

SuperCon<sup>2</sup> interface

Raw material	Name	Formula	Doping	Tc	Applied Pressure	Section	Sub section	View Document	DOI	Year
					G					
Ba(FeCo) 2 As 2	-	Ba(FeCo) 2 As 2	-	27 K	1 GPa	body		48ba234393	10.1063/1.4947056	2016
Ba(Fe,Co) 2 As 2	-	Ba(Fe,Co) 2 As 2	-					4393	10.1063/1.4947056	2016
CaH 6	-	CaH 6	-					0e67	10.1063/1.5053650	2019
Fe 1.01 Se	-	Fe 1.01 Se	-					3569	10.1088/0953-2048/28/7/075001	2015

From LaH<sub>10</sub> to room-temperature superconductors

M. Kostrzewa<sup>1</sup>, K. M. Szczęśniak<sup>2</sup>, A. P. Durajski<sup>3\*</sup> & R. Szczęśniak<sup>1,3</sup>

Thermodynamic parameters of the LaH<sub>10</sub> superconductor were an object of our interest. LaH<sub>10</sub> is characterised by the highest experimentally observed value of the critical temperature:  $T_C^a = 215$  K ( $p_a = 150$  GPa) and  $T_C^b = 260$  K ( $p_b = 190$  GPa). It belongs to the group of superconductors with a strong electron-phonon coupling ( $\lambda_a \sim 2.2$  and  $\lambda_b \sim 2.8$ ). We calculated the thermodynamic parameters of this superconductor and found that the values of the order parameter, the thermodynamic critical field, and the specific heat differ significantly from the values predicted by the conventional BCS theory. Due to the specific structure of the Eliashberg function, the theoretical description of the superconducting state occurring in H<sub>2</sub>S and H<sub>3</sub>S one can find in 2018, there were held the groundbreaking experiments, which confirmed the existence of the superconducting state of extremely high values of  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa (and then  $T_C^a \sim 215$  K for  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa). It was proved on the theoretical basis<sup>19</sup> that the results achieved by Dronov *et al.*<sup>20</sup> can be related to the induction of the superconducting phase in the *R3m* structure ( $T_C = 206-213$  K). The experimental results reported by Somayazulu *et al.*<sup>21</sup> should be related to the superconducting state induced in the *Fm3m* structure, where the critical temperature can potentially reach even the value of 280 K. From the materials science perspective, the achieved results imply that all possible actions should be taken in order to examine the hydrogen-containing materials with respect to the existence of the high-temperature superconducting state at room temperature. Attention should be paid to the importance of the discovery of the high-temperature superconducting state in LaH<sub>10</sub> because La can form stable hydrogenated compounds with other metals. Such materials can exhibit so large hydrogen concentration, that they are presently taken into account as basic components of the hydrogen cells intended for vehicle drives<sup>22</sup>.

The purpose of this work is, firstly, to present the performed analysis of the thermodynamic properties of the superconducting state in the LaH<sub>10</sub> compound. We took advantage of the phenomenological version of the Eliashberg equations, for which we fitted the value of the electron-phonon coupling constant on the basis of the experimentally found  $T_C$  value. Our next step consisted in examining the hydrogenated compounds of the LaX<sub>10</sub> ( $X = Y, Sc$ ) type (LaXH-type) on the basis of the achieved results in order to find a system with an even higher value of the critical temperature. Taking into account the structure of the Eliashberg function for hydrogenated

Recent measurements have set a new record for the superconducting transition temperature ( $T_C$ ) at which a material loses electrical resistivity and exhibits ideal diamagnetism. Theory-oriented experiments show that the compressed hydride of Group VI (hydrogen sulfide, H<sub>2</sub>S) exhibits a superconducting state at 203 K. Moreover, a Group V hydride (phosphorus hydride, PH<sub>3</sub>) has also been studied and its  $T_C$  reached a maximum of 103 K. The experimental realisation of the superconductivity in H<sub>2</sub>S and PH<sub>3</sub> inspired us to search for other hydrogen superconductors. Herein, we report theoretical studies of the electronic, vibrational, and superconducting properties of hydrogenated chlorine (H<sub>2</sub>Cl, representative of the Group VII hydride). First-principles calculations performed for H<sub>2</sub>Cl in the pressure range 150-250 GPa show that the investigated *Im3m* phase has a large electron-phonon coupling parameter and the resulting application of the Migdal-Eliashberg formalism yields a remarkably high superconducting temperature of 198 K at 150 GPa. Published by AIP Publishing. <https://doi.org/10.1063/1.5031202>

