Data in cluster model of molecules

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The term "cluster model of molecules" was proposed by de Gennes. De Gennes pointed out that the key to the glass state theory is to find the spin interaction between two adjacent hard-sphere molecules (HSMs). This interaction has now been discovered as the de Gennes $n = 0$ cluster-interaction boson (CI-boson), which is the unit length vector making up the interface of the 2D clusters at the bottom of the potential well. All CI-boson-derived 2D cluster data are divided into seven sections: the discovery process of CI-boson, the definition of new concepts, symbols and labeling methods, the cluster-peculation transition at the Kauzmann temperature, the largest 2D cluster at the glass transition, the 20-fold symmetry of CI-boson, the 20 CI-boson interaction maps of each HSM, and closed-loop hop path for each HSM in the soft matrix. All of these are the geometric data of the $n = 0$ 2D spin system inherent to disorder system itself**.**

SM 1. Why is five-HSM / five-cluster / five-local field model ?

(1) Need to build a soft matrix of the largest cluster along one direction from small to large

Molten polyester can transform entangled random macromolecules into structurally stable fully oriented polyester fibers (the glass transition has been complete) at a super-stretch rate of 30,000% within a few milliseconds under super-high-speed spinning conditions. However, under normal spinning speeds, the resulting fibers are not fully oriented and have unstable structures, and it takes hours or even days to complete the glass transition. The super-high-speed spinning line of polyester melt can link the abnormal viscosity of the entangled polymer melt to the super-tensile hydrodynamic mode and the oriented glass transition within a few milliseconds. One possible explanation is that only the largest 2D cluster (soft matrix) can move. There is a plurality of spatially oriented soft matrices in each localized region of the melt. All soft matrices in the supercooled liquid on the molten super-high speed spinning line are facing the same direction. The normal glass transition involves randomly selecting one direction of the soft matrix in each local area. In the super-high-speed spinning of polyester, within a few milliseconds, the temperature of the molten filament dropped from 300 degrees to room temperature and was stretched by more than 30,000%, which indicates that the formation of the soft matrix is independent of temperature and material deformation.

Experimental data on the cooperative orientation activation energy, $\Delta E_{co} = 2035$ (k_BT), of an on-line measurement of polyester under super-high-speed spinning[57] supports this view. In the experiment, 1/6 $\Delta E_{co} = 339$ (k_BT) is the energy of the glass transition temperature T_g ($\approx 339\ K \approx 67$°C) of polyester. The coefficient 1/6 is derived from the ideal random orientation distribution of macromolecules in the melt. This may mean that the average orientation energy of a soft matrix, whether in the melt or in the glass state should be k_BT_g, independent of system temperature T.

On the other hand, whether glass state, glass transition, or moltenthe, the average (directionally coupled electron-pair interface excited state) energy of each soft matrix is Hamiltonian $H = k_BT_g$° emerging in the local domain,, but the direction of all soft matrices in the system is random. Therefore, the average energy H of the system can be expressed by the disorder energy k_BT whose "molecular scale" reaches the soft matrix scale, that is, $H = k_BT_g$..

(2) The largest cluster (soft matrix) on the 2D *x–y* projection plane is oriented along the *z*-axis

Based on **(1)**, it can be reasonably proposed that the molten *z*-component chains of the entangled polymer freezes into a **±*z*-axis** oriented glassy structure on the *x*– *y* projection plane.

(3) Based on **(2)**, in order to make all HSMs in the 2D lattice oriented along the ±*z*-axis, there must be one or more interface excitation (IE) closed loops on the four sides of each HSM to form a dynamic Ising-spin model, see Fig. 1 and figures S2, S3 and S4.

(4) The constructed soft matrix must contain about 200 HSMs

200-HSM is the critical molecular weight of entangled polymer chain obtained through experiments, and requires theoretical support or to verify theory. If it is considered that 200 HSMs are also 200 different spatiotemporal states of a *z*-component chain on the molten super-high-speed spinning line, and are statistically equivalent to 200 *z*-direction chain units on 200 different chains, the projection of these 200 *z*-direction chain units on the 2D *x*-*y* plane is the largest orientation cluster in the glass state, that is, in the dynamic balance of the generation and disappearance of the soft matrix, the soft matrix must contain an average of 200 HSMs. The five-HSM/five-cluster /five-local field model can meet this requirement. The 3-HSM, 4-HSM or 6-HSM models cannot achieve this goal.

(5) In order for the local center a_0-HSM to establish three independent walking 2D soft matrices on the three projection planes in the *x*-, *y*- and *z*-axes, respectively.

Based on **(1)**, if it is considered that jumping in a certain direction in the glass transition is the largest cluster soft matrix rather than molecules, in order for the molecules to travel randomly in the melt, it must be possible to respectively construct three independently walking 2D soft matrices, ±*z*-S_9 (a_0), ±*x*-S_9 (a_0), ±*y*-S_9 (a_0), of a_0-HSM along the ±*z*-, ±*x*- and ±*y*-axis[14]. The formation of the +*z*-a_0-soft matrix is the 9 closed-loop jumps of the positively charged central particle of a_0-HSM [M^+-P(a_0) choosing a 4-diagonal path in the +*z*-direction on the 2Δd cubic lattice / equilateral hexahedron. Only five-HSM model can do this, 3-HSM, 4-HSM or 6-HSM models cannot build a micro-cubic lattice in two-HSM clustered collisions. It also shows that there can be three directions of 2D soft matrix potential energy in 3D space, respectively, balanced with thermal disordered kinetic energy k_BT_g.

