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Research Article

Dynamic Mechanism of TSC Condensation Motion

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Abstract

This paper discusses and explains the time-dependent quantum-mechanical behavior of electron-clouds in 4D/TSC (tetrahedral symmetric condensate) condensation motion by the Langevin equation, in comparison with steady ground state electron orbits and their de Broglie wave lengths for the D-atom and D_2 molecule. An electron orbit in a "d–e–d–e" quasi-molecular system of a face of 4D/TSC under time-dependent condensation makes a spiral track, finally reaching the center-of-mass point of the TSC, with a tail of time-varying effective wave length. The role and merit of the heavy mass electronic quasi-particle expansion theory (HMEQPET) method for approximating time-dependent TSC trapping potential and relating it to the estimation of time-dependent Coulomb barrier penetration probabilities of a 4D cluster is explained.
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Keywords: Tetrahedral symmetric condensate, 4D cluster, condensation motion, Langevin equation, Time-dependent trapping potential, Barrier penetration, Fusion rate

1. Introduction

The formation of 4D/TSC (tetrahedral symmetric condensate) at or around a T-site of a regular PdD lattice under D-phonon excitation; or on the topological (fractal) nano-scale surface of PdDx; and/or along the interface of metal–oxide–metal nano-composite, has been proposed as the seed of deuteron-cluster fusion, which produces heat with helium-4 as 4D fusion ash [1]. The dynamic motion of TSC condensation was quantitatively studied by the quantum-mechanical stochastic differential equation (Langevin equation) for many-body cluster systems of deuterons and electrons under Platonic symmetry [2–6].

By the ensemble averaging of the Langevin equation with the weight of quantum mechanical wave-functions for electrons and deuterons, we could further derive a time-dependent one-dimensional Langevin equation for expectation value $\langle R_{dd} \rangle$, which is nonlinear, but could be solved by the Verlet's time-step method [2,3]. We showed in our previous work [4] that only 4D(or H)/TSC, among D_2, D_2^+, D_3^+, 4D/TSC and $6D^{2-}$/OSC clusters, can condense ultimately to form a very small charge-neutral entity, with a radius of about 10–20 fm. At the final stage of 4D/TSC condensation in about 2×10^{-20} s, 4D fusion with two ^{4}He products takes place with almost 100% probability, according to our heavy

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mass electronic quasi-particle expansion theory (HMEQPET) calculation [3,4] for barrier factors and the fusion rate formula by Fermi's first golden rule.

This paper presents further discussions and explanations of the time-dependent quantum-mechanical behavior of electron clouds in 4D/TSC condensation motion, in comparison with steady ground state electron orbits and their de Broglie wave lengths for the D-atom and D_2 molecule. An electron orbit in a "d–e–d–e" quasi-molecular system of a face of 4D/TSC under time-dependent condensation makes a spiral track, finally reaching the center-of-mass point of the TSC, with a tail of time-varying effective wave length. Electron kinetic energy at $t = 0$ is 19 eV, and it continuously increases during the condensation time (1.4007 fs) reaching finally 57.6 keV at $R_{dd} = 25$ fm. The trapping potential depth of TSC was estimated to be −130.4 keV at $R_{dd} = 25$ fm.

The role and merit of the HMEQPET method for approximating time-dependent TSC trapping potential and relating to the estimation of time-dependent Coulomb barrier penetration probabilities of 4D cluster is explained. HMEQPET provides a practical method for calculating time-dependent (hence time-averaged) fusion rate under TSC condensation, based on Fermi's first golden rule.

2. Condensation motion of 4D/TSC by Langevin equation

The basics of methods with Langevin equations for D-cluster dynamics, especially for D-atom, D_2 molecule, D_2^+ ion, D_3^+ ion, in a 4D/TSC (tetrahedral symmetric condensate) and $6D^{2-}$/OSC (octahedral symmetric condensate) are described in our latest paper [4].

First, one-dimensional Langevin equations for D-clusters with the R_{dd} (d–d distance) are formulated under the Platonic symmetry [2] of multi-particle D-cluster systems with deuterons and quantum-mechanical electron centers. Under the orthogonally coupled Platonic symmetry for a Platonic deuteron system and a Platonic electron system, dynamic equations for so-many-body system of deuterons and electrons with metal atoms, a simple one-dimensional Langevin equation for the inter-nuclear d–d distance R_{dd} can be formulated, as we showed in the previous paper [4]. The Langevin equation of electron-cloud-averaged expectation value of d–d distance R_{dd} for D-cluster is given by

$$N_e m_d \frac{d^2 R}{dt^2} = -\frac{k}{R^2} - N_f \frac{\partial V_s}{\partial R} + f(t). \tag{1}$$

This is the basic Langevin equation for a Platonic symmetric D-cluster having N_e d–d edges and N_f faces of "d–d–e" (D_2^+) or "d–e–d–e" (D_2) type. Here, R is the d–d distance and m_d is the deuteron mass, V_s is the d–d pair trapping potential of either "d–e–d–e"-type ($i = 2$) or "d–d–e"-type ($i = 1$) molecule. The first term on the right side in Eq. (1) is the total Coulomb force (converted to one-dimensional variable R) of the D-cluster system, and $f(t)$ is the fluctuation of force for which we introduce a quantum mechanical fluctuation of deuteron positions under condensation motion. The quantum mechanical effect of electron clouds is incorporated with the second term on the right-hand side as "friction" in Langevin equation. Parameters for different D-clusters are given in Table 1.

