The injection saturation of transient photovoltage in single layer organic photovoltaic material: the real time investigations

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Organic photovoltaic devices have attracted extensive interests in the last decade. Theoretically, similar with its inorganic counterpart, Onsager's theory has been devoted into the organic systems to solve the relation between dissociation rate and field. Monte Carlo method and relative disorder model are used to study the dynamical properties with the disorder of organic materials taken into account. Meanwhile, a so-called device model method, which has been successfully used in inorganic materials, is also applied to simulate the whole physical process in different organic devices. However, those methods mostly consider the steady state only, which is time-independent, and lose important information, the whole process from unequilibrium to equilibrium. Experimentally, an advantageous technique to get the time-dependent measurement is the transient photovoltage (TPV). This tool has been used to observe the light-electricity conversion in many materials. A significant phenomenon found is the changed polarity of TPV, which was directly related to the different diffusion coefficients of carriers. Meanwhile, the effect of excitons was also considered to be essential in this phenomenon. Nevertheless, due to the lacking of time-dependent theoretical tools, the quantitative analysis is absent up to now.

In our work, we apply the widely used device model method with our modifications to simulate the time-dependent light-electric process in a single-layer organic photovoltaic device. This method could properly rebuild the experimental observations. Moreover, we find, from our calculation, a new effect, that is injection saturation of TPV with the increasing strength of light, which is verified by our experiments. We have investigated the different influence of both excitons and carriers, respectively. We find that, the effect is robust in the motion of excitons and it is mainly the minority carrier that dominates this effect. This finding is inspired that, one can hopefully apply it to measure the mobility of minority carrier, which is difficult using other existing technique, to our knowledge.