1. INTRODUCTION

Searching for the superconducting state at critical temperature as high as possible is currently one of the major activities in condensed matter physics.<sup>1-4</sup> The great breakthrough in this area occurred in 2014 when the hydrogen sulfide (H<sub>2</sub>S) was predicted theoretically by Li *et al.* to be a novel conventional high-temperature superconductor with an estimated maximal transition temperature of about 80 K at 160 GPa.<sup>5</sup> Shortly after this theoretical report, compression in a diamond anvil cell of a sulfur hydride system leads to the confirmation of these predictions and direct experimental observation of two superconducting states: (i)  $T_C = 80-150$  K for low-temperature prepared samples and (ii)  $T_C = 170-203$  K for room-temperature prepared samples.<sup>8</sup> The superconducting state of extremely high values of  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa (and then  $T_C^a \sim 215$  K for  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa). It was proved on the theoretical basis<sup>19</sup> that the results achieved by Dronov *et al.*<sup>20</sup> can be related to the induction of the superconducting phase in the *R3m* structure ( $T_C = 206-213$  K). The experimental results reported by Somayazulu *et al.*<sup>21</sup> should be related to the superconducting state induced in the *Fm3m* structure, where the critical temperature can potentially reach even the value of 280 K. From the materials science perspective, the achieved results imply that all possible actions should be taken in order to examine the hydrogen-containing materials with respect to the existence of the high-temperature superconducting state at room temperature. Attention should be paid to the importance of the discovery of the high-temperature superconducting state in LaH<sub>10</sub> because La can form stable hydrogenated compounds with other metals. Such materials can exhibit so large hydrogen concentration, that they are presently taken into account as basic components of the hydrogen cells intended for vehicle drives<sup>22</sup>.

electrical resistance measurements<sup>2,13,15,16</sup> confirming that the stable *Im3m* phase is responsible for high- $T_C$  superconductivity. Interestingly, Guigue *et al.* conducted experiments which employed direct synthesis of pure H<sub>2</sub>S from S and H elements.<sup>17</sup> At high pressure, the obtained H<sub>2</sub>S samples are identified to have the *Ccm* phase up to 160 GPa. On this basis, Guigue *et al.* suggested that the body-centered *Im3m* structure is rather more metastable than the thermodynamic ground state.<sup>4,17</sup> Most recently, Goncharov *et al.* reported that *Ccm* is admittedly stable in a wide pressure range, but unlike the previous observations of Guigue *et al.*, they found that *Im3m* H<sub>2</sub>S is the most favorable crystalline phase above 140 GPa.<sup>18</sup> The measured critical temperature exhibits a pronounced isotope shift consistent with BCS theory.<sup>19,20</sup> This fact allows considered H<sub>2</sub>S to be a conventional phonon-mediated superconductor.

material

name: H 3 Cl

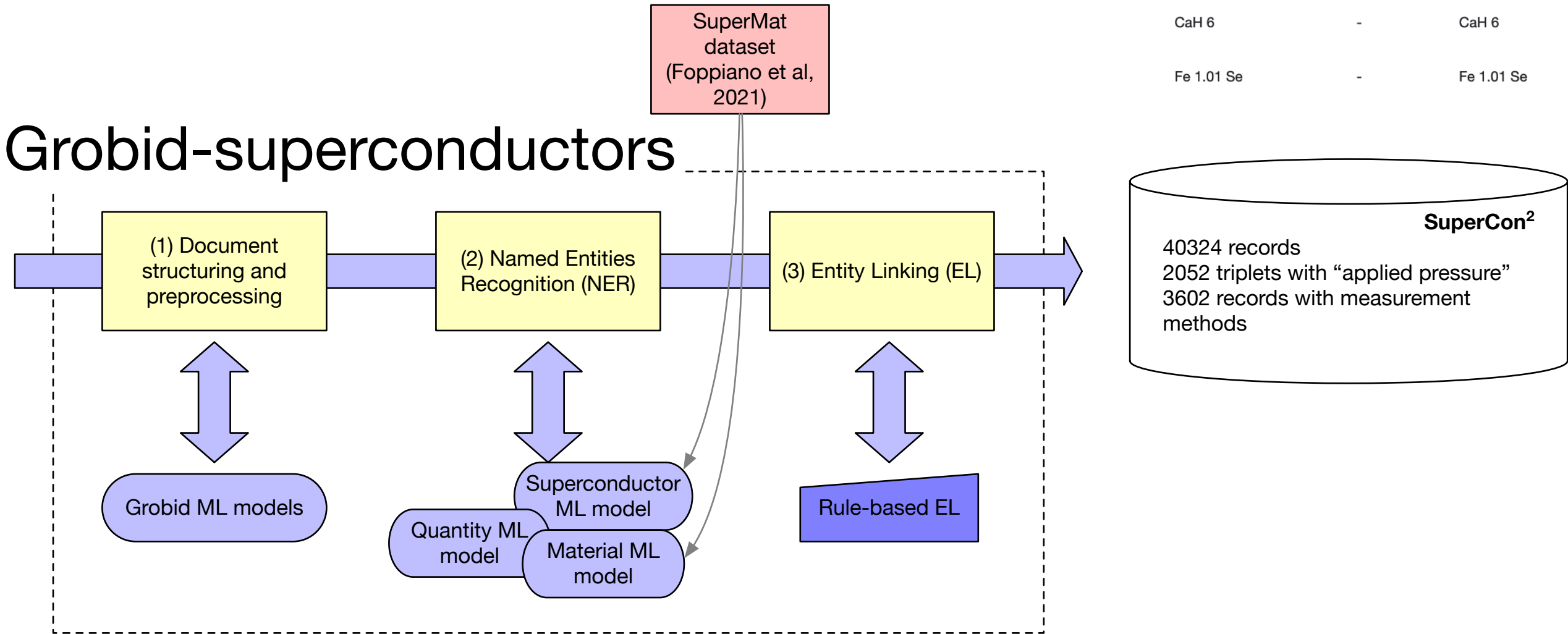
Linked: 198 K (toValue)