Table 1. Parameters of D-cluster Langevin equation.

Cluster	N_e (number of d–d edges)	K (total Coulomb force parameter, keV pm)	Type of electron trapping potential on a surface	N_f (number of faces)
D_2	1	0	$i = 2$	1
D_2^+	1	0	$I = 1$	1
D_3^+	3	6.13	$i = 1$	6
4D/TSC	6	11.85	$i = 2$	6
$6D^{2-}$/OSC	12	29.3	$i = 1$	24

By taking the QM ensemble average with d–d pair wave function, assumed as Gaussian distribution of Eq. (5), we derived the Langevin equation for 4D/TSC as Eq. (2). By taking QM ensemble average of Eq. (3) using Eq. (4), we obtained Eq. (6) for expectation value $\langle R_{dd}\rangle$. We obtained the time-dependent TSC-cluster trapping potential [4] as Eq. (7). The balancing to the Platonic symmetry after distortion (deviation from symmetry) works by the third term of Eq. (7).

$$6m_d\frac{d^2R_{dd}(t)}{dt^2} = -\frac{11.85}{[R_{dd}(t)]^2} - 6\frac{\partial V_{s2}(R_{dd}(t);1,1)}{\partial R_{dd}(t)} + \langle f(t)\rangle + f'(t), \tag{2}$$

$$f'(t) = f(t) - \langle f(t)\rangle, \tag{3}$$

$$f(t) = \left[-\frac{\partial \Delta E_c(R_{dd})}{\partial R_{dd}}\right] \bmod [X^2(R'_{dd};\, R_{dd}(t))], \tag{4}$$

$$X^2(R'_{dd};\, R_{dd}(t)) = \frac{1}{\sqrt{2\pi\sigma^2}}\exp[-(R'_{dd} - R_{dd}(t))^2/(2\sigma^2)], \tag{5}$$

$$6m_d\frac{d^2\langle R_{dd}\rangle}{dt^2} = -\frac{11.85}{\langle R_{dd}\rangle^2} - 6\frac{\partial V_s(\langle R_{dd}\rangle; m, Z)}{\partial\langle R_{dd}\rangle} + 6.6\left\langle\frac{(R' - R_{dd})^2}{R_{dd}^4}\right\rangle, \tag{6}$$

$$V_{TSC}(R' : R_{dd}(t)) = -\frac{11.85}{R_{dd}(t)} + 6V_s(R_{dd}(t); m, Z) + 2.2\frac{|R' - R_{dd}(t)|^3}{[R_{dd}(t)]^4}. \tag{7}$$

A similar Langevin equation and trapping potential were derived for $6D^{2-}$ ion molecule also. We compared the central potential curve (at $R' = R_{dd}$) in Fig. 1. We found that 4D(or H)/TSC can condense ultimately to a very small charge neutral entity and has no stable or ground state. This may be the reason that we do not observe the D_4 molecule in nature. On the contrary, $3D^+$ molecule and $6D^{2-}$ molecule have stable and ground states [4].

Equation (6) was numerically solved by the Verlet method [3], with the result shown in Fig. 2.

Time-dependent barrier penetration probabilities (as a function of R_{dd}, since we have a one-to-one relation between elapsed time and $R_{dd}(t)$) are calculated by HMEQPET method [3] and shown in Table 2.

The fusion rate is calculated by the following Fermi's golden rule [3,4],

$$\lambda_{nd} = \frac{2}{\hbar}\langle W\rangle P_{nd}(r_0) = 3.04\times 10^{21} P_{nd}(r_0)\langle W\rangle. \tag{8}$$

Table 2. Calculated time-dependent (equivalently R_{dd} dependent) barrier factors of 4D/TSC condensation motion.

Elapsed time (fs)	R_{dd} (pm)	P_{2d} (2D barrier factor)	P_{4D} (4D barrier factor)
0	74.1 (D_2 molecule)	1.00E–85	1.00E–170
1.259	21.8 (dde*(2,2); Cooper pair)	1.30E–46	1.69E–92
1.342	10.3	2.16E–32	4.67E–64
1.3805	4.12	9.38E–21	8.79E–41
1.3920	2.06	6.89E–15	4.75E–29
1.3970	1.03	9.69E–11	9.40E–21
1.39805	0.805 (muon-dd molecule)	1.00E–9	1.00E–18
1.39960	0.412	9.40E–7	2.16E–13
1.40027	0.206	3.35E–5	1.12E–9
1.40047	0.103	1.43E–3	2.05E–6
1.40062	0.0412	1.05E–2	1.12E–4
1.40070	0.0206 (TSC-min)	4.44E–2	1.98E–3

Here P_{nd} is the barrier factor for nD-cluster and $\langle W \rangle$ is the averaged value of imaginary part of nuclear optical potential [3,4]. The extrapolation of $\langle W \rangle$ value to 4D fusion was made [3] by using the scaling law $\langle W \rangle \propto (\text{PEF})^5$ with PEF-value which is given in unit of derivative of one pion exchange potential (OPEP) (simple case of Hamada–Johnston potential [4] for pion exchange model. We estimated the next value of 4D fusion yield per TSC generation,

$$\eta_{4d} = 1 - \exp\left(-\int_0^{t_c} \lambda_{4d}(t)\mathrm{d}t\right). \tag{9}$$

Using the time-dependent barrier factors as given in Table 2, we obtained [3] $\eta_{4d} \cong 1.0$. This result means that we have obtained a simple result that 4D fusion may take place with almost 100% yield per a TSC generation, so that macroscopic 4D fusion yield is given simply with a TSC generation rate Q_{TSC} in the experimental conditions of CMNS.

