NONEQUILIBRIUM RELAXATIONS AND AGING EFFECTS IN A 2D COULOMB GLASS

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Introduction

Previous studies of a 2D electron system (2DES) in Si have demonstrated [1,2] the onset of glassy behavior, which occurs as a precursor to the metal-insulator transition (MIT), *i.e.* at a density $n_g > n_c$ (n_c – the critical density for the MIT). For densities $n_s < n_g$, the equilibration time τ_{eq} diverges as temperature $T \rightarrow 0$, suggesting a glass transition at T_g=0 [3]. However, even at T that are not too low (*e.g.* ~1 K), τ_{eq} exceeds the age of the Universe, making it relatively easy to study the out-of-equilibrium dynamics of a 2DES. Here we describe the relaxations of conductivity $\sigma(t)$ after the temporary change of n_s during the "waiting time" t_w. The measurement history was varied systematically by changing t_w and T. The dependence of the system response on history in addition to the time t ("aging") is a key characteristic of relaxing glassy systems.

Experimental

Measurements were done on a 2DES in Si (the peak 4.2 K mobility ≈0.06 m^2/Vs with the applied substrate bias of –2 V) with the sample dimensions 1×90 and 2×50 μm^2. The samples have been described in detail elsewhere [1]. The experimental protocol starts with the 2DES, induced by the gate voltage V_0, in equilibrium at 10 K. The 2DES is then cooled to the measurement T, and the equilibrium $\sigma_0(V_0,T)$ is thus established. The gate voltage V_g (density n_s) is then changed rapidly (within 1 s) to a different value V_1, where it is kept for a time t_w. Finally, it is switched back (again within 1 s) to V_0, and the slowly evolving $\sigma(t,V_0,T)$ is measured. t=0 is defined as the time when V_g reattains its original value V_0. At the end of each measurement, the sample is warmed up to 10 K, and the procedure is repeated for different values of the parameters.

Results and Discussion

Figure 1 shows some typical data obtained for different t_w at a fixed T. In general, the waiting time has a dramatic effect on the relaxations, both qualitatively (overshooting *vs.* no overshooting of the equilibrium value σ_0) and quantitatively (in some cases, there can be more than two orders of magnitude difference in σ for different t_w at a given T), including instances of overshooting when t_w dependence vanishes [Fig. 1(b)]. A careful analysis of the data for many different T, t_w, V_0, and V_1 shows [4] that aging (t_w dependence with no overshooting) occurs for $t_w \ll \tau_{eq}$, where τ_{eq} is the equilibration time in the state with V_1. If $\tau_{eq} \ll t_w$ (the 2DES is excited out of thermal equilibrium at V_1), the t_w dependence vanishes (the system loses memory of the time it spent at V_1) and the overshooting occurs. In the crossover regime $t_w \sim \tau_{eq}$, both effects are observable.

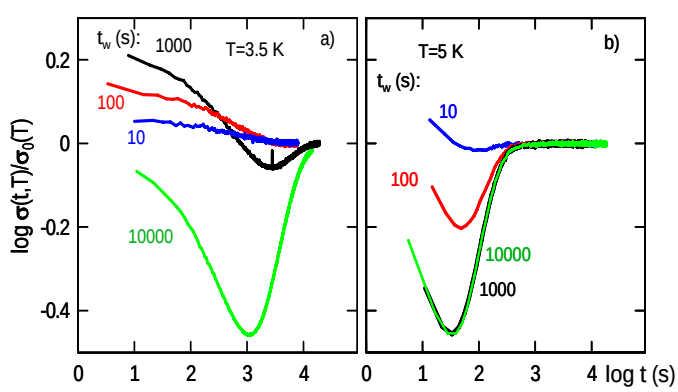

Figure 1 $\sigma(t)$ for different t_w at fixed T, as shown. V_0=8 V [$n_s(10^{11}cm^{-2})$=7.33≤ n_g], V_1=11 V [$n_s(10^{11}cm^{-2})$=20.26].

Conclusions

We have demonstrated that the 2DES in Si exhibits aging, one of the hallmarks of glassy behavior. We have also identified the conditions that lead to memory loss and nonmonotonic response. The complex dynamics of the electronic transport in this model system is strikingly similar to that of a variety of glasses and other systems that are far from equilibrium.

Acknowledgements

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References

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