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Research Article

On Condensation Force of TSC

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Abstract

Primitive analysis and discussion are given for possible condensing force of tetrahedral symmetric condensate (TSC) of four deuterons (or protons) plus four spin-regulated (bosonized) electrons. Once TSC is formed by the ordering-constraint-organization process in condensed matter of metal-D(H) system, there may happen strong central squeezing force (and negative Coulomb energy of total TSC system) until when four deuterons (protons) get into the range of strong interaction (or Pauli repulsion at classical electron radius). After elementary quantum-mechanical results for D(H)-atom and, $D_2(H_2)$-molecule, primitive estimations are done for TSC.

Keywords: Deuteron cluster fusion, Central squeezing force, Four deuterons, Tetrahedral symmetric condensate

1. Introduction

As a theoretical model for Condensed Matter Nuclear Effects (CMNE), Electronic Quasi-Particle Expansion Theory with Tetrahedral Symmetric Condensate (EQPET/TSC) has been proposed [1] and elaborated [2–7]. Qualitative and quantitative results of EQPET/TSC have provided reasonable agreements with major results of CMNE experiments [5], although some of key conditions for TSC formation and squeezing motions are of open questions; for example, where TSC can be generated and how is the mechanism in condensed matter, how TSC can condense transiently into a very small charge-neutral pseudo-particle and what is the driving force of squeezing condensation motion into central focal point, and so on. We need further elaboration to make the model more substantial.

This paper gives a primitive analysis on possible condensing force of TSC by Coulombic interaction under Platonic symmetry [8] and discusses the relation to biding forces of D(H)-atom and $D_2(H_2)$-molecule.

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2. Coulomb Energy of D(H)-Atom

The ground state electron wave function of H(D)-atom is the 1S-wave function as given (see standard text books of quantum mechanics) as

$$\Psi_{100}(r) = \frac{1}{\sqrt{\pi a^3}} \mathrm{e}^{-r/a}. \tag{1}$$

Here a becomes Bohr radius ($a_\mathrm{B} = 52.9$ pm) for H(D)-atom, and is modified for EQPET atom de* [4,7]. The system Coulomb energy is given by

$$\langle \Psi_{100} | E_{\mathrm{C-D}} | \Psi_{100} \rangle = \int_0^\infty (-\mathrm{e}^2/r)\Psi_{100}^2 4\pi r^2 \mathrm{d}r = -1.44/r \quad \text{with} \quad r = a_\mathrm{B}. \tag{2}$$

Here Coulomb energy is given in unit of keV with r in pm unit. Using Bohr radius 52.9 pm, we get

$$\langle E_{\mathrm{C-D}} \rangle = -27.2\,\mathrm{eV}. \tag{3}$$

The total system energy is given as kinetic energy plus potential energy, by evaluating Hamiltonian integral

$$\langle H \rangle = \langle \Psi_{100} | H | \Psi_{100} \rangle = \left\langle \Psi_{100} \left| -\frac{\hbar^2}{2m}\nabla^2 - \frac{e^2}{r} \right| \Psi_{100} \right\rangle = E_0 = -13.6\ \mathrm{eV}. \tag{4}$$

Using

$$\langle H \rangle = \langle E_\mathrm{k} \rangle + \langle E_{\mathrm{C-D}} \rangle, \tag{5}$$

we get mean kinetic energy of electron as $\langle E_\mathrm{k} \rangle = 13.6$ eV. Please note that in classical QM, we equate centrifugal force and Coulomb attractive force for orbital electron, $\frac{mv^2}{r} = \frac{e^2}{r^2}$ to get the same result.

$$\langle E_\mathrm{k} \rangle = \frac{1}{2}mv^2(r = a_\mathrm{B}) = \frac{e^2}{2r} = 13.6\,\mathrm{eV}. \tag{6}$$