The ultimate condensation is possible only when the double Platonic symmetry of 4D/TSC is kept in its dynamic motion. The sufficient increase (super screening) of barrier factor is also only possible insofar as the Platonic symmetric 4D/TSC system is kept. Therefore, there should be always four deuterons in the barrier penetration and fusion process, so that 4D simultaneous fusion should take place predominantly. The portion of 2D (usual) fusion rate is considered to be negligible [3].

Typical nuclear products of 4D fusion are predicted to be two 23.8 MeV α-particles, although the final state interaction of ^{8}Be* is too complex to be studied yet [5,6].

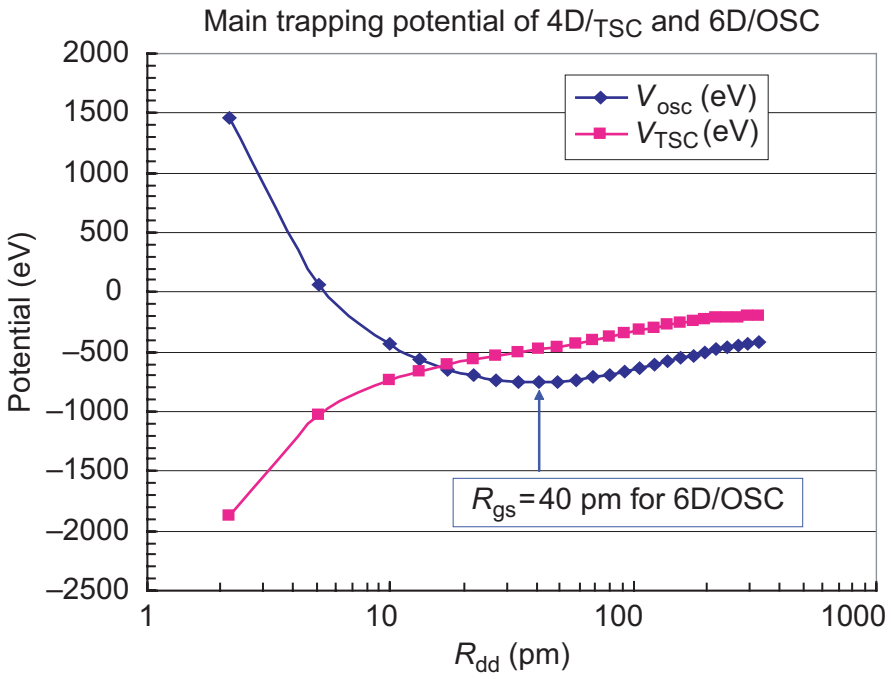

Figure 1. Comparison of cluster trapping potential between 4D/TSC and $6D^{2-}$/OSC. TSC condenses ultimately to very small R_{dd} value (ends at R_{dd-min} = about 20 fm), while OSC converges at R_{dd} = about 40 pm (corresponding to the ground state).

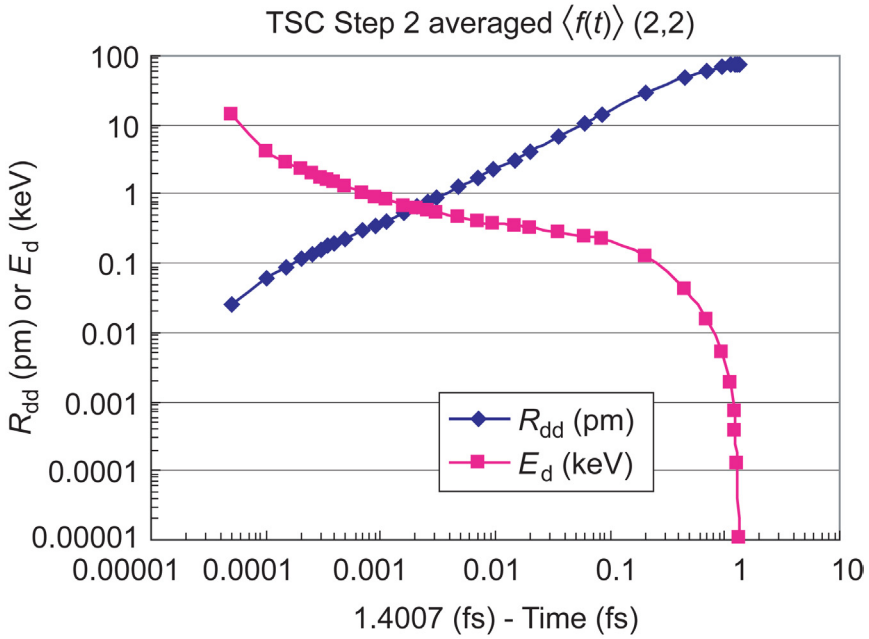

Figure 2. Numerical solution of Eq. (6) by the Verlet method [3]. Time is reversed starting from the condensation time 1.4007 fs.

