Spin glass and electron glass, similarities and differences

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Although glass technology dates back several millennia [1], a modern theory of glasses is only a few decades old, with the concept of glass widely extended from the conventional glass to include spin glass [2], polymer aggregates [3], models for neural networks [4], protein folding [5], electron glass [6]. The two most essential elements of a glass are disorder (lack of crystal symmetry) and interactions. The Hamiltonian thus includes an interaction term and a local term; the disorder is represented by the randomness in either or both terms. Phenomenologically the most important property is an extremely slow non-exponential relaxation to equilibrium (τ), the time of relaxation exceeds any reasonable experimental times, i.e. glasses violates the essential ergodic condition [7] under which conventional statistical mechanics applies. I shall discuss this problem briefly in introductory remarks.

I shall first describe the spin glass, present some experimental observations and then describe modern theoretical approaches to the problem. Experimental systems consist largely of magnetic impurities (e.g. Mn) in a non-magnetic host (e.g. Cu) [8]. Theoretically, focus shall be mainly on the simplest systems with short range Ising interaction between spins. The most common model used in theory is the Sherrington–Kirkpatrick model [1] which allows the use of mean field theory. The most commonly used approach to a solve this model is Parisi's replica theory [1].

Next I shall describe the electron glass and again present some experimental observations and theoretical models and approaches. The experimental systems are disordered semiconductors, notably indium oxide [9], granular metals [10], and doped semiconductors [11]. The theoretical models largely include strong Anderson localization and long range Coulomb interaction. Approaches to solve the model relied heavily on computer simulation that I shall discuss. In addition I shall outline a recent simple analytical theory [12] that does not rely on a mean field approach. As yet there is no consensus on the subject of the electron glass and I shall point out the controversies.

Being now ready to compare the two glasses I shall first discuss the similarities, in the experimental results, in the models, and in the in theoretical results. Very important are certain similarities of the Hamiltonians and the exponential dependence of transition times on a random variable. Finally, I shall point out several important differences between the two types of glasses that raise some questions whether the two glasses can be dealt with by similar methods.

Bibliography

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