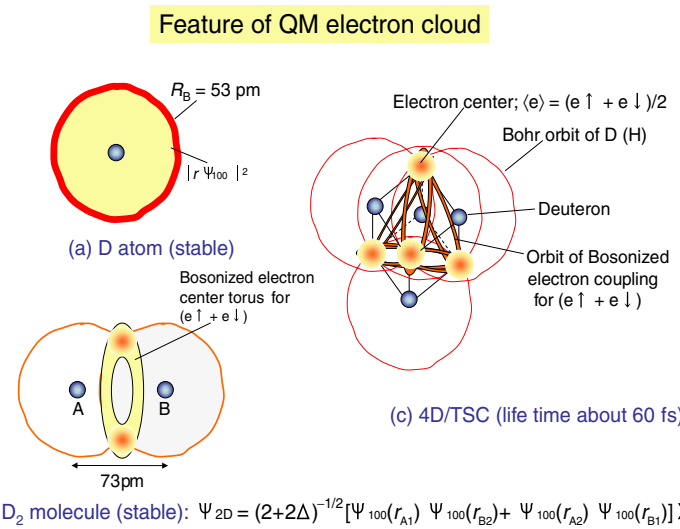

Figure 1. Weight-distributions of electron wave functions for D(H)-atom, $D_2(H_2)$-molecule, and 4D(H)/TSC transient pseudo molecule.

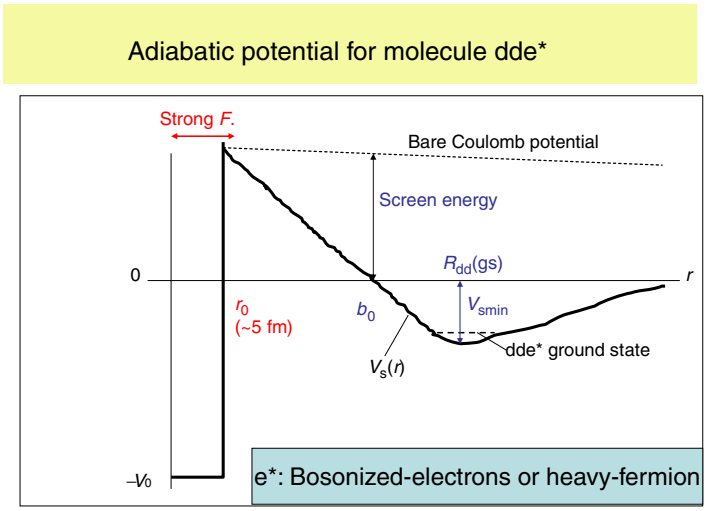

Figure 2. Conceptual view of dde* molecular potential; scales in X–Y are deformed (not linear), enlarged very much strong interaction range and depressed barrier height.

Also note that we use the normalization condition as

$$\int_0^\infty (\Psi_{100}(r))^2 4\pi r^2 \mathrm{d}r = \int_0^\infty 4\pi (r\Psi_{100}(r))^2 \mathrm{d}r = 1. \tag{7}$$

Therefore, the function $|r\Psi_{100}(r)|^2$ having peak at Bohr radius draws the radial distribution of electron weight for H(D)-atom, as shown in Fig. 1. This feature corresponds to the view of classical Newtonian motion of orbital electron at Bohr radius rotating around central plus charge of deuteron (or proton) with kinetic energy of 13.6 eV. However, in QM view, 13.6 eV is the mean kinetic energy of electron with 1S-wave function. In Fig. 1, features of electron wave functions for D_2-molecule and 4D/TSC ($t = 0$) are also drawn [5–7].

3. Coulomb Energy of $D_2(H_2)$ Molecule

Using variational method for ddee system, Pauling–Wilson–type potential (screened Coulomb potential) is derived [4] and wave function of $D_2(H_2)$ molecule is given as

$$\Psi_{2D} = \frac{1}{\sqrt{2+2\Delta}} \left[\Psi_{100}(r_{A_1})\Psi_{100}(r_{B_2}) + \Psi_{100}(r_{A_2})\Psi_{100}(r_{B_1})\right] X_s(S_1, S_2). \tag{8}$$

Here $X_s(S_1, S_2)$ is the singlet spin wave function for anti-parallel pairing of spins (S_1 and S_2) of two 1-σ electrons. And total system energy is given [5,7] as (see also Table 1, and Fig. 2) result of variational calculation to get energy eigen value,

$$\langle \Psi_{2D} | H | \Psi_{2D} \rangle = -37.8\,\mathrm{eV}. \tag{9}$$

The ground state internuclear, p–p or d–d distance is 73 pm by calculation as well known (exact value is 74.16 pm).

Approximate estimation of system Coulomb energy can be estimated from classical balance of Coulombic forces between particles (plus and minus charged) forming regular square form by alternatively positioned dede or pepe system.