3. Time-dependent QM behavior of electron clouds

We consider now the dynamic condensation motion of TSC in the view of the Heisenberg uncertainty principle (HUP). In the starting condition of 4D/TSC ($t = 0$), d–d distance R_{dd} was estimated to be the same value (74.1 pm) as that of a

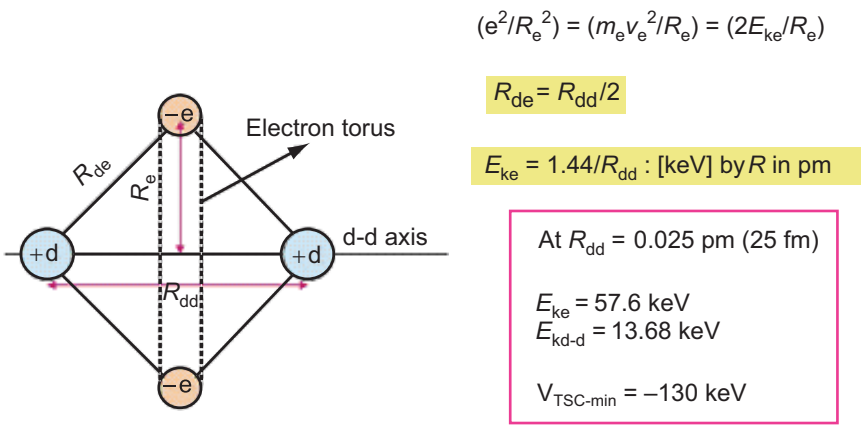

Figure 3. Semi-classical model of "d–e–d–e" EQPET molecule as a face of 4D/TSC (left), and estimated electron kinetic energy at $R_{dd} = 25$ fm (right). Time-dependence of mean electron kinetic energy can be estimated, by assuming the adiabatic quasi-steady state of "d–e–d–e" system in every small time-step.

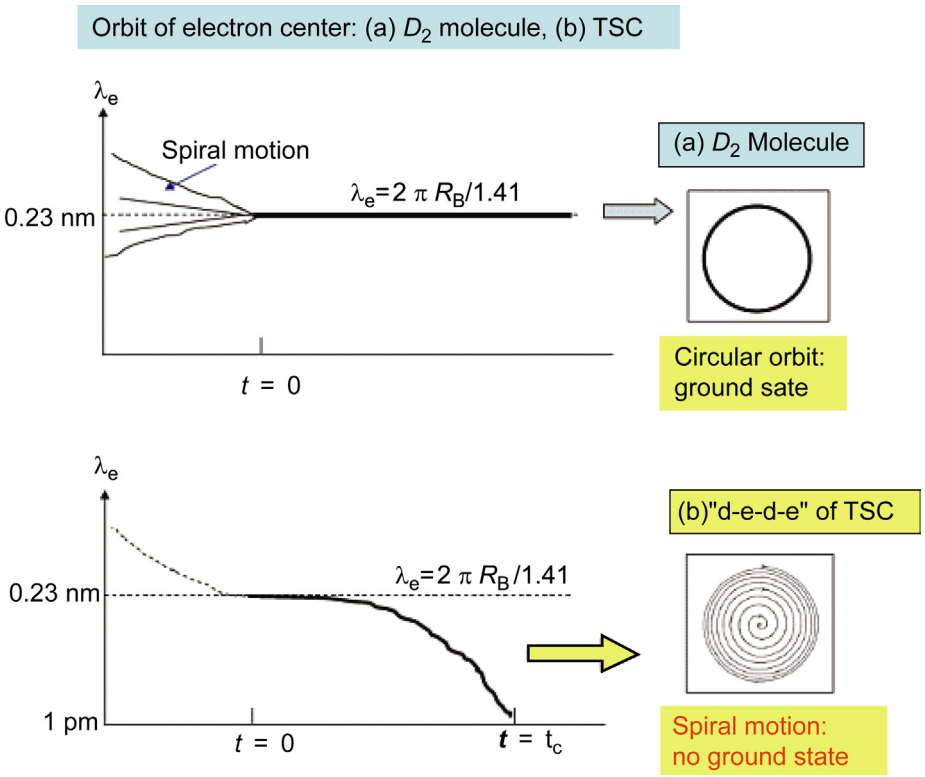

Figure 4. Time-dependent behavior of effective electron wave length: (a) D_2 molecule, (b) "d–e–d–e" EQPET molecule of 4D/TSC.

D_2 molecule. At this starting point, mean electron kinetic energy of one "d–e–d–e" face EQPET molecule out of TSC six faces was 17.6 eV (19 eV by semi-classical model). During the non-linear condensation of TSC, as the parameters given in Table 2 show, the size of "d–e–d–e" EQPET molecule as a face of 4D/TSC decreases from $R_{dd} = 74.1$ pm at $t = 0$ to $R_{dd} = 20.6$ fm at $t = 1.4007$ fs. In the view of HUP, the electron wave length should decrease accordingly to the decrement of R_{dd}. At around $t = 1.4007$ fs, the mean kinetic energy of the electron for a "d–e–d–e" EQPET molecule was estimated [3] to be 57.6 keV. A semi-classical model of "d–e–d–e" EQPET molecule is shown in Fig. 3. This semi-classical model reflects the original Langevin equation for the D_2 molecule, before the quantum-mechanical ensemble averaging is done, as given by,

$$m_d \frac{d^2 R_{dd}}{dt^2} = -(4\sqrt{2} - 2)\frac{e^2}{R_{dd}^2} + \frac{2m_e v_e^2}{(R_{ee}/2)} - \frac{\partial V_{s2}(R_{dd}; 1, 1)}{\partial R_{dd}} + f(t). \tag{10}$$

Here we consider the averaged force-balance between the first term and the second term on the right-hand side of Eq. (10), with ensemble averaging by weight of "adiabatic electron wave function" of modified 1S wave function with decreased de Broglie wave length during every small time step interval.

