Low-Temperature Nuclear Spin-Lattice Relaxation in Amorphous Materials

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Recently, amorphous materials with tunneling two-level systems (TLS) are studied with great intensity. It is well known that TLS are formed in amorphous materials (glasses) as well as in insulating crystals with defects at temperatures below 1K. For the first time model of TLS has been developed for spin glasses, then for hydrogenous metals and solid solutions. Excitations, observed in experiments, can be described by means of TLS. On the basis of the TLS model one can consider that they form atoms or atomic groups which can occupy, with almost equal probability, two equivalent positions. Energetically these positions represent two levels of TLS. A number of papers have been devoted to nuclear spin-lattice relaxation caused by TLS. This article is devoted to the analyses of nuclear spin-lattice relaxation of atoms with electrical spins which represent TLS. The mechanism of this relaxation is based on indirect interaction between nuclear spins and TLS by means of hyperfine interaction between nuclear spin and electrical spin of an atom, and interaction of electrical spins with TLS on the other hand. Latter interaction is caused by the fluctuation of g-factor, which is the coefficient connecting spin moment with magnetic one. The reason of the fluctuation of g-factor is the change of internal crystallic field because of tunneling.

We consider amorphous diamagnetic material in magnetic field. The material contains paramagnetic impurities, which have electrical spin, and represents TLS. Electrical spin moment is 1/2. In this case, main contribution in electrical spin-phonon interaction and consequently in the interaction between electrical spins and TLS, makes Zeeman part of effective spin Hamiltonian. Using the averaging method we obtain the expression for the Hamiltonian of the interaction between nuclear spin and TLS. Finally, we obtain the nuclear spin-lattice relaxation rate, for which the method of non-equilibrium statistical operator (NSO), proposed by Zubarev, has been used. This mechanism of relaxation has been compared with other mechanism connected with the fluctuation of the constant of dipole-dipole interaction between nuclear spin and electric spin of external atom (fluctuation of dipole-dipole interaction constant is caused by the atom transition from one state of TLS to another). As a result of this comparison it has been found that the mechanism of relaxation, which we have proposed, is effective.