Nonlinear Relaxation of Interacting Two Level Systems in Amorphous Solids

A. L. Burin[1], Yu. Kagan[2], I. Ya. Polishchuk[2]
[1] Department of Physics and Astronomy, Northwestern University, Evanston, IL, 60208, the USA
[2]RRC Kurchatov Institute, 123182, Moscow, Russia

Model of two level systems (TLS) accounts for acoustic properties of amorphous solids at low temperatures T~1K. At very low temperatures T<0.1K the remarkable deviations on the TLS model predictions are found for the sound attenuation, that are interpreted in terms of the TLS interaction (for review see [1] and other reviews in the cited book). The interaction creates dynamically coupled pairs of TLS and the interaction of this pairs leads to the irreversible relaxation similar qualitatively to the experimental observations. However, quantitative discrepancy exists between the theory and the experiments. The experimental relaxation rate turns out to be faster by orders of magnitude than the theory prediction. The low theoretical value of the relaxation rate is caused by the weakness of TLS interaction described by the small dimensionless product χ of the TLS density P_0 and the interaction constant U_0 that is less than 10^{-3}. It is important that the sound attenuation measurements are always performed with the sound wave of the finite amplitude ε and the frequency ω. The variation of the TLS energy $a \sim \gamma\varepsilon$ caused by this field is always much larger than the vibration quantum $\hbar\omega \sim 10^{-12}$eV ($\gamma \sim 1$eV is the coupling constant). When the field is "strong" in the above sense ($a >> \hbar\omega$) it usually affects dynamic properties of a disordered medium and may cause the delocalization of excitations even under conditions of full localization without the applied field[2].

In this contribution we report the study of the effect of an alternate field on the TLS relaxation when the field is strong $a >> \hbar\omega$, always satisfied in acoustic or dielectric measurements in amorphous solids. Using the Floquet state formalism we show that the effective coupling strength between TLS is gained by the factor of $G = (a/(\hbar\omega))^{1/2}$. This effect is due to the increased dimensionality of the problem because of the quasi-energy degree of freedom that enables the dynamic coupling between TLS with energies differing by the integer number of vibration quanta $\hbar\omega$. The resulting TLS coupling strength is given by the product $\chi^* = \chi G$.

The increase of TLS coupling is predicted to change the dynamic properties of excitations. When the coupling parameter χ^* approaches unity the Anderson delocalization occurs within the TLS ensemble. The relaxation rate of TLS and the sound attenuation are expected to be large and temperature independent at very low temperature in that regime. This is interesting phenomenon that can be studied experimentally at T~0.1mK, $\omega \sim 100$Hz and the sound wave amplitude $\varepsilon \sim 10^{-6}$.

Even at lower amplitudes of the external field, where the Anderson delocalization does not occur the interaction stimulated relaxation rate is increased by the factor G. This factor can explain existing quantitative discrepancy between theory and experiment for the very low temperature. The possible ways of experimental verification of our predictions are discussed.

1. A. L. Burin, D. D. Natelson, D. D. Osheroff, Yu. Kagan, Chapter 5 in "Tunneling Systems in Amorphous and Crystalline Solids", ed. P. Esquinazi, p.243 (Springer, 1998)
2. M. Holthaus, G. H. Ristow, D. W. Hone, Phys. Rev. Lett. **75**, 3914 (1995).