics of some superconductors.

Table 3 shows that (1) the electrons orbits of the outmost electrons layer of the elements carrying superconductivity determines the electrons symmetry of superconductors; (2) regardless of the bond pattern between the elements, the sub-electrons orbits of the outmost layer of bonded elements carrying conductivity determines the symmetry of superconductor electrons pairs.

Table 4 lists some energy gap characteristics of some

superconductors.

In Table 4, it can be learned that the way how elements bond together in superconductors determines the characteristics of energy gap in the superconductors.

3.2 Superconductivity Mechanism Characteristics

Table 5 lists some superconductivity characteristics of chemical bond superconductors.

Table 5 shows that (1) elements bonding pattern in superconductors may change but the superconductivity mechanism remains the same. In other words, in chemical bond (covalent and ionic), superconductivity arises from electron-phonon mechanism; (2) the value of T_c in superconductors is not related to superconductivity mechanism. In other words, T_c may change greatly when elements are built with chemical bond (covalent and ionic), but the superconductivity

Table 5 superconductivity characteristics of some chemical bond superconductors.

superconductors	T_c (K)	Bonding pattern between elements	Superconductivity mechanism	Superconductor theory
MgB ₂ [11]	39	C, I	e-h	BCS
M ₃ C ₆₀ [12]	19	C, I	e-h	BCS
LiTiO ₄ [6]	13.7	I	e-h	BCS
Pb(Mo ₆ S ₈) [6]	14.7	C, I	e-h	BCS
NbC [6]	9	I	e-h	BCS
NbN [6]	17	I	e-h	BCS
TaC [7]	10.2	I	e-h	BCS
MoC [8]	14	I	e-h	BCS
MDT-TSF [10]	4.5	C, I	e-h	BCS
BaPb _{1-x} Bi _x O ₃ [2]	13	I	e-h	BCS

C stands for covalent bond, I for Ionic bond and e-h for electron-phonon mechanism.

Table 6 some superconductors doped with C₆₀.

Doping elements	Formula	Element Bond	T_c (K)	Lattice constant (Å)	Superconductivity mechanism	Superconduction theory
Alkali metal	K ₃ C ₆₀	C, I	19.3	14.240	e-h	BCS
	Rb ₃ C ₆₀	C, I	30	14.384	e-h	BCS
	RbCsC ₆₀	C, I	29		e-h	BCS
	Rb ₂ CsC ₆₀	C, I	31.3	14.431	e-h	BCS
	RbCs ₂ C ₆₀	C, I	33	14.555	e-h	BCS
	KRb ₂ C ₆₀	C, I	26	14.323	e-h	BCS
	K ₂ CsC ₆₀	C, I	24	14.293	e-h	BCS
	K ₂ RbC ₆₀	C, I	23	14.243	e-h	BCS
	K _{1.5} Rb _{1.5} C ₆₀	C, I	22	14.253	e-h	BCS
	Na ₂ Cs(NH ₃) ₄ C ₆₀	C, I	29.6	14.173	e-h	BCS
	Na _x N _y C ₆₀ ($x = 3 \sim 4$)	C, I	13	14.34	e-h	BCS
	Na ₂ CsC ₆₀	C, I	12	14.134	e-h	BCS
	Na ₂ RbC ₆₀	C, I	2.5	14.028	e-h	BCS
	Li ₂ CsC ₆₀	C, I	12	14.120	e-h	BCS
Alkaline earth metal	Sr ₆ C ₆₀	C, I	4	11.01	e-h	BCS
	Ba ₆ C ₆₀	C, I	7	11.171	e-h	BCS
	Ca ₆ C ₆₀	C, I	8.2~8.8	11.179	e-h	BCS
Alkali metal and alkali earth	K _{2.7} Ba _{0.3} C ₆₀	C, I	17		e-h	BCS
Rare earth metal	Y _{2.75} C ₆₀	C, I	6	27.87 × 27.98 × 27.873	e-h	BCS
	Sm _x C ₆₀ ($x < 3$)	C, I	8	28.17 × 28.07 × 28.27	e-h	BCS

C stands for covalent bond, and I for Ionic bond.

mechanism remains the same [13].

Table 6 lists some superconductivity characteristics of superconductors with C₆₀ doping.

Table 6 shows that chemical bond (covalent and ionic) is formed in superconductors with the same mechanism and T_c value of superconductivity may change. That is, the T_c value is unrelated to superconductivity mechanism.

From the analysis in 3.1 and 3.2, we can come to the

conclusion that the superconductivity characteristics may be different because of the different bonding pattern of superconductors elements, but the mechanism for all superconductors remains the same [14, 15].

4. Conclusions

Through an analysis of the superconductivity characteristics of different types of superconductors, a

meaningful conclusion is drawn that the mechanism for all superconductors remains the same and the different performance of superconductivity characteristics is resulted from the difference in elements bonds pattern of superconductors.

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