Considering the relations, $\lambda\!\!\!^{-} = \hbar/mv$ of de Broglie wave length and (kineticenergy) $= (1/2)mv^2$, we understand that the effective quantum mechanical wave length of a trapped electron in TSC has decreased dramatically in the 1.4007 fs condensation time. The estimated trapping potential depth of TSC at around $t = 1.4007$ fs was -130.4 keV.

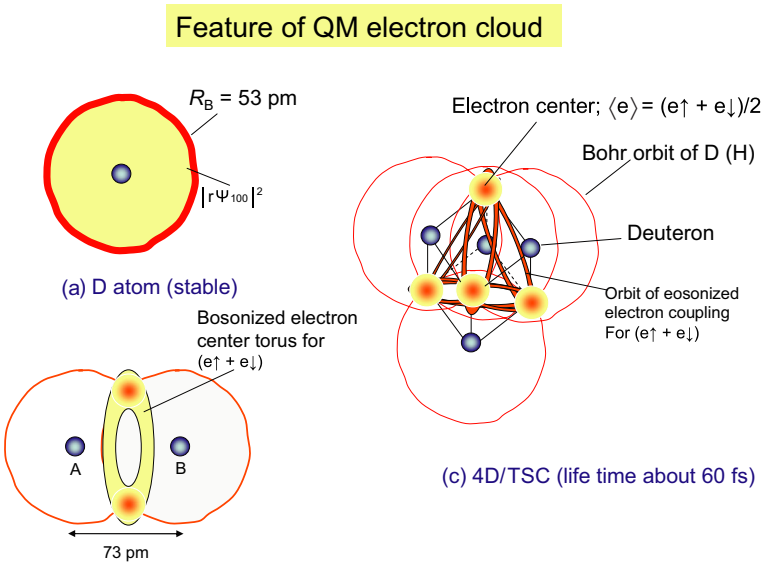

Figure 5. Quantum-mechanical feature of electron clouds for (a) D-atom, (b) D_2 molecule and (c) 4D/TSC ($t = 0$).

This state is understood as an adiabatic state in a very short time interval (about 10^{-20} s) to trap such high kinetic energy (57.6 keV) electrons in very deep (−130.4 keV) trapping potential, to fulfill the HUP condition. By the way, the mean kinetic energy of relative d–d motion was estimated [3] to be 13.68 keV in this adiabatic state, which also diminishes the relative deuteron wave length trapped in the adiabatic TSC potential. In this way, very short R_{dd} (in other words, super screening of mutual Coulomb repulsion) is realized in the dynamic TSC condensation in very fast condensation time ($t_c = 1.4007$ fs) to give, however, a very large 4D simultaneous fusion rate [3,4].

We know that the ground state of the electron orbital (sphere) of D (or H) atom is the Bohr radius ($R_B = 52.9$ pm). The mean kinetic energy of 1S electron is 13.6 eV, the de Broglie wave length of which is 332 pm. And we know $2\pi R_B = 332$ pm to satisfy the continuation of 1S electron wave function by one turn around central deuteron. No other states with a shorter or longer wave length can satisfy the condition of a smooth continuation of wave function, as ground state, for which we must keep the condition that mean centrifugal force equals mean centripetal force.

By the way, quantum mechanical feature of electron clouds are illustrated in Fig. 5, for D-atom, D_2 molecule and 4D/TSC ($t = 0$), respectively.

In contrast to the ground state electron orbital, the electron orbit in a "d–e–d–e" quasi-molecular system makes a spiral track to the center-of-mass point of the TSC, as discussed above. The role and merit of HMEQPET (heavy mass electronic quasi-particle expansion theory) method for approximating time-dependent TSC trapping potential and relating to the estimation of time-dependent Coulomb barrier penetration probabilities of 4D cluster is explained in Section 4.

Similar to the D-atom case, the ground state electron wave function of a D_2 molecule has a steady ground state torus (ring) orbit of two centers of electron clouds [4]. The mean kinetic energy of centrifugal electron motion around the center-of-mass point (middle point of d–d distance) was calculated to be 17.6 eV (19 eV by semi-classical model in Fig. 3), the de Broglie wave length of which is 234 pm and equals $2\pi R_B/1.4142$ to satisfy the smooth continuation of electron wave function along the torus orbit around the center-of-mass point. The dynamic motion of "d-e–d–e"