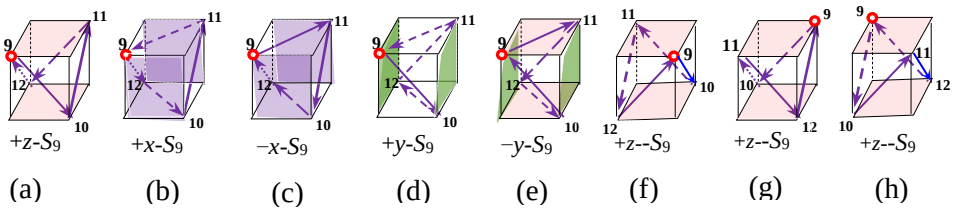

Figure S1. M^+-P(a_0) located at the starting point of the 4-diagonal closed loop (small red circle, point 9), selects 3 different closed loop paths among the 4 vertices (4 trap states) of its 2Δd cubic lattice to cycle 9 times forming three soft matrices, **a**. +*z*-S_9, **b**. +*x*-S_9, **d**. +*y*-S_9), which walk independently along the +*z*-, +*x*- and +*y* axes, respectively. There are four ways to form the same +*z*-S_9, which are **a**, **f**, **g**, and **h**.

(6) 200-HSM soft matrix can explain geometrical frustration

Based on **(4)**, there must be a mechanism to interrupt cluster growth. The largest cluster is also controlled by geometrical frustration. A mechanism including geometric frustration must be found to interrupt the cluster growth. Five-local field model can do this.

(7) Can be linked to the existing concept of fluctuations in molecular number density

Each interfacial excitation (IE) closed loop corresponds to a "local phase transition" and results in a sudden change in molecular number density.

(8) A strict definition can be given for the excluded volume between polymer chain units (HSMs)

The excluded volume of a_0-HSM is the volume enclosed by a_0-HSM and its four adjacent HSMs 4×16 sequential overlap-collisions of 0.27%, this volume is not occupied by other HSMs. That is, the excluded volume is actually a molecular interface excited spin in the form of a dynamic equilateral hexahedron, bounded by the oriented 4×16 coupled electron pair (CEP) IE states.

(9) Satisfy the clustered fluctuation symmetry in the random system

In the soft matrix with a_0 as the center, a_0 collides sequentially with its four adjacent molecules, b_0, c_0, d_0 and e_0, preferentially form $V_0(a_0)$ cluster. Then, based on the fluctuating symmetry, clusters centered on b_0, c_0, d_0 and e_0 are sequentially formed: $V_0(b_0)$, $V_0(c_0)$, $V_0(d_0)$ and $V_0(e_0)$. After that, $V_0(a_0)$ sequentially interacts with $V_0(b_0)$, $V_0(c_0)$, $V_0(d_0)$ and $V_0(e_0)$ to form $V_1(a_0)$ cluster.... In the five-local field, the fluctuation symmetry of the five soft matrices is self-similar to the fluctuation symmetry of the five clusters in the a_0 soft matrix, see Figure S3. The advantage is that the energy of rearranging a_0-soft matrix is $kT_m° = kT_g° + 4\varepsilon_0$, when $V_8(b_0)$, $V_8(c_0)$, $V_8(d_0)$ and $V_8(e_0)$ appear in fluctuations. ε_0 is the potential well energy.

SM 2. Interface excited state and interface excited arrow and *A*-local area

An interface excited (IE) state is actually a z-axial excited state of the coupled electron pair (CEP) between a_0 and one of its adjacent HSMs (b_0, c_0, d_0 and e_0). An IE-arrow (CI-boson refers to a vector with a unit interface scale $(1 + d_L)$ formed by the appearance of 16 z-axial eigenvalues from one end of the interface to the other to form 2D clusters on the $x-y$ plane. The key is that the λ-th collision-overlapping IE state of two adjacent HSMs can occur repeatedly m times, and the overlapping relaxation time is $\tau_i°$ ($m = i + 1$), which means that the two HSMs overlap only in $\tau_i°$ time and are each in a random state during two adjacent non-overlapping time intervals. This property will have an important influence on the thermodynamics of the glass transition. When a_0 is clustered with b_0, c_0, d_0 and e_0 in turn, a z-axis dynamic cubic lattice (HSCL) with $(1 + d_L)$ sides composed of 4×16 IE states surrounding a_0 will be formed. The five HSMs are called the zeroth cluster $+z$-$V_0(a_0)$ of a_0-HSM, and these four IE-arrows are marked as the zeroth $+z$-$V_0(a_0)$-loop of a_0-HSM, and in the theory of de Gennes $n = 0$, the $+z$-$V_0(a_0)$-loop can be defined as the $+z$-axis spin of IE states surrounding a_0, denoted as $+z$-$S_1(a_0)$ (Figure 1a). Therefore, when the IE-loop around a_0 appears for the i-th time, the $+z$-$V_0(a_0)$ cluster and $+z$-$V_0(a_0)$-loop and $+z$-$S_1(a_0)$ with time τ_i are respectively marked as $+z$-$V_0(a_0, \tau_i)$, $+z$-$V_0(a_0, \tau_i)$-loop and $+z$-$S_m(a_0)$, $m = i + 1$.