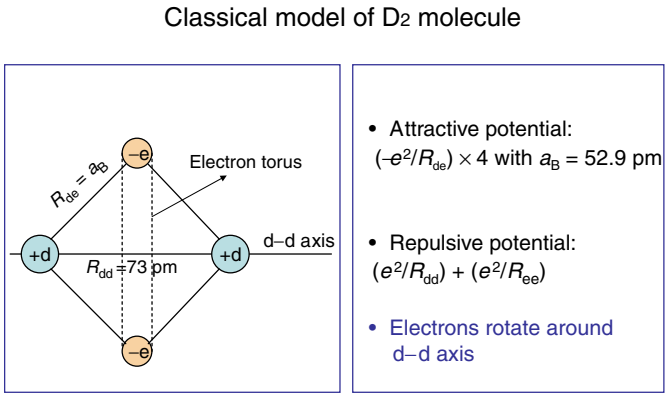

Figure 3. Classical model of D_2 molecule; electrons are rotating with mean kinetic energy of 16.25 eV around the d–d axis with radius about 37.4 pm. In QM view, mean electron orbit is the center torus of Fig. 1b.

This classical model corresponds to QM feature as follows. We know (see Figs. 1b and 3), the distance between plus-charge (deuteron or proton) and the center-circle-line of "bosonized" central electron torus is $a_B = 52.9$ pm for attraction force and d–d (or e–e) distance is $\sim \sqrt{2}a_B = 74.8$ pm (but 73 pm by QM calculation, see Table 1). We estimate system-averaged Coulomb energy as follows.

Using a classical model picture of $D_2(H_2)$ molecule as shown in Fig. 3, we obtain

$$\langle E_{C-2D} \rangle = 4\left(-\frac{e^2}{a_B}\right) + 2\left(\frac{e^2}{\sqrt{2}a_B}\right) = -70.3 \text{ eV}. \tag{10}$$

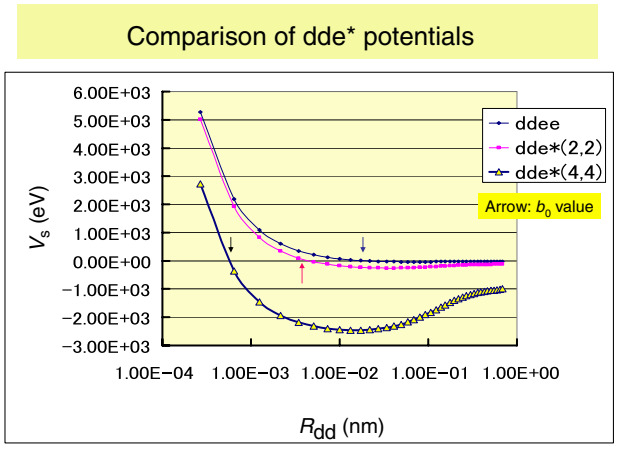

Figure 4. Shielded Coulomb potentials for ddee (namely D_2), dde*(2,2) and dde*(4,4) states with b_0-parameters (shown by arrows); Drastic decrease of b_0-parameters (see position of arrows) for the change from regular molecule D_2 to dde*(2,2) and then the change from dde*(2,2) to dde*(4,4) corresponds to the deepening of trapping potential depths (negative potential depths), which induce strong condensing force for forming 4d/TSC state [9].

Table 1. Negative Coulomb energies (trapping depths) of D_2 molecule and dde* EQPET molecule; here b_0-values are measure for barrier penetration of d–d nuclear fusion

e*(m, Z)	V_{smin}(eV)	b_0 (pm)	$R_{dd(gs)}$(pm)
Parameters of dde* potentials			
(1,1); Normal electron	−15.4	40	101
(1,1) × 2; D_2	−37.8	20	73
(2,2); Cooper pair	−259.0	4	33.8
(4,4); Quadruplet e	−2, 460	0.36	15.1
	Trapping depth		Ground state

Then averaged electron kinetic energy is given as

$$\langle E_{k-2D}\rangle = \langle H_{2D}\rangle - \langle E_{C-2D}\rangle = 70.3 - 37.8 = 32.5\,\text{eV}. \tag{11}$$

This gives average kinetic energy per 1-σ electron as 16.25 eV (cf. 13.6 eV for H(D)-atom).

