The Boson Peak, P-Soliton-Interaction System, and Glass-Transition

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In order to understand the dynamics of supercooled liquids and the glass transition, we need to study the short-range structures of the supercooled liquids and glasses. Incompatibility in gauge theory is a generalization of the theory of defects in condensed matter. If an internal parameter (matter field) is given everywhere within a continuum, this defines a mapping between the base space and the manifold, M, of states of the internal parameter (the fiber of the bundle) . It has been proposed that the parameter $\rho(r, u)$ in two-dimensional and three-dimensional metallic glasses is specified by rigid-body rotation, which are related to gauge fields of So(3) symmetry for S^2 and So(4) symmetry for S^3, respectively [1,2]. Extending the Sethna-Sachdev-Nelson formula [1,2], the present author [3,4] has introduced the effective Lagrangian in the gauge-invariant formula with spontaneous symmetry breaking for two dimensional and three dimensional metallic glasses.In glasses and amorphous materials, the broad maximum of Raman spectra and neutron scattering is due to excess vibrational density of states. It is called Boson peak because its intensity changes with T in accordance with the Bose-Einstein factor. It is thought that the vibrational states responsible for the boson peak contribute also to the thermal conductivity plateau, because the energy range spanned by the plateau covers that of the boson peak spectra, indicating that acoustic excitations must cease to propagate when their wavelength λ reaches the nm range. That is, acoustic modes may become strongly localized modes, satisfying the Ioffe-Regel condition. By a computer simulation of a soft sphere glass, it is found that there are (quasi-) localized modes with effective masses ranging from 10 atomic masses upwards, which are related to the boson peak. In the present theoretical formulation, the effective Lagrangian represents three massive vector fields A^1_μ, A^2_μ, and A^3_μ, which are localized within a radius, $\sim 1/|m_1|$, around the hedgehog-like clusters . Thus, it is suggested that the localized gauge fields A^1_μ, A^2_μ, and A^3_μ around the hedgehog-like clusters (solitons) are related to the (quasi-) localized modes of the boson peak. That is, the localized gauge fields A^1_μ, A^2_μ, and A^3_μ introduce the localized strain tensor $u_{k\mu} \sim C^{-1}_{ijk\mu}\varepsilon_{ik\mu}\varepsilon_{jm\alpha}\partial_k\partial_m A^\alpha_\mu \quad (\alpha = 1, 2, 3)$ around the hedgehog-like cluster (soliton), where $C_{ijk\mu}$ is the elastic tensor. It should be noted that localized modes around the hedgehog-like clusters (solitons) are required naturally through the gauge invariant condition in the present theory. In this study, we will discuss the origin of the boson peak and the glass transition, taking into account the p-soliton-interaction. The present model might be related to Zr-based bulk metallic glasses.

References

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