The four adjacent domains of the A_0-domain, B_0-, C_0-, D_0- and E_0-domain, all have the same 5-clusters as the A_0-domain, centered on the a_0-HSM at the center of the respective domain. For example, in the B_0-field along the μ_b-direction, its five clusters are respectively labeled as μ_b-$V_{iB}(a_0)$, μ-$V_{iB}(b_0)$, μ-$V_{iB}(c_0)$, μ-$V_{iB}(d_0)$ and μ-$V_{iB}(e_0)$. Note that there are topological connections in the cluster model: The four directions of the four clusters in the A_0-field, μ_b-$V_0(b_0)$, μ_c-$V_0(c_0)$, μ_d-$V_0(d_0)$ and μ_e-$V_0(e_0)$, are also the four directions of the four fields, B_0-, C_0-, D_0- and E_0-field. After averaging five soft matrices with different orientations in 5-local field (A_0, B_0, C_0, D_0 and E_0) centered at A_0 of a_0, the z-axial a_0-soft matrix

will contain 196 + 4 σ-HSMs and five HSCLs "central cavity spaces". The 4 σ-HSMs here are the four σ-HSNs in V_{0A} (a_1) of a_1 on the z-component chain N_z in the SM 3.

In a referenced A_0-domain (-field, SM 2), by replica symmetry, μ_b-V_0 (b_0), μ_c-V_0 (c_0), μ_d-V_0 (d_0) and μ_e-V_0 (e_0) in four different directions adjacent to a_0 appear in sequence, and project again in sequence to the z-axial and clustered collide with z-V_0 (a_0) to form a new 2D $-z$-V_1 (a_0)-cluster [and $-z$-V_1 (a_0)-loop] and L– J potential f_1 (σ_1 /q_1), and σ_1 (a_0) has 17 σ HSMs (SM 3). And so on, along the q-axis of the nine z-axial L– J potentials, nine 2D a_0-clusters V_i (a_0)-cluster, and nine 3D a_0 hard-spheres σ_i (a_0) inverse cascades from small to large, up to the largest 2D z-V_8 (a_0)-cluster (soft matrix).

SM 3. Clusters and percolation transition and soft matrix

The clustering constant for HSMs: $\Delta d = 0.05514\ldots$. The "cage" of the HSM is a micro-cubic lattice (equilateral hexahedron) with a side length of $2\Delta d$, and the HSM makes 1 to 9 closed-loop jumps along the 4×16 singularities on the micro-cubic lattice. Each face of the $2\Delta d$ micro-cubic lattice in the cluster is an equipotential face, which has a potential energy of 1/16 relative to the center of the lattice (the bottom of the potential well). When the M^+-P of a_0-HSM starts from point 9 in Fig. 2 along the 4-diagonal closed loop path on the $2\Delta d$ cubic lattice and returns to point 9, the a_0-HSM obtains the 1/16 potential energy on the $+z$-axis, and the c_0-HSM that circulates synchronously with a_0 obtains the 1/16 potential energy on the $-z$-axis. Each HSM in the V_i-loop has a potential energy of 1/16 either on the $+z$-axis if its IE-loop is along the $+z$-axis (marked as $+z$-HSM, or $+z$-HSCL), or on the $-z$-axis if its IE-loop is along the $-z$-axis (marked as $-z$-HSCL). In Figure. S2, (a) and (b) shows the charge balance between V_2 (a_0) and V_2 (b_0) in the cluster. Dynamic charge balance occurs between 5 $+z$-HSCLs in V_2 (a_0) and 5 $-z$-HSCLs in V_2 (b_0). This property applies to the clustering of all two adjacent clusters.