By bosonization of electron pairs, dde* molecule can condense (shrink) to smaller size. As shown in Table 1, d–d distance at ground state decreases from 73 to 33.8 pm by the generation of Cooper pair e*(2,2). Orthogonal coupling of two Cooper pairs generates quadruplet e*(4,4) which makes much stronger condensation. Change of Pauling–Wilson-type potential [4,5] by bosonization of electron pairs is drawn in Fig. 4. Here b_0-parameter values correspond to the degree of barrier penetration probabilities of d–d pair through Pauling–Wilson-type shielded Coulomb potentials [5]. Diminishing shift of b_0-parameter by the bosonization corresponds to driving mechanism of transient Bose-type condensation [4,5,9].

We can consider that the bosonization (microscopic Cooper pair generation) of electron pairs may be a seed of TSC formation in metal plus deuteron systems [9].

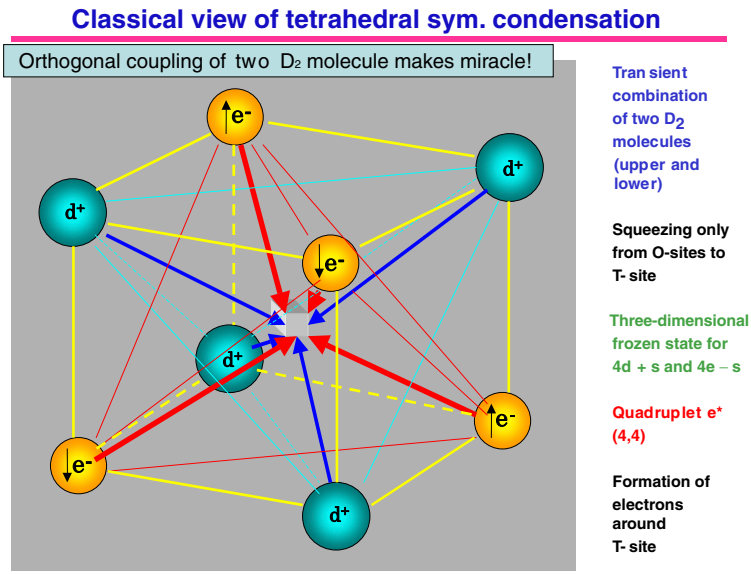

Figure 5. Classical view of TSC (tetrahedral symmetric condensate) [5].

4. Coulomb Energy and Condensing Force of TSC

Approximate wave function for TSC at $t = 0$ was given [6] as,

$$\begin{aligned}\Psi_{4D} \sim\ & a_1[\Psi_{100}(r_{A_1})\Psi_{100}(r_{B_2}) + \Psi_{100}(r_{A_2})\Psi_{100}(r_{B_1})]X_s(S_1, S_2)\\ & + a_2[\Psi_{100}(r_{A_1})\Psi_{100}(r_{D_4}) + \Psi_{100}(r_{A_4})\Psi_{100}(r_{D_1})]X_s(S_1, S_4)\\ & + a_3[\Psi_{100}(r_{A_2})\Psi_{100}(r_{C_4}) + \Psi_{100}(r_{A_4})\Psi_{100}(r_{C_2})]X_s(S_2, S_4)\\ & + a_4[\Psi_{100}(r_{B_1})\Psi_{100}(r_{D_3}) + \Psi_{100}(r_{B_3})\Psi_{100}(r_{D_1})]X_s(S_1, S_3)\\ & + a_5[\Psi_{100}(r_{B_2})\Psi_{100}(r_{C_3}) + \Psi_{100}(r_{B_3})\Psi_{100}(r_{C_2})]X_s(S_2, S_3)\\ & + a_6[\Psi_{100}(r_{C_3})\Psi_{100}(r_{D_4}) + \Psi_{100}(r_{C_4})\Psi_{100}(r_{D_3})]X_s(S_3, S_4). \end{aligned} \tag{12}$$

Here suffixes A, B, C, and D denote positions of four deuterons in TSC configuration.

