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COMMENT

Comment on "The electron glass in a switchable mirror: relaxation, ageing and universality"

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Abstract

A simple explanation for the logarithmic ageing of the photoconductivity in $YH_{3-\delta}$ is proposed. We show that the scaling ('simple' ageing) of the relaxation response with the illumination time t_w is consistent with the superposition of independently relaxing excitations with time offsets distributed over a window of width t_w.

In a recent article [1], Lee *et al* reported interesting glassy behaviour in the relaxation of photoinduced conductivity in doped yttrium hydrides, $YH_{3-\delta}$ with $\delta \approx 0.039$. The relative decrease of the conductivity was found to be a scaling function of the ratio between the time t elapsed after the excitation, and the illumination time t_w, $\delta\sigma(t; t_w)/\Delta\sigma_{\rm tot}(t_w) = \mathcal{F}(t/t_w)$, where $\Delta\sigma_{\rm tot}(t_w)$ is the total excess conductivity induced by the illumination. This scaling is very similar to the 'full' or 'simple' ageing observed in polymers, spin glasses [2] and electron glasses [3], except for the fact that the normalization with the amplitude $\Delta\sigma_{\rm tot}(t_w)$ has no counterpart in those systems.

The observation of full ageing is often taken as an indicator for a glass phase with a rugged energy landscape due to strongly frustrated interactions. Indeed, if the energy landscape is pictured as a collection of valleys with a wide distribution of escape times (with a non-integrable tail), full ageing generically arises because the typical relaxation time, i.e., the escape time of the last visited valley, is of the order of the time t_w during which the system has explored the phase space [4].

However, as we will argue below, in $YH_{3-\delta}$ the scaling of the relaxation function is probably due to a different mechanism which only requires a large distribution of relaxation times for a collection of independent non-interacting excitations, similarly to two-level systems in strong glass formers. This illustrates that the logical conclusion 'full ageing $\rightarrow$ interacting, collectively glassy system' does not always hold.

We propose a simple model to explain the observations of [1]. The illumination of $YH_{3-\delta}$ with energetic photons creates a number of local excitations, each of which independently contributes to the increase of hopping carriers. The precise nature of these excitations is not known. Possible mechanisms could be changes in the bonding configuration between Y and H or the creation of pairs of close hydrogen vacancies by the light-induced hopping of vacancies.

Below the saturation threshold, the increase of conductivity is roughly proportional to the number of excitations, and thus proportional to the total photon energy injected ($\Delta\sigma_{\rm tot}(t_w) \sim t_w$).

The excitations relax very slowly, presumably via tunnelling processes, as suggested by the temperature independence of the experimental data (for $T < 140$ K). If we assume a broad distribution of tunnelling barriers the number of excitations decreases logarithmically with time. More precisely, the fraction $f(t, t')$ of excitations which were created at time t' and have relaxed by the time t grows as $f(t, t') = C \log[(t - t')/t_0]$ where $C \approx 1/\log(t_M/t_0)$ and t_0, t_M are the shortest and the longest relaxation times, respectively.

After illumination over a time window t_w and an additional relaxation period t, the number of remaining excitations, and hence the excess photoconductivity, is proportional to

$$\sigma(t; t_w) \approx \Delta\sigma_{\rm tot}(t_w) \int_{-t_w}^{0} (1 - C \log[(t - t')/t_0]) \frac{{\rm d}t'}{t_w}. \tag{1}$$

For the relative decrease of the conductivity after illumination we obtain the result

$$\begin{aligned} \frac{\sigma(0; t_w) - \sigma(t; t_w)}{\sigma(0; t_w)} &= C \int_0^{t_w} \frac{{\rm d}t'}{t_w} \log\left[\frac{t + t'}{t'}\right] \\ &= C\left[(t/t_w + 1)\log(t/t_w + 1) - t/t_w \log(t/t_w)\right], \end{aligned} \tag{2}$$

which fits very well [5] with the scaling function of t/t_w found in [1]. The good agreement of our simple model with the experimental data suggests that the glassiness in $YH_{3-\delta}$ is of a similar type to that of strong glass formers. Note that the necessity to normalize the relaxation by the total excess conductivity $\Delta\sigma_{\rm tot}(t_w)$ is very natural within this model. The validity of this scenario and, in particular, the correlations between excitations could be tested by studying the conductance noise.

We note an interesting property of the logarithmic relaxation kernel which distinguishes it from other time-translational invariant kernels, $f(t, t') \equiv f(t - t')$. One can prove that the relative conductivity decrease takes a scaling form $\mathcal{F}(t/t_w)$ *if and only if* $f(\tau) = C \log(\tau/t_0)$, in which case $\mathcal{F}(t/t_w)$ is necessarily of the universal form (2).

In the above model the 'full' ageing (2) arises simply due to the superposition of logarithmic relaxations with different temporal offsets. The scaling of the relaxation data therefore does not imply the existence of a rugged free energy landscape or a glass phase due to strong electron–electron interactions. However, the scenario of independently relaxing excitations can certainly not apply in a situation where the observed scaling function $\mathcal{F}$ deviates significantly from equation (2). This seems to be the case for ageing experiments on indium oxides [3], where a logarithmic behaviour is observed only for times *shorter* than t_w, and a crossover to faster relaxation is observed around t_w. In contrast, the scaling function (2) assumes a logarithmic behaviour only for times $t \geqslant t_w$, without saturating on experimental timescales in YH.

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