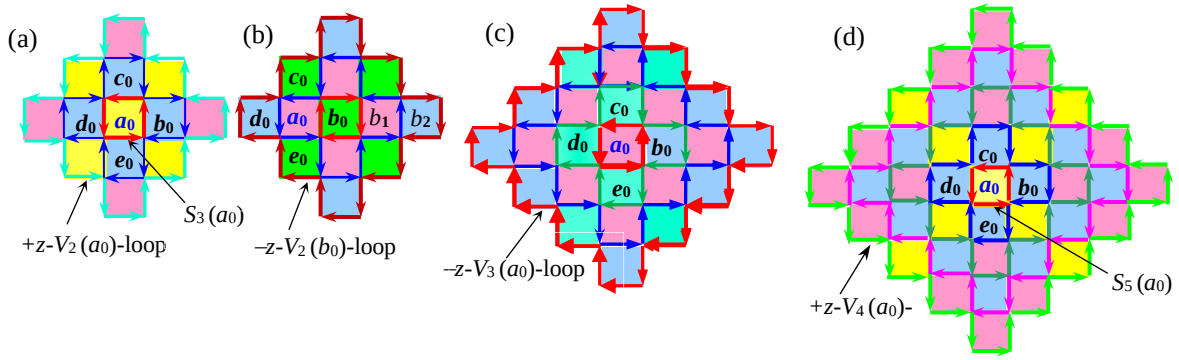

Figure S2. Mosaic structure of positive-negative charges in cluster enlargement. a. V_2 (a_0) cluster contains 33 HSMs, 20 of which are edge particles. There are 9 $+z$-HSNs (red and yellow) and 4 $-z$-HSNs (blue) in the V_2(a_0)-loop. After the energy on the $+z$-axis and $-z$-axis cancel each other out, there are 5 $+z$-HSNs left (yellow). **b.** There are 5 $-z$-HSNs left (green) in $-z$-V_2 (b_0)-loop. **c.** V_3 (a_0) cluster contains 53 HSMs, 28 of which are edge particles. There are 9 $+z$-HSNs (red) and 16 $-z$-HSNs (blue and lake green) in the V_3 (a_0)-loop, and there are 7 $-z$-HSNs left (lake green). **d.** V_4 (a_0) cluster contains 77 HSMs, 36 of which are edge particles. There are 25 $+z$-HSNs (red and yellow) and 16 $-z$-HSNs (blue) in the V_4 (a_0)-loop, and there are 9 $+z$-HSNs left (yellow).

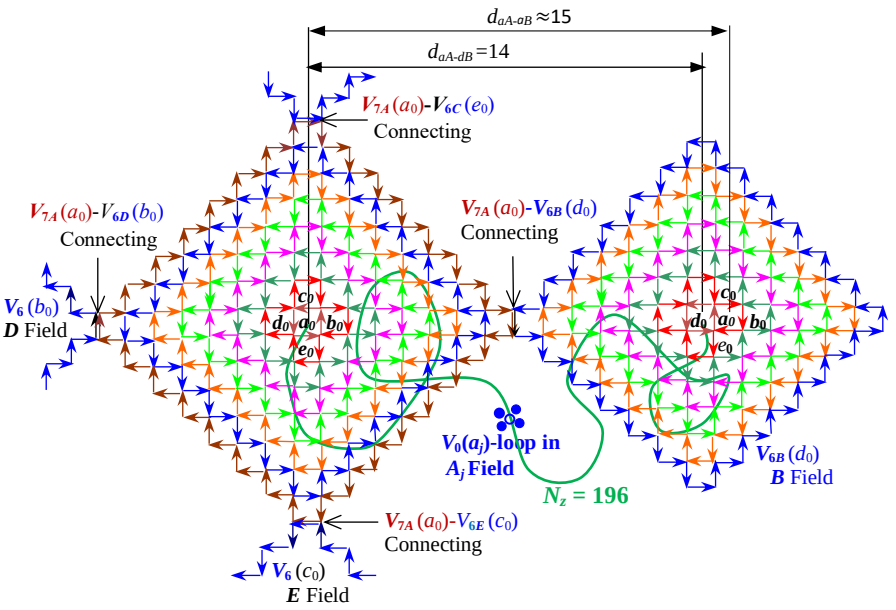

Figure S3 The image of the percolation transition connected by $V_{7A}(a_0)$-loop and $V_{6B}(d_0)$-loop. When $V_{7A}(a_0)$-loop appears, the $V_{7A}(a_0)$-loop formed by 60 IE arrows is connected to the $V_{6B}(d_0)$-loop formed by 52 IE arrows. Two of the IE arrows merge into one arrow at the connected interface and reduce the two edge particles between the two clusters $V_{7A}(a_0)$ and $V_{6B}(d_0)$, thereby reducing the lattice Hamiltonian. $V_7(a_0)$ cluster contains 173 HSMs, 60 of which are edge particles. There are 64 $-z$-HSCLs and 49 $+z$-HSCLs in the $V_7(a_0)$-loop, and there are 15 $-z$-HSMs left. $V_6(a_0)$ cluster contains 137 HSMs, 52 of which are edge particles. There are 49 $+z$-HSCLs and 36 $-z$-HSCLs in the $V_6(a_0)$-loop, and there are 13 $+z$-HSCLs left. The critical length of polymer chain entanglement is 200 HSMs. The 196 HSMs (green curve) in the A-field are represented as a_0, a_1, a_2,... a_j,... and a_{195}, and the field of the a_j-th HSM forming the a_j-soft matrix is denoted as A_j-field. The other 4 HSMs (blue) out of the 200 HSMs are the four HSMs that form $+z$-$V_0(a_j, \tau_i)$. Since the background temperature is T_k, $+z$-$+z$-$V_0(a_j, \tau_i)$ is now $+z$-$V_0(a_j, \tau_7)$. The z-component chain N_z is a random chain in z-space (2D x-y projection plane) with one end a_0 is located at a_0 in the A_0-field (domain), and the other end a_{195} is located at d_0 in the B_0-field. Due to random distribution, $196 = 14^2 = (d_{aA-dB})^2$, d_{aA-dB} is the mean square end distance of random statistics chain. Note: For the chain N_z of a specific local area in the solid state, the distance between the two endpoints of the chain N_z can be a random number, such as 12 or 17, etc., but for the statistical average of an infinite number of local regions, the statistical chain N_z is equivalent to an ideal free chain with a mean squared end-to-end distance of 14.

