

## Why the glass transition problem remains unsolved ?

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Central to the glass transition or vitrification of wide classes of substances is the structural relaxation. Most glass-forming substances are made of fundamental units that are densely packed together and have nontrivial interactions between units. This means that relaxation and diffusion in these systems are many-body irreversible processes in statistical mechanics (*i.e.*, many-body relaxation). The glass transition problem is further complicated by the presence of randomness and the change of density and entropy with temperature and pressure, and all these factors need to be considered as well. Many-body relaxation and diffusion is an unsolved problem in statistical mechanics to this date. Consequently, all theories and models of glass transition bypass the task of solving the many-body relaxation problem. Some rely solely on the change of thermodynamic variables or constructs with temperature and pressure, *e.g.*, the free volume, the configurational entropy, and the energy landscape. Neither the Mode Coupling Model nor the Coupling Model of the author can be considered as full solution of the many-body relaxation.

Although many-body relaxation remains an unsolved problem, some of its characteristics have shown up in experiments. The stretch exponent,  $n$ , in the Kohlrausch correlation function,  $\phi(t) = \exp[-(t/\tau_\alpha)^{1-n}]$ , of the terminal many-body structural  $\alpha$ -relaxation is a convenient measure of the many-body relaxation dynamics. Evidences of the importance of the many-body dynamics can be seen from the empirical facts that  $n$  either governs or correlates with many general  $\alpha$ -relaxation properties. Global many-body  $\alpha$ -relaxation originates from local one-body elementary relaxation (*i.e.*, the primitive relaxation). The evolution of the relaxation dynamics with time from the primitive relaxation to the terminal  $\alpha$ -relaxation are processes constituting the experimentally observed universal Johari-Goldstein (JG) secondary relaxation. Thus, the relaxation times  $\tau_0$  and  $\tau_{JG}$  of the primitive and the JG relaxations respectively are comparable. Importance of the primitive and the JG relaxation for solution of the many-body relaxation is evidenced by the proportionality of  $\log(\tau_\alpha/\tau_0)$  and  $\log(\tau_\alpha/\tau_{JG})$  to  $n$  found in many glass-formers of different kinds, and even in binary mixtures. There are other connections between JG relaxation with the  $\alpha$ -relaxation. Thus, I do not see any hope for solving the glass transition problem unless these outstanding and general properties of the many-body dynamics are addressed and accounted for.

In this presentation, some examples of experimental data showing that  $n$  either governs or correlates with the relaxation properties of glass-formers will be given. Although the Coupling Model is neither a full solution of the many-body dynamics nor a complete solution of the glass transition problem, it has a relation in which  $n$  plays a pivotal role in determining relaxation properties. The relation can explain the experimental findings.

It turns out that some of the many-body relaxation and diffusion properties of glass-forming substances are shared by other interacting systems. These include conduction and diffusion of ions in crystalline, glassy and molten ionic conductors, entangled polymer chains, semidilute polymer solutions, colloidal particle suspensions, colloidal dispersions of magnetic nanoparticles (or ferrofluids), and etc.. These shared properties across different disciplines make the solution of the many-body relaxation problem more pressing and profitable. The Coupling Model of the author has been applied to the many-body relaxation dynamics of glass-formers and the other interacting systems. Its predictions are able to explain the properties, but I will not discuss the other systems due to time limitation.