Hydride Features and Superconductivity

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Abstract: In this paper, the properties of hydride materials are analysed by the chemical bonding theories. The types of hydride materials are numerous, which include the organic hydride, inorganic hydride, ionic organic hydride, covalent hydride and hydrogen plus materials, and so on. Through analyzing the features of different hydride materials, we conclude that all the hydride materials can be divided into three types. One is ionic bonding hydride materials, another covalent chemical bonds, and the third is hydrogen plus materials. The hydride materials with different bonding type show different characteristics of superconductivity.

Key words: Hydrides, superconductivity, chemical bonding theories.

1. Introduction

In 1911, Onnes, H. K. first discovered mercury metal to be superconductivity [1]. The temperature at which mercury becomes superconducting is 4.1 K, very close to the boiling point of liquid helium. Subsequently, very many solid materials were discovered to be superconducting, with the highest T_c 's generally in the intermetallics compounds of niobium [2]. Superconductors permit electric currents to flow no less of energy. Also, they can act as perfect diamagnets in a magnetic field. These two unique features make superconductors technologically important in applications prohibited with the superconducting transition temperature, the search for a higher temperature superconductors has focused to find the new type materials. A series superconductors made of ceramics called cuprates have until now held the record for the warmest temperature at which they can operate [3, 4], but a new class of materials could change that [5]. The new material belong to hydrogen sulphide [5], which are pressured close to those a half of the pressures to those inside Earth's core, the research reports say that it was

superconductive at 203 K (-70°C). The high T_c superconductivity of hydrogen sulphide is quite shocking, which will be a historic discovery. Especially, the hydrogen sulphide belongs to the hydrides, but the hydride materials are numerous. The hydride features and superconductivity study are of great significance.

2. Method

Pulling gave the definition of the chemical bonds [6] that as far as two atoms or atomic groups are concerned. If the force that acted between them could lead to the formation of aggregation and the stability of the aggregation is big enough for chemists to treat it as an independent category of elements, it is claimed that there are chemical bonds between these atoms or atomic groups and in the chemical bonds there are ionic bonds and covalent bonds.

According to the properties of hydride materials and chemical bonding definition, the hydride materials can fall into three categories:

(1) Ionic bonding hydrides, in which hydrogen elements are bonded other elements together through ionic bond.

(2) Covalent bonding hydrides, in which hydrogen elements are bonded other elements together through

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covalent bond.

(3) Non-bonding hydrides, in which hydrogen elements are combined other elements together through physical adsorption.

3. Discussion

Table 1 shows the types of different hydride materials and compositions.

There are also another type hydride materials, such as Be_nH_{2n} , Al_nH_{3n} , $(\text{MgH}_2)_n$, boron alkane and hydrocarbon.

The hydrides have many different physical properties when the contents of hydrogen elements and hydride structures change [7].

Duan, D. F. and co-worker [8] on theoretical had investigated the characteristics of H_2 -containing compounds $(\text{H}_2\text{S})_2\text{H}_2$ and pointed that those compounds should remain superconducting up to about 191 to 204 K when exposed to a pressure of 200 GPa. Eremets, M. and his colleagues [5] that placed a sample of hydrogen hydride are exposed to a pressure about one hundredth of a millimeter atmospheres. They found that under a pressure of 155 GPa, the resistance dropped suddenly at about 203 K, suggesting that a transition to superconductivity had occurred. The researchers attribute this higher-than-expected “critical” temperature to the breakdown of hydrogen sulphide into molecules containing relatively larger numbers of hydrogen atoms. According to the results of experiments, the bearing superconducting elements are hydrogen element, therefore, the hydrides may produce much superconducting. There are dihydrides, trihydrides and quahydrides. Eespecially, the dihydrides and trihydrides compounds are worth to examine

experiment. The covalent levels of hydrides are closely relation to the electronegativity difference between the hydrogen elements and other combine elements.

The differences of electronegativity are more, which may be more advantage to producing superconducting. This points are future to be investigated. i.e.:

$$x_{\text{other}}^p - x_{\text{H}}^p = \Delta x \quad (1)$$

where, x_{other}^p is the electronegativity value of other elements definite by Pauling, x_{H}^p is hydrogen element, Δx is the difference of electronegativity. When $\Delta x > 0$, such the covalency levels is more higher; And when $\Delta x < 0$, Δx is larger, the covalency level is more strength.

The hydrogen sulphide belongs to the oxygen clan hydride, those other hydrides have the similar structure of hydrogen sulphide, such as H_2O , H_2Se and H_2Te . According to the principle of chemical compounds, the similar structures determine they to be the same properties, such as cuprate superconductivity. Therefore, the H_2O , H_2Se and H_2Te may had superconductivity, which are only the condition difference of producing superconductivity.

Table 2 lists the properties of oxygen clan elements and hydrides.

From Table 2, we can learn that the properties of elements and hydrides on oxygen clan are very similar.

Based on the Table 2 and Eq. (1), the T_c value of oxygen clan hydrides could be $T_c^{\text{H}_2\text{O}} > T_c^{\text{H}_2\text{S}} > T_c^{\text{H}_2\text{Se}} > T_c^{\text{H}_2\text{Te}}$, where, the $T_c^{\text{H}_2\text{O}}, T_c^{\text{H}_2\text{S}}, T_c^{\text{H}_2\text{Se}}, T_c^{\text{H}_2\text{Te}}$ stands for the T_c values of the H_2O , H_2S , H_2Se and H_2Te , respectively.

Table 1 Lists the molecular compositions of some hydride materials.

Ionic hydride	LiH , NaH , KH , RbH , CsH , CaH_2 , SrH_2 , BaH_2
Covalent hydride	B_2H_6 , Al_2H_6 , Ga_2H_6 , CH_4 , SiH_4 , SnH_4 , GeH_4 , NH_3 , PH_3 , AsH_3 , SbH_3 , H_2O , H_2S , H_2Se , H_2Te , HF , HCl , HBr , HI
Plus hydride	$\text{TiH}_{1.7}$, $\text{ZrH}_{1.9}$, TiH_2 , $\text{PdH}_{0.6}$, $\text{LaH}_{2.87}$, $\text{YbH}_{2.55}$, $\text{PuH}_{2.75}$, UH_3

Table 2 The properties of oxygen clan elements and hydrides.

Elements	O	S	Se	Te
Atomic mass	16	32	78.9	127.6
Valent electronic structures	2S ² 2P ⁴	3S ² 3P ⁴	4S ² 4P ⁴	5S ² 5P ⁴
Electronegativity	3.5	2.6	2.4	2.1
Ionization potential	I 13.61	I 10.36	I 9.75	I 9.01
	II 35	II 23.4	II 21.5	II 18.6
Hydride molecule	H ₂ O	H ₂ S	H ₂ Se	H ₂ Te
Geometry structures	Plane triangle	Plane triangle	Plane triangle	Plane triangle

Note: I stands for the potential values of first grade ionization; II stands for those second grade.

4. Conclusions

The chemical bonding compounds are important superconductors, which have high T_c values to be a role in such applications. Therefore, the theoretical studies of chemical compound superconducting features have been extensively conducted over the past several years. We use the chemical theories to analyze the hydride features and have arrived at the conclusion that the hydrides may produce superconducting characteristics. The assumptions must be carefully tested and verified, although it remains insignificant at the moment.

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