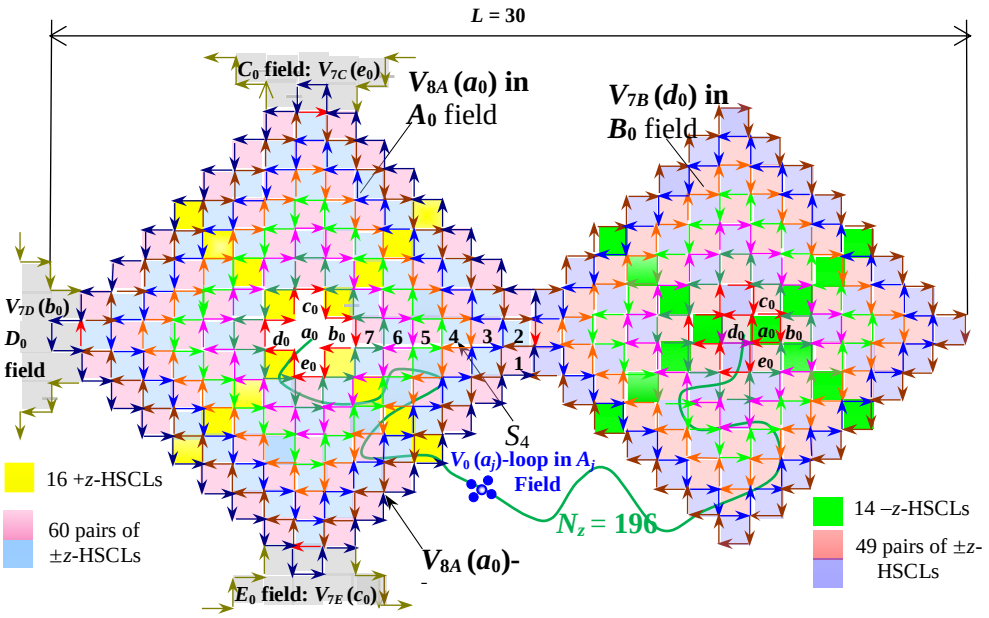

Figure S4. The image of the $V_{8A}(a_0)$-soft matrix-loop and $V_{7B}(d_0)$-cluster-loop. The lattice Hamiltonian to generate the soft matrix is the average energy of 60 IEs (56 dark blue arrows plus 4 reverse red arrows) with a relaxation time of τ_8. When four clusters $V_{8A}(b_0)$, $V_{8A}(c_0)$, $V_{8A}(d_0)$ and $V_{8A}(e_0)$ appear sequentially, $V_{8A}(a_0)$ disappears, and the four sides (four arrows) of the IE-spin of a_0 disappear and the vacancy space of 5-HSM appears. $V_8(a_0)$ cluster contains 200 HSMs, 60 of which are edge particles. There are 136 HSCLs, 76 +z-HSCLs and 60 –z-HSMs in the $V_8(a_0)$-loop. When the $V_{8A}(a_0)$ soft matrix appears, there are unbalanced 16 +z-HSCLs (yellow) in the $V_{8A}(a_0)$-IE-loop. Each +z-HSCL has 1/16 potential energy, and 16 +z-HSCLs in the $V_8(a_0)$-loop. At this time, the average position of all negative charges, the midpoint position of all z-axis repulsive electron pairs, is at the bottom of the potential well (set the potential to 0); And the average position of all positive charges is the equipotential point of 1/16 of the start and end points of each M^+-P in the 16 yellow +z-axis HSCLs in the soft matrix along its 4-diagonal closed-loop jump. At the glass transition temperature T_g, the +z-$V_0(a_j, \tau_7)$ of the A_j-field can now also be in the +z-$V_0(a_j, \tau_8)$-soft matrix state in the mean field representation. That is, the statistical chain of (196 + 4) HSMs in the z-space is a self-avoiding random walk (n_z-steps) chain satisfying de Gennes n = 0, and the satisfying way is to sequentially appear a soft matrix composed of (196+4) HSMs,

SM 4. Theoretical derivation of anomalous viscosity of entangled polymer melts

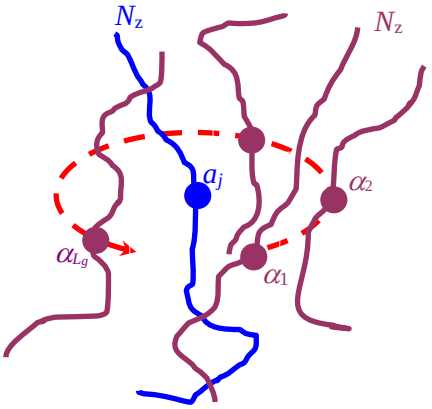

Figure S5. The N z-axial soft matrices appearing in sequence share the generation energy $k_BT_g°$ of a z-axis soft matrix.. Due to the inverse cascading, the energies of the CEP IE states in the a_j-soft matrix all evolve into the V_8-IE-loop energy $k_BT_g°$ of the soft matrix. And V_8-IE-loop energy $k_BT_g°$ can be equivalent to a "loop-flow" composed of α_{Lg} ($= k_BT_g° / \varepsilon_0$) equivalent particles ($\alpha_1$, α_2, α_3 ... α_{Lg}).