Classical view of TSC configuration is shown in Fig. 5

By assuming Platonic symmetry for the wave function, namely absolute values of coefficient a_j are same and orthogonal in vector products, we can approximately estimate the system Coulomb energy. Let the distance between deuteron (or proton) and nearest electron-ball (or electron-particle in classical view) to be R_{de}. We write the d–d distance as

$$R_{dd} = \sqrt{2}R_{de}. \tag{13}$$

By assuming the balance of classical Coulomb forces between particles at vertexes of cube, we get approximate value of Coulomb energy as (see Fig. 6),

$$\langle E_{C-TSC}\rangle = 12\left(-\frac{e^2}{R_{de}}\right) + 12\left(\frac{e^2}{R_{dd}}\right) + 4\left(-\frac{e^2}{\sqrt{3}R_{de}}\right) = -\frac{8.38}{R_{de}} \tag{14}$$

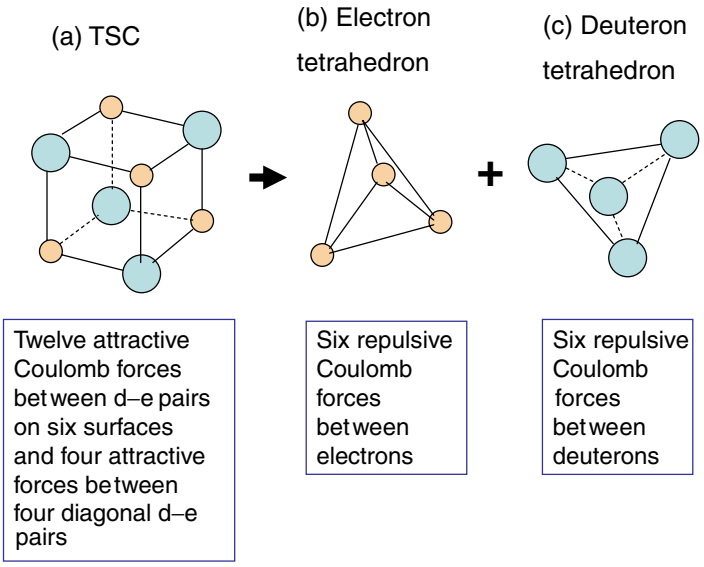

Figure 6. TSC (**a**) as combination of two regular tetrahedrons (**b**, **c**) and Coulomb forces between particles.

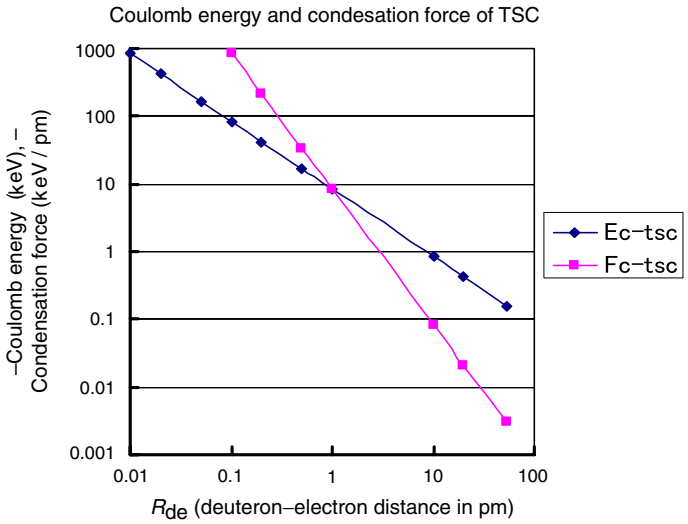

Figure 7. Coulomb energy and condensing force of TSC.

(in keV unit with pm unit for R). In three terms of Eq. (14), the first one is attractive forces on six surfaces of TSC cube, the second one is repulsive forces between d–d or e–e and the third term is the attractive forces between d–e for diagonal lines of cube.

Assuming the averaged effective kinetic energy for electron-balls are very small compared with Coulomb energy, due to coherently central squeezing motion, we can get rough estimation of condensing force of TSC by

$$F_{\mathrm{C-TSC}} = -\frac{\partial U}{\partial r} = -\frac{\partial E_{\mathrm{C-TSC}}}{\partial R_{\mathrm{de}}} = -\frac{8.38}{R_{\mathrm{de}}^2} \tag{15}$$

(in keV/pm unit with pm unit for R).

Calculated Coulomb energies and condensing forces as a function of R_{de} is shown in Fig. 7.