[simple]

class: Alloys, Hydrides

formula: H 3 Cl

Grobid-superconductors



Example

(1)

OPEN

Title

Abstract

Body

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The experimental discovery of the high-temperature superconducting state in the compressed hydrogen and sulfur systems H<sub>2</sub>S ( $T_C = 150$  K for  $p = 150$  GPa) and H<sub>3</sub>S ( $T_C = 203$  K for  $p = 150$  GPa)<sup>1,2</sup> accounts for carrying out investigations, which can potentially lead to the discovery of a material showing the superconducting properties at room temperature. For the first time, the possibility of the existence of the superconducting state in hydrogenated compounds is induced by the conventional electron-phonon interaction. This fact made possible the high-temperature superconductivity, following his first work written in 1968, in which he propounded the existence of the high-temperature superconducting state in metallic hydrogen<sup>3</sup>. The superconducting state in hydrogenated compounds is induced by the conventional electron-phonon interaction. This fact made possible the theoretical description of the superconducting phase in H<sub>2</sub>S and H<sub>3</sub>S even prior to carrying out the suitable experiments<sup>4-6</sup>. The detailed discussion with respect to the thermodynamic properties of the superconducting state occurring in H<sub>2</sub>S and H<sub>3</sub>S one can find in references<sup>4-6</sup>.

In 2018, there were held the groundbreaking experiments, which confirmed the existence of the superconducting state of extremely high values of the critical temperature in the LaH<sub>10</sub> compound:  $T_C^a = 215$  K for  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa (and then  $T_C^a \sim 215$  K for  $p_a = 150$  GPa and  $T_C^b = 260$  K for  $p_b \in (180-200)$  GPa). It was proved on the theoretical basis<sup>19</sup> that the results achieved by Dronov *et al.*<sup>20</sup> can be related to the induction of the superconducting phase in the *R3m* structure ( $T_C = 206-213$  K). The experimental results reported by Somayazulu *et al.*<sup>21</sup> should be related to the superconducting state induced in the *Fm3m* structure, where the critical temperature can potentially reach even the value of 280 K. From the materials science perspective, the achieved results imply that all possible actions should be taken in order to examine the hydrogen-containing materials with respect to the existence of the high-temperature superconducting state at room temperature. Attention should be paid to the importance of the discovery of the high-temperature superconducting state in LaH<sub>10</sub> because La can form stable hydrogenated compounds with other metals. Such materials can exhibit so large hydrogen concentration, that they are presently taken into account as basic components of the hydrogen cells intended for vehicle drives<sup>22</sup>.

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Material

Tc expression

Pressure

Temperature

(2)

The experimental discovery of the high-temperature superconducting state in the compressed hydrogen and sulfur systems H<sub>2</sub>S ( $T_C = 150$  K for  $p = 150$  GPa) and H<sub>3</sub>S ( $T_C = 203$  K for  $p = 150$  GPa)<sup>1,2</sup> accounts for carrying out investigations, which can potentially lead to the discovery of a material showing the superconducting properties at room temperature. For the first time, the possibility of the existence of the superconducting state in hydrogenated compounds is induced by the conventional electron-phonon interaction. This fact made possible the high-temperature superconductivity, following his first work written in 1968, in which he propounded the existence of the high-temperature superconducting state in metallic hydrogen<sup>3</sup>. The superconducting state in hydrogenated compounds is induced by the conventional electron-phonon interaction. This fact made possible the theoretical description of the superconducting phase in H<sub>2</sub>S and H<sub>3</sub>S even prior to carrying out the suitable experiments<sup>4-6</sup>. The detailed discussion with respect to the thermodynamic properties of the superconducting state occurring in H<sub>2</sub>S and H<sub>3</sub>S one can find in references<sup>4-6</sup>.

(3)

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Material	Critical temperature	Applied pressure
H 2 S	150 K	150 GPa
H 3 S	203 K	150 GPa
LaScH	52 K	150 GPa