The rough original proof of this section is shown in Ref.12, which is now partially corrected and more accurate. Taking inspiration from SM 1 (1), we can derive the theory of glass state from the theoretical derivation of the abnormal viscosity of the 3.4 power law of entangled polymer melts. The author's research method differs from that of most scholars. First, he correctly guessed the expression for the anomalous viscosity that matched the experiment very well. For flexible chains, equation (1) derives $\eta \sim N^{3.4}$, and for non-flexible chains, equation (1) also matches the existing experimental data .

$$\boldsymbol{\eta \sim N^{9\,(1-T_g/\,T_m)}} \tag{1}$$

Due to the exponential relationship, the reliability of equation (1), which is highly consistent with the experiment, is high. The pattern of molecular collective jumping and the theory of glass state should be included in equation (1) , so the theoretical proof of equation (1) is an effective way to explore the nature of glass state.

De Genre's snake model gives an expression for the anomalous viscosity of the entangled polymer melt

$$\eta \sim N^3 \tag{2}$$

One possible explanation for the ultra-high-speed spinning mechanism is that the only soft matrices in all local regions in the melt that can beat are in the z-axial direction. Because the hydrodynamic mode is characterized by the total number of degrees of freedom (DoF) of the system. Thus, the chain length N in equation (2) is replaced by the total number of DoF N^* required for N chain particles to spread freely.

$$N^* = N_z^* \cdot N_x^* \cdot N_y^* = (N_z^*)^3 \tag{3}$$

Equation (2) is rewritten as

$$\eta \sim (N_z^*)^9 \tag{4}$$

The glass state theory to be sought is thus contained in the rigorous proof of equations (3) and (5).

$$N_z^* \sim N^{(1-T_g/\,T_m)} \tag{5}$$

In the glass transition, all N soft matrices that are excited and to be excited in each local area jump n_z steps along the same direction (as in the z-axis) in sequence. The z-axis repulsive electron pairs in the N V_8-IE-loops form a dynamic "wall" of length N whose energy, expressed in terms of temperature T, is the same as the wall energy of a_0-V_8-loop, both are k_BT_g.

Each equivalent particle has a unit DoF energy $\boldsymbol{\varepsilon_0}$ and is located on its own equivalent chain of chain length N_z (z-component chain of chain N). The probability that a $V_8(a_j)$-loop of a_j occupies the N associated V_8-loops on chain N_z is $1/N$. Since the energy of N related V_8-loops on chain N_z is still numerically k_BT_g ($= k_BT_g°$), the L_g equivalent particle can be equivalent to the association of N V_8-loops, as long as each equivalent particle is regarded as having a $V_8(a_j)$-loop and the probability of occupying N V_8-loops is also $1 / N$.

Statistically, the occurrence probability $\hat{p}_+$ of the $V_8(a_0)$-soft matrix is equal to the probability of simultaneous occurrence of L_g equivalent particles in the $V_8(a_0)$-loop:

$$\hat{p}_+ = (1/N_z)^{k_BT_g/\varepsilon_0} \tag{6}$$

Like the generation energy of $V_8(a_0)$-soft matrix, the O(a_0) cavity in its center is also shared by all chain HSMs on the N_z chain. Let the occupied share of a_0 in the O(a_0) cavity be n_z, similar to Eq. (6), the probability $\hat{p}_-$ of the disappearance of $V_8(a_0)$-soft matrix is

$$\hat{p}_- = (n_z)^{k_B T_m / a_0} \tag{7}$$

From $\hat{p}_+ = \hat{p}_-$ and $(1/N_z)^{T_g} = (n_z)^{T_m}$

$$n_z = (N_z)^{-T_g / T_m} \tag{8}$$

For the flexible chains $T_g/T_m = 5/8$, take $N = 200$ in Eq. (8) to adapt to the small molecule system, and obtain

$$n_z \leq 0.036 \tag{8}$$

n_z is also the step-size and the number of DoF for a_0 to walk. Therefore, the number of DoF N_z^* required to "move the entire n_z steps" of the chain N_z along the $+z$ axis is

$$N_z^* = N \cdot n_z = (N)^{(1 - T_g/T_m)} \tag{10}$$

This is Eq. (5). Equation (10) shows that the z-axis IE energy in all N z-axis V_8-loops in each local region, from the glass state to the molten state, is correlated with the loss of potential energy in the A-q_L interval (Fig. 2) in the z-axis L– J potential, and maintains the value $k_B T_g^*$ (= $k_B T_g$) shared by the N soft matrices that appear sequentially. In particular, at the glass transition temperature T_g, on average, only one soft matrix is excited in each local region, and the energy of the disappearing soft matrix is lacking, so there is almost no isolated wave beating of the soft matrix. Further, the lower the temperature is T_g, the less soft matrices describe the collective beating of molecules, and the greater the viscosity.