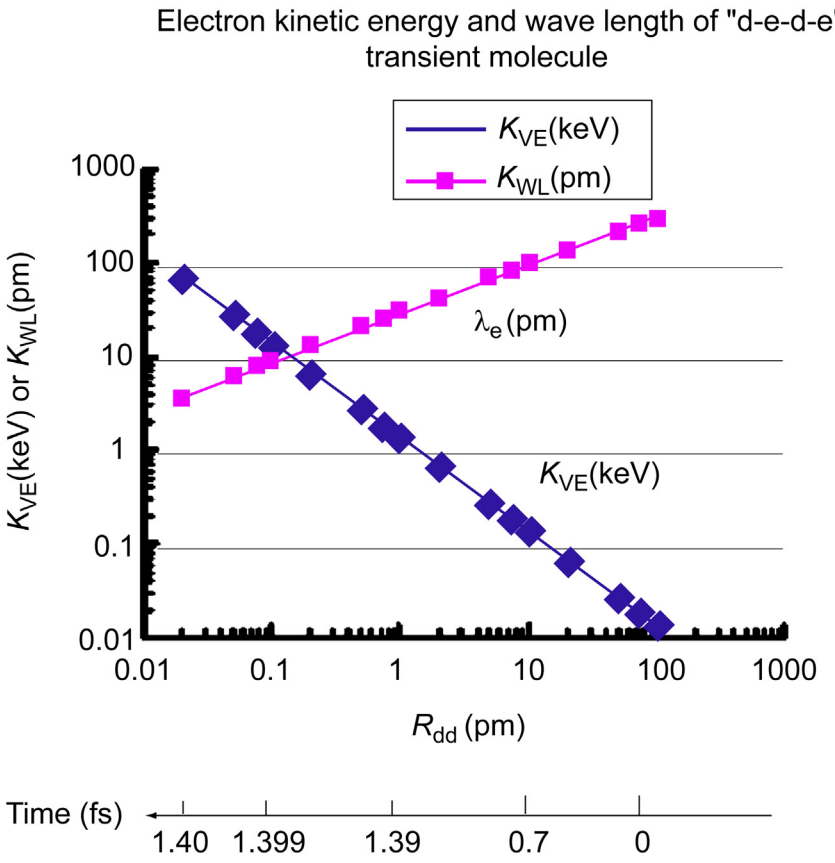

Figure 6. Time variation of mean electron kinetic energy (EKE) and its wave length (EWL) during the 4D/TSC condensation motion in 1.4007 fs condensation time.

four-body system by Langevin equation [Eq. (10)] is illustrated in Fig. 4a. When starting with an arbitrary electron wave length (or momentum), the center of electron cloud follows a spiral orbit to converge finally to the steady torus (ring or circle) orbit with 234 pm one turn length which equals to the ground state effective electron wave length of a D_2 molecule. When we have the strong constraint of TSC trapping potential, the center of the electron cloud follows a spiral orbit time-dependently (Fig. 4b) without a converging ground state. The calculated mean (eigen) energy-values of the D_2 molecule are E_{gs} (ground state system energy) $= -35.1$ eV, E_c (mean Coulomb energy) $= -70.3$ eV, E_{d-d} (mean relative deuteron energy) $= 2.7$ eV and E_{ke} (mean electron kinetic energy) $= 35.2$ eV for two electrons (17.6 eV per electron) [3].

As a result, the centrifugal electron motion in a "d–e–d–e" face follows a spiral curve converging to the central focal point as illustrated in Fig. 4b. If we do not have the strong centripetal Coulombic condensation force by the first term of Eq. (1) right side, for 4D/TSC, the "d–e–d–e" EQPET molecule must go back and converge to the ground state orbit of D_2 molecule, as shown in Fig. 4a.

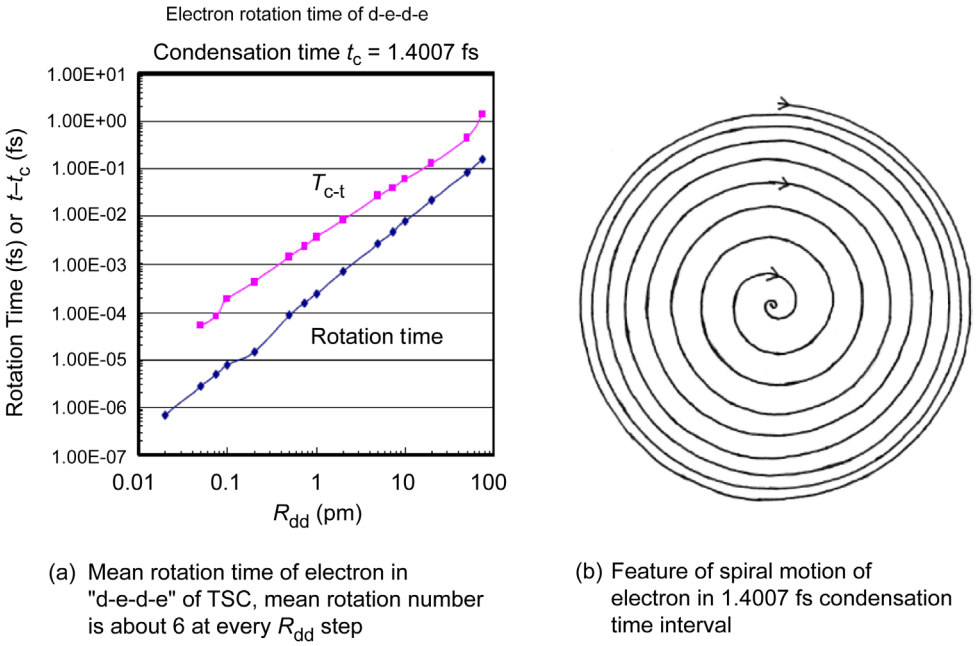

Figure 7. Mean rotation time of electron cloud center under 4D/TSC condensation motion (left) and expanded feature of electron spiral motion (right).

4D/TSC has no steady ground state and the effective electron wave length of a "d–e–d–e" face varies from time to time as illustrated in Figs. 4b and 6.

The spiral motion of the electron center under 4D/TSC condensation is illustrated with expanded scale (right figure), compared with the estimation of mean rotation number of electron in each discrete change of R_{dd} steps, in Fig. 7.

The electron center rotates about six times in each step of R_{dd} changes in Fig. 7. This means the time-dependent electron wave function distributes with a "long" tail along the spiral orbit. This situation does not contradict the Heisenberg uncertainty principle, as a steady ground state does not exist and particles are non-linearly moving.

