Quantum Effects of Electromagnetic Fluxes in Cold Glasses

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Relaxation spectroscopy is potentially a powerful means of probing the low-energy excitations in glasses. The rate at which a glass recovers its equilibrium state with a thermal bath after suffering a perturbation due to changes of thermodynamic fields can be measured. The interpretation of all these dynamic measurements outside the linear response regime, however, requires the solution of proper field equations for boundary and initial values which can be controlled by the experiments.
Based on the coupled Boltzmann equations for phonons and localized tunneling systems field equations for cold glasses in electromagnetic fields are derived. It is shown that the solutions of these hyperbolic field equations for given boundary and initial values of thermal and dielectric relaxation experiments are in agreement with experimental data obtained in vitreous silica and borosilicate glasses below 1 K. Resonance transfer of energy from the elastic and electromagnetic fields to nuclear, electronic and quantum levels of tunneling states must be taken into account, followed by decay of the excited state energy to the thermal bath.
Below 100 mK, however, the standard tunneling model underlying the field equations does not fully describe the non-linear dielectric response of glasses in electromagnetic fields. The oscillatory behaviour of the electric permittivity induced by static magnetic and time-dependent electric fields, as shown in Figure 1, is interpreted as electromagnetic flux effect. Although in the thermodynamic field theory the electromagnetic field is specified by the electric and magnetic strengths, it turns out that knowledge of the local field strength is not sufficient for the consistent description of the quantum-mechanical state of tunneling systems in glasses at ultra-low temperature. For that reason the tunneling model has been generalized in a simple way [1] considering the motion of a charged particle on a closed path. Based on the comparison of the theoretical results with experimental data the consequences of the generalized tunneling model for the theoretical picture of tunneling states in glasses are discussed.

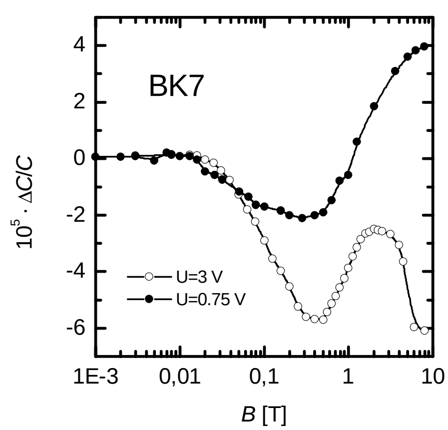

Figure 1 : Magnetic field variation ΔC/C of the capacitance of a borosilicate glass (BK 7) at a temperature of 15.4 mK measured at a frequency of 1 kHz and excitation voltages of 0.75 V and 3.0 V [2].

[1] S. Kettemann, P. Fulde, and P. Strehlow, Phys.Rev.Lett.**83**,4325(1999)
[2] M. Wohlfahrt, thesis, University of Heidelberg, 2001