When the temperature continues to increase, the positively charged central particle of a_0-HSM, M+-P(a0), jumps 9 closed loops along the clustered path of 9→12→10→11→9 in figure S1 **(b)** to obtain the x-axial soft matrix of a_0, written as x-$V_8(a_0)$. In order for the x-$V_8(a_0)$ to jump freely along x-direction, a_0 must consume N_z^* more DoF. Similarly, in order for x-$V_8(a_1)$ to jump freely in the x-direction, a_1 must also consume more N_z^* DoF. Thus, in order for N x-axis soft matrices to jump freely in the x-direction, the chain N seems to consume $N \cdot N_z^*$ DoF. However, as with the N_z component chain, the generation of the N x-axis soft matrix in the N_x component chain is also associated with the disappearance of the A-q_L interval potential of the L– J potential in the x-axial, and the number of DoF required for the N_x chain to freely jump n_x steps in the x-axial is N_x^*, that is, the number of DoF required for the N-chain to spread freely in z-x 2D space is $N_x^* \cdot N_x^*$. This leads to the number of DoF required for a chain of length N to spread freely in 3D space, $N^* = N_x^* \cdot N_x^* \cdot N_y^*$. This is Eq. (3).

SM 5. Cluster structure of molecules in liquid state

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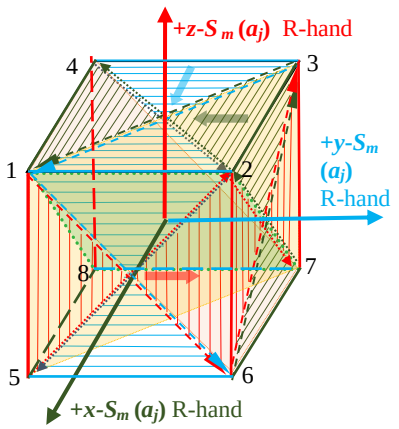

Figure S6. Exclusion volume diagram of mean field hard-sphere molecules in melt (liquid). Each of the 2D interface excited spins can have both left and right hands, indicated by the direction of the arrow of the relative axis.

In the liquid state, in addition to the various crystal structures of molecules described by quantum mechanics, there can be various dynamic equilateral hexahedral space-time structures composed of changes in quenching disordered eigenvalues caused by changes in temperature, pressure, and impurities. The 5-HSM central HSM in the liquid state has 6 ×16 spatial angle-linel states, which can form three axial 2D spins.

SM 6. 20-fold symmetry of CI-boson starting position in the glass state

symbol $a_\alpha b_\alpha$ in Figure S6 indicates that b_0 is projected to a_0-field and the CI-boson between a_0 and b_0 is α, which is also one state in the 20-fold symmetry of the CI-boson interaction between a_0-HSM and its four neighboring HSMs. That is, at any temperature of the entire solid-liquid ↔ transition, each HSM has 20 different spatial positions to construct the first CI-boson, or each HSM has 20 different CI-boson interaction states, which is an inherent geometric property of disordered molecular systems, called the 20-fold symmetry of the glass state.

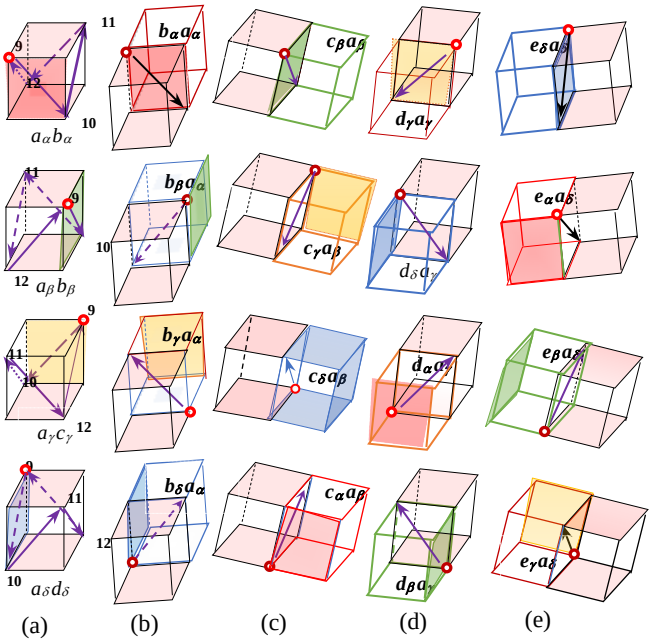

Figure S6. An a_0-soft matrix can be reduced to the positive charge center particle M^+-P of a_0-HSM completing nine closed-loops on the 4-diagonal of the 2Δd cubic lattice (the starting point of the cycle is marked with a small red circle), which is equivalent to four closed-loops of four CI-bosons appearing nine times. **a.** In the V_0 (a_0)-loop, there are 4 options for where the first IE boson appears (four colored interfaces). The formation of the a_0-soft matrix requires its four adjacent V_0-loops. **b.** The four interfaces of μ_b-axial-V_0 (b_0)-loop. **c.** The four interfaces of μ_c-axial-V_0 (c_0)-loop**. d.** The four interfaces of μ_d-axial-V_0 (d_0)-loop. **e.** The four interfaces of μ_e-axial-V_0 (e_0)-loop. So there are 20 choices for the position of the first CI-boson in the glass state to obtain the same z-axis a_0-soft matrix. The symbol $a_\alpha b_\alpha$ means b_0 is projected to a_0-field and the CI-boson between a_0 and b_0 is α, which is the first state in the 20-fold symmetry.