4. HMEQPET method for fusion rate quantification

The Langevin equation of the expectation value for 4D/TSC and its time-dependent trapping potential are given by Eqs. (6) and (7), respectively. The TSC trapping potential at the final stage (TSC-min) of condensation is shown in Fig. 8.

The depth of the trapping potential is −130.4 keV. The calculated relative kinetic energy of d–d pair is 13.68 keV. In approximation, this potential can be regarded as an adiabatic potential having the d–d pair "quasi-ground state" with $E_{gs} = 13.68$ keV trapped in 130.4 keV deep potential for a very short time-interval of 10^{-20} s. In every time step of the numerical calculation (by the Verlet method [3]), we can draw the approximate adiabatic potential which changes continuously with the change of time.

The kinetic energy of particle is given by $E = (1/2)mv^2$. The de Broglie wave length is given by $\lambda\!\!\!^{-} = \hbar/mv$.

Mean electron kinetic energy increases in a "d–e–d–e" face during condensation motion as shown in Fig. 6. An

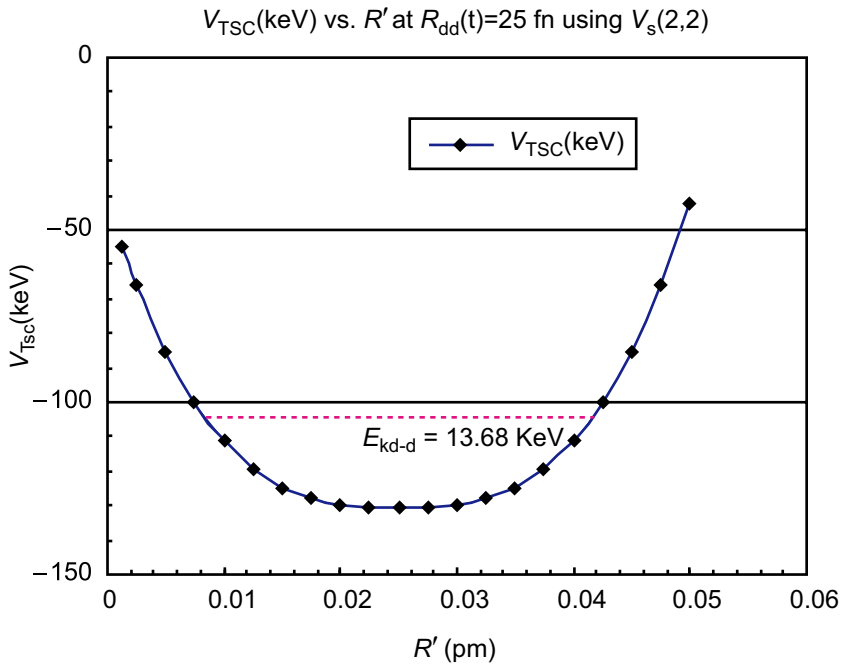

Figure 8. TSC trapping potential at the final stage (TSC-min) of condensation motion by Langevin equation.

electron wave length with increased kinetic energy (or momentum) can be replaced with heavy mass fermion to keep the same "d–e–d–e" size. The HMEQPET method is based on this idea.

From Fig. 3, the mean kinetic energy of an electron in a "d–e–d–e" face is 57.6 keV at $R_{dd} = 25$ fm. A TSC at $t = 0$ has mean electron kinetic energy about 18 eV, the equivalent mass of the "heavy" fermion is estimated to be $\sqrt{57.6 \times 1000/18} = 56.57$ times the electron mass, which is virtual and not the mass of heavy electron in metal physics. The depth of dde*(56.57,2) potential is about −4.8 keV and comparable to the trapping potential of a muonic d–d molecule (see Tables 3 and 2).

Since the depth of 4D/TSC trapping potential at R_{dd}= 25 fm was –130.4 keV, we must assume a much heavier fermion to quantitatively approximate the TSC trapping potential by EQPET dde*(m,Z) potential [1].

We used a Gaussian wave function for d–d pair in Langevin equations. As discussed [3], we cannot use a Gaussian wave function for the estimation of the Coulomb barrier penetration probability (barrier factor), because the tail of the Gaussian function is not accurate enough. Instead, we can use trapping potentials of dde*(m,2) EQPET molecule and Gamow integrals. The assumed quasi-particle state is a heavy Cooper pair e*(m,2) of two "heavy" electrons in a "d–e–d–e" system.

If there exists a one-to-one relation between m and $\langle R_{dd}\rangle(t)$, we can replace all time-dependent TSC trapping potentials with $V_s(R_{dd}(t);m,2)$ potentials of HMEQPET, by continuously adopting a real number of m.