Here we considered that effective kinetic energy of four electron-balls on TSC represents the apparent averaged apparent kinetic energy of four "bosonized" electrons. In one of our models [5,6], we assume for TSC formation by phonon excitation in PdD lattice,

$$\left\langle E_{\mathrm{k,e-ball}} \right\rangle = 4\left(\frac{1}{2} m_{\mathrm{e}} {v_{\mathrm{d}}}^2\right) = 4\left(\frac{m_{\mathrm{e}}}{M_{\mathrm{d}}}\right) E_{\mathrm{d}} \leq 0.88\,\mathrm{eV}. \tag{16}$$

One forth of this energy was corresponded to seventh phonon-energy (one phonon 64 meV) for deuteron as harmonic oscillator in PdD lattice and nearly equal to the barrier height of Bloch potential trapping deuterons in Pd-metal O-sites (see part-II of Takahashi and Yabuuchi [7]). This very low effective kinetic energy seems to be attained by the Platonic symmetry for ordered-constrained-organized condition in forming TSC cluster in metal-D(H) systems. We should note here that local kinetic energy of electrons in a torus-orbit of a shrinking dde* molecular group in TSC would be much larger (larger than 16.2 eV for D_2 molecule), due to decreased d–d distance, if we would regard TSC as a steady state molecule. However, the process is under very rapid transient condensation motion.

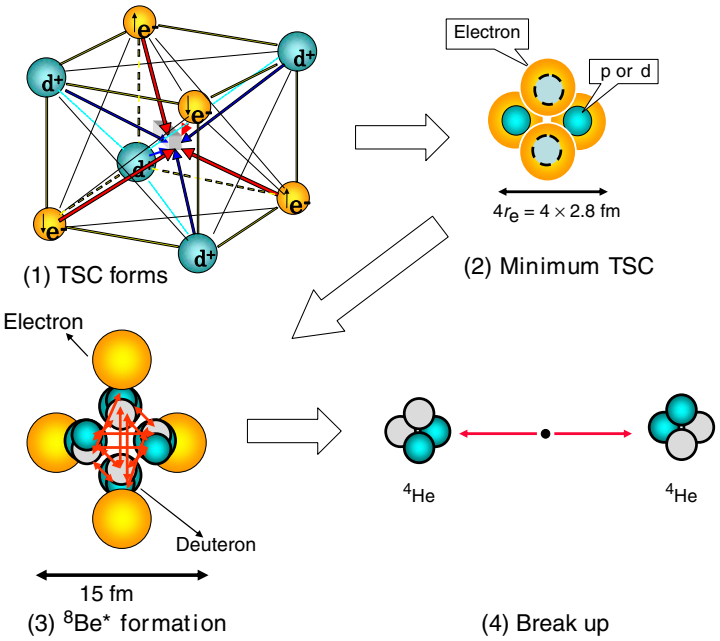

Figure 8. Feature of TSC condensation and 4D fusion reaction; (1) TSC is formed at $t = 0$, and squeezing with Newtonian motion to condense onto the central focal point, (2) end of squeezing motion at the size of TSC-minimum when getting into the range of strong force, (2) four deuterons exchange charged-pions to form shrinking ^{8}Be* intermediate compound nucleus with very short life (less than 1 fs), and charge neutrality of TSC is broken, and (3) ^{8}Be* breaks up to two alpha-particles with 23.8 MeV each [7]. It will take about 60 fs for the process.

Coulomb energy of TSC at 11 pm for R_{de}(corresponding 15 pm for R_{dd}; see Table 1) is about −0.9 keV, which can be compared to −2.46 keV of trapping depth by dde*(4,4) EQPET molecule. Bosonization of electron pair helps much condensing force increased.

As shown in Fig. 7, condensing force of TSC increases as d–e or d–d distance decreases. Consequently, once TSC is formed, it squeezes ultimately to condense into the central focal point until when some other force like strong interaction breaks the charge-neutrality of TSC. We copy [5–7] the figure of squeezing motion with 4D fusion reaction in Fig. 8.

5. Conclusion

Due to platonic symmetry in TSC formation, effective Coulomb energy and resulting condensing force of squeezing TSC-system becomes very large. The charge neutrality and balance of Coulombic forces keep this condition until TSC gets into the strong interaction range.

Bosonization of electron pairs may play a key role to trigger or generate TSC at some focal points in metal plus deuteron (proton) systems of condensed matter.

More exact quantum mechanical analysis on the mechanism of time-dependent TSC motion is to be explored in future.

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