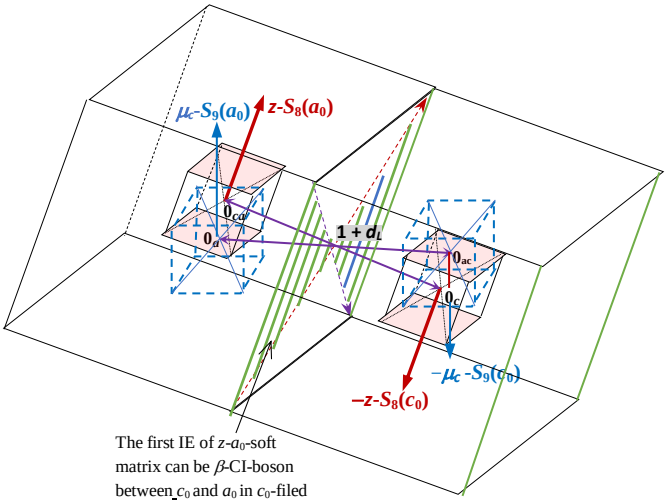

Figure S7. Symmetry of orientation fluctuation of MIES. In z-$S_9(a_0)$ and z-$S_8(c_0)$ projected from c_0 to a_0-field (two blue dashed 2Δd cubic lattices), the distance between the two vibrational equilibrium centers 0_a and 0_{az} is $1+ d_L$. Similarly, in the projection from a_0 to c_0-field, the distance 0_{ca} and 0_c between the two centers of vibration equilibrium is still $1+ d_L$. When the first CI-boson in the path forming the a_0-soft matrix is the β--CI-boson between c_0 and a_0 in the c_0-field, the site of M^+-P(a_0) is marked with a small red circle and the a_0 state is marked as $c_\beta a_\beta$ (Figure S6c).

SM 7. Correlation of closed-loop hop paths for all HSMs in the soft matrix

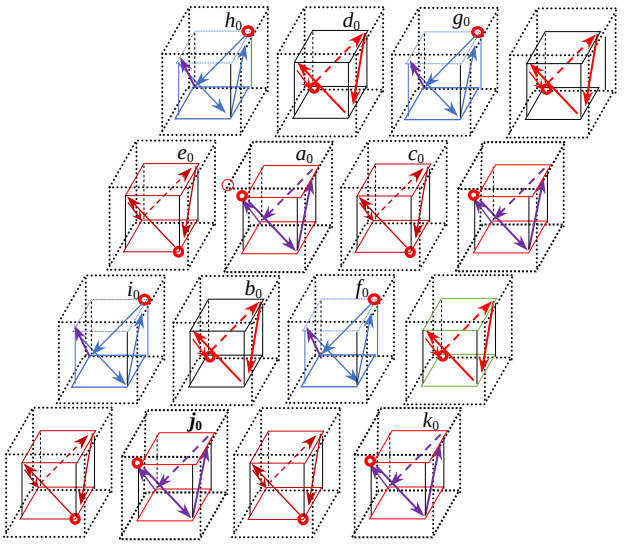

Figure S8. Distribution of four closed-loop paths (four colors) in a soft matrix. The starting position (phase) of each M^+-P in the soft matrix when it performs a 4-diagonal closed loop jump on its 2Δd micro-cubic lattice. Once the M^+-P (a_0) has determined its 4-diagonal path, the 4 diagonal closed-loop paths of all M^+-Ps in the soft matrix have been confirmed. A phase difference of $2\pi i$ is allowed between two M^+-Ps with the same starting position, and i is the i in the Vi cluster where the M^+-P is located. For example, j_0 belongs to the V_1 cluster [3], and its starting phase lags behind a_0 (V_0 cluster) 2π, and k_0 belongs to the V_2 cluster, its phase lags behind a_0 4π. Each HSM in the polymer soft matrix has 3 concentric HSCLs[14]. The dotted cubic lattice in the figure is a cubic lattice of H^+-P (the positively charged particle of hydrogen atom) that jumps synchronously with M^+-P.

Figures S6 and S7show only the spatial geometry of the CI-boson interaction states of HSM. When considering the temporal nature of an CI-boson that can be repeated at the same spatial location, an +z-axial a_0-soft matrix centered on a_0-HSM has four equivalent representations in different scenarios. They are: +z-V_8 (a_0)-cluster, +z-V_8 (a_0)-loop, +z-S_9(a_0) and +z-V_0 (a_0, τ_8). The fourth representation refers to the completion of 9 closed loops by four CI-bosons at the four interfaces of the +z-axis of the (1 + d_L) cubic lattice of a_0-HSM, with a relaxation time of τ_8