Typical parameters of calculated $V_s(R_{dd}(t);m,2)$ potentials are shown in Table 3. From this table, we derive the following empirical laws:

$$b_0(m, 2) = 0.206 R_{gs}(m, 2), \tag{11}$$

$$m = 9000/b_0(m, 2). \tag{12}$$

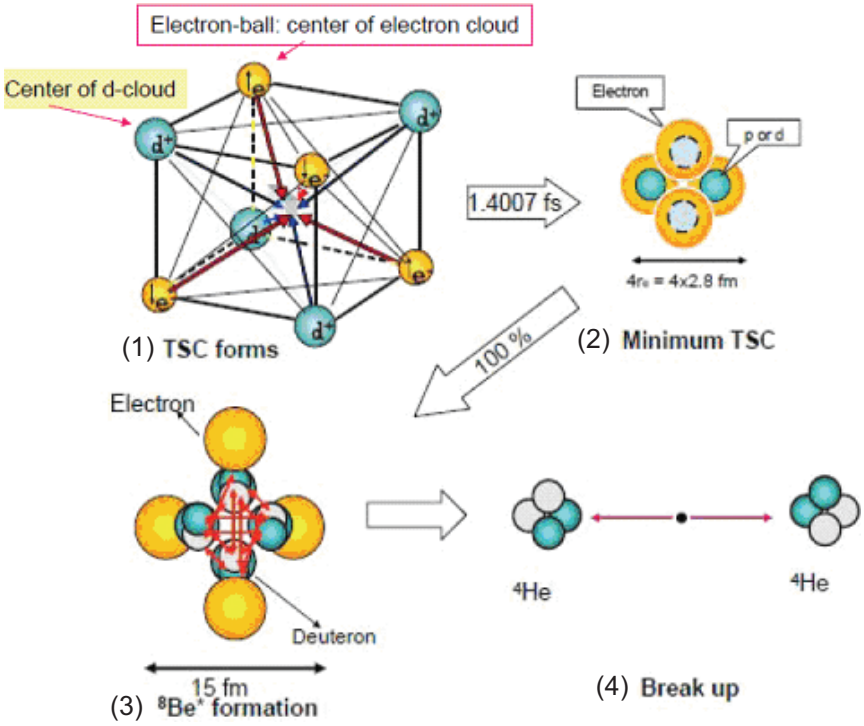

Figure 9. Brief illustration of 4D/TSC condensation motion, in four steps.

Here b_0 and R_{gs} values are given in fm units. Muonic dd-molecule has $R_{gs} = 805$ fm, and $m = 54\,m_e$ of HMEQPET potential corresponds to it. The final stage of TSC potential corresponds to $m = 2000\,m_e$.

Calculated barrier factors by HMEQPET method are already given in Table 2. Finally, we again illustrate the 4D/TSC condensation motion in Fig. 9.

Table 3. Calculated HMEQPET potentials and their parameters. E_{gs}–V_{s-min} gives mean relative kinetic energy of a trapped d–d pair

Molecule	b_0 (pm)	R_{min} (pm)	V_{s-min}(keV)	E_{d-d} (keV)	R_{gs} (pm)	E_{gs} (keV)
D_2	22	70	–0.03782	0.00268	**76.69**	–0.03514
dde* (2,2)	4.5	19.3	–0.1804	0.01013	**21.82**	–0.17027
dde*(5.2)	1.9	7.6	–0 4509	0.0208	**8.72**	–0.43007
dde* (10,2)	0 90	3.8	–0.9019	0.0418	**4.36**	–0.86012
dde* (20,2)	0.45	1.9	–1.8039	0.0837	**2.18**	–1.7202
dde*(50,2)	0.18	0.76	–4.5097	0.2094	**0.873**	–4.3003
dde*(100,2)	0.09	0.38	–9.0194	0.4196	**0.436**	–8.5998
dde* (200,2)	0.045	0.19	–18.039	0.843	**0.218**	–17.196
dde* (500,2)	0.018	0.076	–45.097	2.135	**0.0873**	–42.968
dde*(1000,2)	0.009	0.038	–90.194	4.336	**0.0436**	–85.858
dde* (2000,2)	0.0045	0.019	–180.39	8.984	**0.0218**	–171.406

5. Conclusions

Further explanation of the 4D/TSC condensation motion by quantum-mechanical stochastic differential equations (Langevin equations) has been given in this paper. The electron orbit in a "d–e–d–e" quasi-molecular system of a face of 4D/TSC under time-dependent condensation makes a spiral track finally reaching the center-of-mass point of the TSC, with a tail of time-varying effective wave length. There is found no contradiction with the Heisenberg uncertainty principle.

The role and merit of HMEQPET (heavy mass electronic quasi-particle expansion theory) method for approximating the time-dependent TSC trapping potential and relating to the estimation of time-dependent Coulomb barrier penetration probabilities of 4D cluster is explained.

Dynamics analyses by Langevin equations for D- (or H-) clusters are useful tools to quantitatively estimate the time-dependence of expectation values and trapping potentials, as well as time-dependent fusion rates.

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References

[1] A. Takahashi, A theoretical summary of condensed matter nuclear effects, *J. Condensed Matter Nucl. Sci.* **1** (2007) 129–141.
[2] A. Takahashi, N. Yabuuchi, Condensed matter nuclear effects under Platonic symmetry, *Proc. ICCF13*, Sochi, Russia, 2007 (to be published).
[3] A. Takahashi, N. Yabuuchi, Study on 4D/TSC condensation motion by non-liniear Langevin equation, *LENR Source Book, American Chemical Society*, 2007, to be published from Oxford Univ. Press, August 2008.
[4] A. Takahashi, N. Yabuuchi, D-cluster dynamics and fusion rate by Langevin equation, *Proc. 8th Int. Workshop on Anomalies in D/H Loaded Metals*, Catania, Italy, 2007, to be published in 2008.
[5] A. Takahashi, A chronicle of condensed cluster fusion models, *Proc. JCF8*, Kyoto, 2007, pp. 51–62, Japan CF Research Society, 2008.
[6] A. Takahashi, "*Cold Fusion 2008 – mechanism of condensed cluster fusion*" (in Japanese), Kogakusha, Tokyo, 2008.